

# Québec Geoscience Centre

**Annual Report  
2016-2017**

Canada 

**INRS**  
UNIVERSITÉ DE RECHERCHE  
A RESEARCH UNIVERSITY

**Resources and the Environment:**

**Bridging two worlds**

The Geological Survey of Canada (GSC-Quebec) and the Eau Terre Environnement Research Centre at the Institut national de la recherche scientifique are partners in a collaboration agreement called the **Québec Geoscience Centre**. This partnership promotes closer ties and collaboration among scientists through research projects of common interest that address socio-economic issues in the fields of regional geology, georesources and environmental geoscience.

## GSC-INRS Synergy

### Regional Geology

The focus of this theme is to define the regional geological framework or to study the parameters delineating the evolution of sedimentary basins. Bedrock and surficial survey activities are concentrated in Eastern and Northern Canada. Particular emphasis is placed on defining the geological context in order to provide a solid foundation for thematic studies on resources and the environment.

### Georesources

This theme involves detailed metallogenic studies, the proposal of metallogenetic basins that can be used as part of the development of economic potential and the development of guides for exploring georesources. Experts are involved in gold deposits, volcanogenic massive deposits, as well as conventional and unconventional hydrocarbons.

### Environment

The activities under this theme include the characterization and dynamics of groundwater and regional aquifers, the study of geological risks, the dynamics of modern environments, the rehabilitation of contaminated sites and climate change as well as issues combining the environment and the development of natural resources, including environmental geochemistry.

### Field of Expertise

- Appalachians
  - Canadian Shield
  - St. Lawrence Lowlands
  - Quaternary Geology
  - Structural and tectonic geology
  - Metamorphic and igneous petrology
  - Geochemistry of igneous and sedimentary rocks
  - Sedimentology, stratigraphy
  - Biostratigraphy, paleogeography
  - Organic petrography, diagenesis
  - Marine geology
- Metallogeny
  - Metallurgy
  - Mineralization-stratigraphy-structure connections
  - Geology of organic materials and clays
  - Diagenesis, hydrothermalism
  - Petrogenetic potential and reservoirs
  - Unconventional energy resources
  - Drift prospecting, geology of the Quaternary Period
  - Lithochemical prospecting
  - Physical simulations
  - Interpretation and processing of geophysical data in 3D
- Geomorphology
  - Geological risks
  - Geochemistry of trace elements, organic and inorganic geochemistry, isotopic geochemistry
  - Dendrochronology
  - Paleolimnology, limnogeology
  - Sedimentary processes
  - Regional hydrogeology
  - Geophysics of sub-surfaces (magnetism, electromagnetism and geoelectric tomography)
  - Fluid dynamics, multi-phase flow
  - Characterization, rehabilitation and environmental management

## Laboratories

- **QGC Laboratory (Analytical Geochemistry)**  
Stéfane Prémont, INRS; Yves Michaud, GSC  
Joint INRS-GSC laboratory for the characterization of rocks, sediment and trees.
- **Dendrochronology and Dendrogeochemistry Laboratory**  
Christian Bégin, GSC  
Analysis of the physical and geochemical parameters of tree ring sequences.
- **Stable Isotope Geochemistry Laboratory (Delta Lab)**  
Martine Savard, GSC  
Analysis of stable isotopes (H, C, N and O) applied to hydrogeological and environmental studies.
- **Geochemistry, Imaging and Radiography of Sediments Laboratory**  
Pierre Francus, INRS  
Non-destructive radiography analyses coupled with micro-x-ray fluorescence chemical analysis of rocks, soil and sediment.
- **Applied Geoscience Laboratory**  
Marc Richer-Laflièche, INRS  
Geophysical studies applied to mineral, gas and oil exploration, geotechnics and archaeology
- **Environmental Hydraulics Laboratory**  
Taha Ouarda, INRS  
Large-scale flume to simulate waves, tides and strong river currents to develop sustainable approaches to coastal management.
- **Hydrogeology and Environmental Characterization Laboratory**  
Daniel Paradis and Nicolas Benoit, GSC  
Field equipment for groundwater characterization and numerical modeling equipment.
- **Contaminant Hydrogeology Laboratory**  
Richard Martel, INRS, in partnership with Defence Research and Development Canada (Valcartier)  
Study of soil and groundwater contaminants and development of *in situ* treatment processes at the intermediary level between the laboratory and the field.
- **Geophysical Imaging and Measurements Laboratory**  
Erwan Gloaguen, INRS  
Applied work mainly in the characterization of reservoirs for CO<sub>2</sub> sequestration, hydrogeology and oil.
- **Mobile Laboratory for the Physical, Chemical and Mineralogical Characterization of Rocks**  
Pierre-Simon Ross, INRS  
Non-destructive, high spatial resolution measurements of the physical, mineralogical and chemical parameters of drill cores.
- **CT-Scanning for Civil Engineering and Natural Resources Multidisciplinary Laboratory**  
Pierre Francus, INRS  
Non-destructive measurements of the internal density variations on static bodies (internal structure, porosity, etc.) or dynamic phenomena, mainly in hydrology.
- **Physical, Numerical and Geophysical Simulation Laboratory**  
Lyal Harris, INRS  
Orientation of mining and oil prospecting efforts through the structural and tectonic interpretation of geophysical and field data as well as through the simulation of geological processes.

### For more information:

[inrs.ca/english/research-centres/ete/labs-facilities](https://inrs.ca/english/research-centres/ete/labs-facilities)

## Information Management / Dissemination

- **INRS Specialized Information and Documentation Service (SDIS)**  
INRS library, including the GSC-Quebec document collection.  
[sdis.inrs.ca](https://sdis.inrs.ca)
- **Publications and Reports at Natural Resources Canada (NRCan)**  
Web portal providing access to thematic databases.  
[rncan.gc.ca/publications/1139](https://rncan.gc.ca/publications/1139)
- **The History of the Geological Survey of Canada in 175 Objects**  
[science.gc.ca/gsc175](https://science.gc.ca/gsc175)  
175 objects tell the story of the Geological Survey of Canada and its contributions to the development of Canada since 1842

## List of Joint Activities

### Georesources

Responsibility	Title	GSC-Q Team	INRS Team	INRS Students
Jean Bédard <b>GSC</b>	Geochemistry and Petrology of the ophiolites of Cache Creek, British Columbia, GEM 2	Gabriel Huot-Vézina, Annick Morin	Marc Richer-Lafèche	Anne-Sophie Corriveau (M.Sc.)
Louise Corriveau <b>GSC</b>	Deep Uranium, Iron, Copper, Gold and Rare Earth polymetallic systems, TGI 5	Francis Aucoin, Nathalie Côté, Kathleen Lauzière	Olivier Blein, Lyal Harris	
Lyal Harris <b>INRS</b>	Development of web-based and Google Earth virtual field trips for teaching structural and tectonic geology in Quebec and France	Jean Bédard, Sébastien Castonguay	Michel Malo	
Patrick Mercier-Langevin <b>GSC</b>	Gold through space and time at the Archean, TGI 5	Francis Aucoin, Valérie Bécu, Sébastien Castonguay, Benoît Dubé, Kathleen Lauzière	Michel Malo, Pierre-Simon Ross	Arnaud Fontaine (Ph.D.) Alexandre Krushnisky (M.Sc.)
Patrick Mercier-Langevin <b>GSC</b>	Contrôles lithotectoniques sur la répartition de l'or du Paléoprotérozoïque dans des roches archéennes de la région d'Amaruq, au Nunavut, IGC 5	Francis Aucoin, Valérie Bécu, Sébastien Castonguay, Benoît Dubé, Kathleen Lauzière	Michel Malo	Pierre Grondin-Le Blanc (M.Sc.) Brayden St-Pierre (M.Sc.)
Michel Malo <b>INRS</b>	Study of the public perception on mineral resources development in Quebec compared to the social acceptability of other natural resources development.	Christine Rivard	Karine Bédard, Frédéric Malo	
Nicolas Pinet <b>GSC</b>	Lithotectonic controls on the genesis and distribution of the carbonate replacement-type ("Carlin-style") gold zones of the Rackla gold belt, Selwyn Basin, Yukon, TGI 5	Esther Asselin, Francis Aucoin, Valérie Bécu, Virginia Brake, Benoit Dubé, Kathleen Lauzière, Denis Lavoie, Patrick Mercier-Langevin	Antoine Caté	
Marc Richer-Lafèche <b>INRS</b>	Electromagnetic and geoelectric studies applied to the exploration for deep volcanogenic massive sulfide deposits and to the spectral discrimination of various types of electric chargeability anomalies in Quebec	Patrick Mercier-Langevin		
Pierre-Simon Ross <b>INRS</b>	Controls on the distribution, style, composition and age of gold mineralization zones of the Horne Deposit	Patrick Mercier-Langevin		

**TGI** : Targeted Geoscience Initiative **GEM** : Geomapping for Energy and Minerals

## List of Joint Activities (suite)

### Environmental Geoscience

Responsibility	Title	GSC-Q Team	INRS Team	INRS Students
Jason Ahad <b>GSC</b>	Sources of organic contaminants in the environment surrounding oil sands	Jade Bergeron, Larissa Goh, Marc R. Luzincourt, Martine Savard, Anna Smirnoff	Charles Gobeil, Hooshang Pakdel	Jonas Moreno (Ph.D.)
Christian Bégin <b>GSC</b>	Reconstitution of hydro-climatic conditions to support the hydro-electric industry to better manage the risk associated with low water levels episodes	Lauriane Dinis, Marc Luzincourt, Joëlle Marion, Martine M. Savard, Anna Smirnoff	Stéfane Prémont	
Karem Chokmani <b>INRS</b> Miroslav Nastev <b>GSC</b>	Development and application of a flood risk analysis and management tool on the cross-border Lake Champlain - Richelieu River system	Ahmad Abo-El-Ezz, Nicolas Benoit, Éric Boisvert, Héryk Julien, Heather McGrath, Michel Parent, Alex Smirnoff	Monique Bernier, Yves Gauthier, Jimmy Poulin	Khalid Oubennaceur (Ph.D.)
Richard Martel <b>INRS</b>	Hydrogeological characterization of Canadian military bases	Michel Parent		
Daniel Paradis <b>GSC</b>	Hydrogeology modelling : A predictive tool for indicators of future water resource conditions	Nicolas Benoit, Miroslav Nastev, Christine Rivard, Alfonso Rivera	Angus Calderhead, Clarisse Deschênes-Rancourt, René Lefebvre, Richard Martel	
Michel Parent <b>GSC</b>	Development of a web application for the rapid assessment of natural risks – Integration of Quaternary stratigraphy and inventory of exposure data	Francis Aucoin, Nathalie Côté, Miroslav Nastev, Alex Smirnoff	Monique Bernier, Karem Chokmani, Yves Gauthier, Jimmy Poulin	
Christine Rivard <b>GSC</b> René Lefebvre <b>INRS</b>	Evaluating aquifer vulnerability to gas exploration and development activities – McCully-Elgin (NB)	Jason Ahad, Geneviève Bordeleau, Virginia Brake, Mathieu Duchesne, Denis Lavoie, Xavier Mallet, Nicolas Pinet	Jean-Christophe Aznar	François Huchet (M.Sc.), Pierre Ladevèze (Ph.D.)
Alfonso Rivera <b>GSC</b>	National assessment of aquifers and groundwater NAGA Project (National Aquifer and Groundwater Accounting)	Francis Aucoin, Catherine Domingue, François Létourneau, Daniel Paradis		Pascal Castellazzi (Ph.D.)
Martine Savard <b>GSC</b>	Sources of inorganic contaminants in the atmosphere around oil sands.	Christian Bégin, Jade Bergeron, Cindy Bourgault, Ryan Dhillon, Lauriane Dinis, Larissa Goh, Tamara Guzman, Marc R. Luzincourt, Joëlle Marion, Anna Smirnoff, Guillaume Tétrault	Charles Gobeil	

# Knowledge Dissemination

## Targeted Geoscience Initiative – Increasing Deep Exploration Effectiveness

Canada's reserves of metals have been declining for more than 30 years and deeper exploration for new resources is required to offset the increasing rarity of surface discoveries. The main objective of phase 5 of the Targeted Geoscience Initiative (TGI), a program conducted in close collaboration with industry and academia, is to enhance mineral exploration models. Work aims at developing expert knowledge on mineral systems, from their source rocks to their eventual deposition, including the development and evolution of conduits necessary to the circulation of the resources. This improved knowledge supports the development of models and innovative approaches to detect mineral systems. GSC-Québec contributes significantly to the study of gold systems, nickel-copper-PGE-chrome systems and uranium systems. Many research activities are conducted in close collaboration with the Eau Terre Environnement Research Centre and include several M.Sc. and Ph.D. students. Since the phase 1 of TGI in 2000, this program is a major collaboration initiative for both partners. A dozen researchers and professors have been involved in numerous research activities and supervised 12 Ph.D. and more than 15 M.Sc. research projects and 3 postdoctoral fellowships, for a total of 30 students, registered in INRS Earth Sciences graduate programs, trained in the scope of the TGI and contributing to georesource research and the partnership vitality.

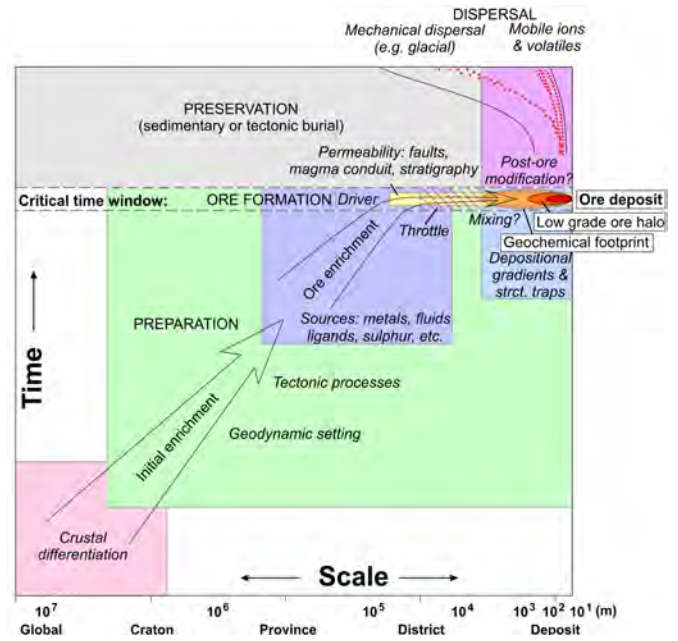


Diagram showing the concept of complex mineral systems and their evolution toward an economic deposit (red ellipse). Modified from Huston et al., 2012

Some members of the Gold System project in Nunavut.



## Knowledge Dissemination (continued)

### The Targeted Geoscience Initiative studies uranium systems and their impact on polymetallic assemblages

This project studies the genetic processes of polymetallic deposits by using the presence of uranium as a diagnostic element, in order to develop efficient exploration tools at the scale of known districts and their possible extensions in virgin terrains. Work conducted has demonstrated a regular spatio-temporal and genetic evolution between uranium and gold-cobalt-uranium deposits hosted in albitites, copper-gold or rare earth deposits in iron oxides and polymetallic deposits in skarns. Alteration facies strongly influence metal precipitation and associations, and their specific compositions can help assess the potential fertility of the studied systems and distinguish them from other deposit families, even those that are highly metamorphosed. The proposed genetic model explains alteration facies and mineralization types observed in the Olympic Dam deposit and newly discovered associated deposits in Australia, as well as Canadian examples. Although the latter are promising targets, they host few mines of this type. Research has also identified a continuum between studied systems and porphyric and epithermal deposits. These advances, combined with the regional interpretation

of various deposit types, alteration facies and geochemical signatures, provide wider exploration targets. The scope of these new tools is now tested in poorly assessed and under explored terrains (Grenville, Makkovik and Appalachian targets) and in world-class metallogenic provinces.



Mapping of the alteration facies and mineral zones of the Bondy gneissic complex, Grenville Province.

### Development of a flood risk analysis and management tool

Climate change is responsible for the steady increase in the number of major floods and there is no known operational tool for the mapping and analysis of the risk associated with floods. INRS and GSC have partnered with the Centre for Security Science, Defence Research and Development Canada, and other provincial and federal government agencies to develop a new flood risk analysis and management tool (GARI). GARI is an application combined with a Geographic Information System that comprises operational modules for the mapping and characterization, visualization and analysis of the flood risk in preparedness and operational modes. The application provides access to detailed real-time information on

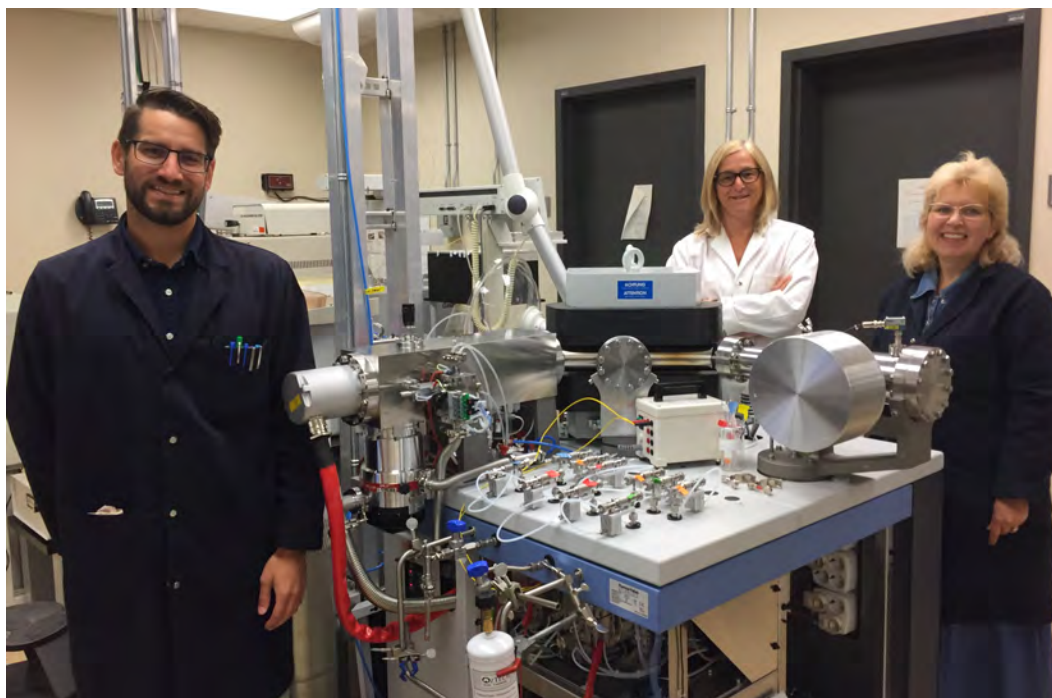
flood risk, actual conditions and the extent of damage to populations, buildings and utilities. This information can not be used to predict floods but it will support municipalities and governments in their decision making on preventing, preparing and operating in the context of flood risk. GARI will first be tested and validated in the municipality of St-Jean-sur-Richelieu, that was heavily flooded in the spring of 2011 and will be the end-user of the project at a local scale. Municipal stakeholders were met in May 2017 to develop the first steps of the project.



Meeting in St-Jean-sur-Richelieu between INRS, GSC, Defence Canada, Sécurité civile du Québec and municipal stakeholders involved in the GARI project. From: Le Canada français, 4 mai 2017.

## Knowledge Dissemination (continued)

### 25<sup>th</sup> anniversary of the Isotopic Geochemistry Laboratory



Spectrometer used for the study of clumped isotopes. This machine is located in the extension of the Delta-Lab.

When it was created in 1992, the isotopic geochemistry laboratory (Delta-Lab), was in the scientific complex of the High Tech Park and was equipped with a stable isotope spectrometer (IRMS) and a small carbonate sample preparation room. Research revolved around the study of C and O isotopes applied to sedimentary basins analysis. In 2004, a new laboratory, comprising 2 IRMS and several peripherals was installed in the INRS building. Research was expanded to the analysis of C, H, N and O isotopes in various matrix, such as carbonates, water, air, and wood. These analyses calibrate exchanges between air, water, soils, rocks and vegetation to better understand various natural processes and support geological, climatic and environmental interpretations. Since 2009, new equipment allow studies of organic components to develop new environmental and paleoclimatic indicators. In 2016, the Delta-Lab was the first Canadian laboratory to study clumped isotopes, that are carbonate molecules composed of at least 2 rare isotopes. This type of analysis generates temperature data that lead to advances in basin analysis, mineral and hydrocarbon deposit formation, paleo-ocean composition and the origin of environmental CO<sub>2</sub>, to name a few applications. In 2017, the Delta-Lab put its activities on hold in order to proceed to a major refurbishment, that included the addition of an enormous fume hood and new equipment. The size of the preparation room has doubled to better process

hundreds of samples every year and to provide a safe work environment. The laboratory now works with 4 IRMS, and the team has expanded from 2 to 12 people, comprising temporary staff, M.Sc. and Ph.D. students and postdoctoral fellows who enjoy the formative environment of the preparation and spectrometry facilities, that are at the forefront of methodological



The recently installed fume hood.



## Knowledge Dissemination (continued)

### – Assessing aquifer vulnerability to shale gas development in New Brunswick

A study on the potential migration of hydrocarbons through natural or induced fractures and faults related to hydraulic fracturing was initiated in 2015 in the Sussex region of New Brunswick. The study area comprises the McCully gas field, in production since 2001, and the Elgin field, considered for its condensate potential. The aim of this project is to provide scientific data to support provincial stakeholders in their decision making on hydrocarbon development. The project's main focus is on the intermediary zone, between the deep formations (more than 2 km underground) of Carboniferous shale and fine-grained sandstone targeted by industry and the shallow aquifers. Data for the intermediary zone are very scarce and this



Permeability tests (slug tests) with compressed nitrogen for the evaluation of hydraulic conductivity

project relies, in addition to geological data, on indirect geophysical, geomechanical, hydrogeology, and rock and water geochemistry data. Work conducted in 2016-2017 comprise observation well drilling, logging, hydraulic tests, and sampling of drilling cores, cuttings and well water. Groundwater chemical analyses show that only several wells contain methane at relatively low concentrations (below 1 mg/L in the McCully field and below 5 mg/L in the Elgin area). Gas present is presumably thermogenic in the McCully field and of mixed origin (mix of thermogenic and microbial gas) or microbial (affected by oxidation processes) in the Elgin area. At one site in the McCully field, ethane (a thermogenic gas indicator) has

been found in groundwater, as well as a small quantity of microbial gaseous methane in drilling cores and bitumen composed of long chain hydrocarbons in cuttings. Thermogenic gas is of deep origin (derived from the thermal transformation of liquid hydrocarbons during burial). Microbial gas is of shallow origin (derived from the near-surface decay of organic



Diamond drilling conducted to gather rock cores

material by bacteria). The origin of thermogenic hydrocarbons is ambiguous and additional analyses are underway. Work globally show that the intermediary zone seems to act as an efficient barrier on the basis of geological interpretations and results from the geomechanical study.

## Regional Outreach

In 2016-2017, the GSC, INRS and the ministère de l'Énergie et des Ressources naturelles du Québec (MERN) joined forces to present special outreach activities in Québec City. The 3 partners hosted the Canadian Museum of Nature travelling exhibit on minerals, a collection of more than 90 spectacular specimens with interactive learning terminals. During the 2 months that it was displayed in the lobby of the INRS building, this high quality exhibit was used to provide learning activities to 5 schools in the region and to reach some 300 external visitors. The exhibit was then relocated at the conference centre, where it was integrated in Québec Mines 2016 activities. It was central to the Discovery Day that was attended by 600 visitors and the M4S Session (Mining for Society), attended by some 1700 people. INRS and MERN have also helped the GSC to start promoting its 175<sup>th</sup> anniversary. The first activity of this anniversary year that will extend to March 2018 was a special session in the technical program of Québec Mines 2016 titled « Geology in Quebec and Canada : 175 years of history ». This session featured presentations on exploration history and the evolution of provincial and federal governmental geological surveys, their roles in society and future perspectives.

Learning activity on minerals



Interactive learning terminal on mineral conductive properties

The exhibit installed in the lobby of the INRS building



## Student Portal

### Interuniversity M.Sc. and Ph.D. programs in the Earth Sciences at the INRS Eau Terre Environnement Research Centre

- Study programs:  
[inrs.ca/english/research-centres/ete/graduate-studies](http://inrs.ca/english/research-centres/ete/graduate-studies)
- M.Sc. and Ph.D. projects:  
[inrs.ca/english/graduate-studies/research-projects](http://inrs.ca/english/graduate-studies/research-projects)

### Continuing education at the INRS Eau Terre Environnement Research Centre

- Earth Science continuing professional training :  
[ete.inrs.ca/ete/etudier/formation-continue](http://ete.inrs.ca/ete/etudier/formation-continue)

### Postdoctoral Internships

- INRS postdoctoral fellowships:  
[inrs.ca/english/graduate-studies/postdoctoral-fellowship](http://inrs.ca/english/graduate-studies/postdoctoral-fellowship)
- Government of Canada postdoctoral research pilot program:  
[nrcan.gc.ca/careers/17880](http://nrcan.gc.ca/careers/17880)

### Student Recruiting

- Summer internships at the INRS Eau Terre Environnement Research Centre:  
[inrs.ca/etudier/stages/stages-ete-premier-cycle](http://inrs.ca/etudier/stages/stages-ete-premier-cycle)
- Federal Student Work Experience Program:  
[jobs-emplois.gc.ca/fswe-pfete/index-eng.php](http://jobs-emplois.gc.ca/fswe-pfete/index-eng.php)
- Federal Research Affiliate Program:  
[jobs-emplois.gc.ca/rap-par/index-eng.php](http://jobs-emplois.gc.ca/rap-par/index-eng.php)

## Publications

### INRS Eau Terre Environnement Research Centre

- Research reports and theses:  
[ete.inrs.ca/ete/publications](http://ete.inrs.ca/ete/publications)
- Scientific articles (in the professor profiles):  
[ete.inrs.ca/les-professeurs/liste/3](http://ete.inrs.ca/les-professeurs/liste/3)

### Geological Survey of Canada

- GEOSCAN database:  
[geoscan.nrcan.gc.ca](http://geoscan.nrcan.gc.ca)  
More than 70,000 publications authored by scientists in the Earth Sciences Sector (ESS).

- Directory of scientists and professionals:  
[science.gc.ca](http://science.gc.ca)  
Science.gc.ca is the official Government of Canada portal into the scientific field and is a source of information on science and technology.

## Internal Activities and Communications

**GSC and INRS were present at the following geoscience conferences to present the projects, programs and online resources of the two partners:**

- **May 25 - 27, 2016** : CWRA 2016, the annual conference of the Canadian Water Resources Association.
- **October 5-6, 2016**: XPLO 2016, the annual conference of the Quebec Mineral Exploration Association.
- **October 30 – November 1, 2016**: annual conference of the Quebec Oil and Gas Association (QOGA).
- **November 7-9, 2016**: EMP 2016, Exploration, Mining and Petroleum New Brunswick.
- **November 21-24, 2016**: Quebec Mines 2016, the annual meeting of the Quebec department of energy and natural resources.

**Both partners also jointly participated in the following activities:**

- **September 6, 2016**: Welcome Day for new students at the INRS Eau Terre Environnement Research Centre.
- **November 4-6, 2016**: Second student conference at the INRS Eau Terre Environnement Research Centre.
- **March 8, 2017**: Guided tour for regional university students of the INRS Laboratories for Scientific and Technological Innovation in Environment (LISTE).
- **March 23, 2017**: Journée des sciences de la Terre et de l'environnement (JSTE). Annual symposium allowing graduate students in the joint INRS-Université Laval Earth Sciences program to present their research projects.



**Canada**

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**Resources and the Environment:**

Bridging the Gap