



Resources
and the Environment:
Bridging two worlds

Québec Geoscience Centre

Annual Report
2015-2016

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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 **Quebec 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	Georesources	Environment
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.	This theme involves detailed metallogenic studies, the proposal of metallogenetic structures 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.	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.
Fields Of Expertise		
<ul style="list-style-type: none"> • 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 	<ul style="list-style-type: none"> • Metallogeny • Metallurgy • Mineralization-stratigraphy-structure connections • Geology of organic materials and clays • Diagenesis, hydrothermalism • Petrogenic potential and reservoirs • Unconventional energy resources • Drift prospecting, geology of the Quaternary Period • Lithogeochemical prospecting • Physical simulations • Interpretation and processing of geophysical data in 3D 	<ul style="list-style-type: none"> • 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, CGC
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-Lafflèche, INRS
Geophysical studies applied to mineral, gas and oil exploration, geotechnics and archaeology.
- **Environmental Hydraulics Laboratory**
Yves Gratton, INRS
Large-scale flume testing 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 CO₂ 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 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

Information Management / Dissemination

- **Digital Cartography and Photogrammetry Laboratory**
cgcq.gscq@rncan.gc.ca
Computer lab for the acquisition, management, analysis and dissemination of geoscientific data.
- **INRS Specialized Information and Documentation Service (SDIS)**
jean-daniel.bourgault@ete.inrs.ca
INRS library, including the GSC-Quebec document collection.
sdis.inrs.ca
- **Publications and Reports at Natural Resources Canada (NRCan)**
nrcan.gc.ca/publications/1138
Web portal providing access to thematic databases.

List of Joint Activities

Regional Geology and Georesources				
Responsibility	Title	GSC-Q Team	INRS Team	INRS Students
Bédard, Jean CGC	Project on the ophiolites of Cache Creek, British Columbia		Marc Richer-Lafèche	Anne-Sophie Corriveau (MSc)
Duchesne, Mathieu CGC	Seismic characterization of the Macasty shale and underlying sedimentary units (Anticosti Island)	Virginia Brake, Denis Lavoie, Nicolas Pinet	Erwan Gloaguen	
Harris, Lyal INRS	Development of web-based virtual field trips for teaching structural and tectonic geology in Quebec and France	Jean Bédard, Sébastien Castonguay, Léopold Nadeau	Michel Malo	
Richer-Lafèche, Marc INRS	High-powered electromagnetic and geoelectric studies applied to the deep volcanogenic massive sulfide deposits and the spectral discrimination of various types of electric chargeability anomalies in Quebec	Patrick Mercier-Langevin		
Mercier-Langevin, Patrick CGC	Mineralogy and geochemistry of Zone 5 of the Horne deposit in Abitibi, Quebec	Valérie Bécu, Benoît Dubé, Kathleen Lauzière	Pierre-Simon Ross	Alexandre Krushnisky (MSc)
Mercier-Langevin, Patrick CGC	Study of Canada's gold deposits	Valérie Bécu, Sébastien Castonguay, Benoît Dubé, Kathleen Lauzière, Nicolas Pinet	Michel Malo, Marc Richer-Lafèche, Pierre-Simon Ross,	Alexandre Krushnisky (MSc) Pierre Grondin-Le Blanc (MSc)
Mercier-Langevin, Patrick CGC	Structural controls on the gold distribution, Whale Tail zone, Amaruq Project, Nunavut	Valérie Bécu, Sébastien Castonguay, Benoît Dubé, Kathleen Lauzière	Michel Malo	Pierre Grondin-Le Blanc (MSc)
Ross, Pierre-Simon INRS	Volcanic architecture of the Waconichi Formation, Abitibi sub-province – implications in the understanding and exploration of volcanogenic massive sulfides (VMS)	Patrick Mercier-Langevin		Alexandre Boulerice (MSc)
Pierre-Simon Ross INRS	Geochemistry and petrogenesis of the host rocks in the Lalor deposit, Manitoba	Valérie Bécu	Erwan Gloagen	Vincent Dubé-Bourgeois (MSc)



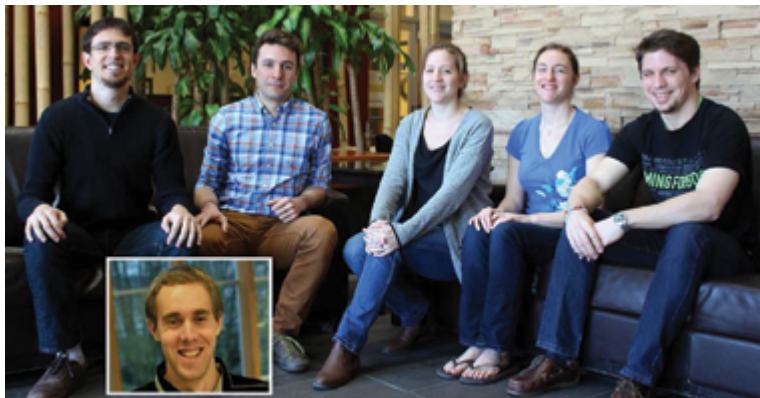
Environmental Geoscience

Responsibility	Title	GSC-Q Team	INRS Team	INRS Students
Ahad, Jason CGC	Sources of organic contaminants in the environment and surroundings of oil sands	Jade Bergeron, Marc R. Luzincourt, Martine Savard, Anna Smirnoff	Charles Gobeil, Hooshang Pakdel	Josué Jautzy (PhD), Jonas Moreno (PhD)
Bégin, Christian CGC	Study of metals as indicators of forest disturbances in the oil sands region	Jason Ahad, Joëlle Marion, Martine Savard	Stéfane Prémont	
Lavoie, Denis Rivard, Christine CGC	Potential impacts on groundwater of exploring and developing shale gas in Eastern Canada	Jason Ahad, Geneviève Bordeleau, Virginia Brake, Mathieu Duchesne, Nicolas Pinet	Abderrezak Bouchedda, Xavier Malet, Erwan Gloaguen, René Lefebvre	François Huchet (MSc), Pierre Ladevèze (PhD)
Malo, Michel INRS	Potential of deep geothermal energy in Quebec	Mathieu Duchesne	Karine Bédard, Félix-Antoine Comeau, Bernard Giroux, Erwan Gloaguen, Lyal Harris, René Lefebvre, Richard Martel, Jasmin Raymond, Marc Richer-Lafèche	Maher Nasr (MSc)
Martel, Richard INRS	Hydrogeological characterization of Canadian military bases	Michel Parent	Uta Gabriel	Guillaume Lefrançois (MSc)
Nastev, Miroslav CGC	Development and application of a flood risk analysis and management tool on the cross-border Lake Champlain – Richelieu River system	Marc-André Carrier, Michel Parent, Alex Smirnoff	Monique Bernier, Karem Chokmani, Yves Gauthier, Jimmy Poulin	Khalid Oubennaceur (PhD)
Parent, Michel CGC	Development of a web application for the rapid assessment of natural risks – Integration of the quaternary stratigraphy and inventory of the exposure data	Marc-André Carrier, Miroslav Nastev, Alex Smirnoff	Monique Bernier, Karem Chokmani, Yves Gauthier, Jimmy Poulin	
Savard, Martine CGC	Sources of inorganic contaminants in the atmosphere around oil sands	Christian Bégin, Jade Bergeron, Marc R. Luzincourt, Joëlle Marion, Anna Smirnoff	Thamara Guzman, Guillaume Tétrault	

Knowledge Dissemination

A Remarkable Second Place Finish in the Integra Gold Gold Rush Challenge

The Data Miners team composed of graduate students in the Earth Sciences Program of INRS took second place at the *Gold Rush Challenge* sponsored by mining company Integra Gold. The Data Miners were the only team consisting entirely of students



The Data Miners, from left to right: Antoine Caté, Vincent Dubé-Bourgeois, Sarane Sterckx, Nathalie Schnitzler and William Oswald
Inset: Fabien Rabayrol (University of British Columbia).

that ranked among the five finalists for the challenge, the others being composed of experienced professionals from the mining sector. The participants had to present innovative ideas for identifying new gold mining targets by interpreting 6 terabytes (6 TB) of data regarding the old Sigma and Lamaque mines in Val-d'Or in Abitibi. The finals were presented at the Annual Convention of the PDAC (Prospectors & Developers Association of Canada), in Toronto, before the general public and a jury using

a formula based on the television show "Dragon's Den". Several members of the team are at the heart of joint GSC-INRS initiatives and the fact that their proposal was so well received among a hundred others attests to the quality of the research projects, the training and the supervision offered as part of the QGC partnership. Without a doubt, this exceptional result will have a real impact on the scientific reputation of the members of the team.

Isotopic Characterization in the Oil Sands Region

In 2015-2016, developments in isotopic geochemistry continued within an environmental perspective in order to differentiate the anthropic contaminants from natural contaminants in sediment from lakes in the Athabasca oil sands region. Innovative isotopic detection methods have demonstrated the presence of petroleum coke, a by-product of oil sands processing, which is an underestimated source of polycyclic aromatic hydrocarbons (PAH) in the atmosphere. The results have shown that the percentage of PAH coming from petroleum coke, identified by the isotopic signature of carbon and hydrogen, has increased over the last two decades in a lake located 150 km north of oil sands mining operations. This means that the atmospheric transport of organic contaminants associated with oil sands development can reach much further areas than previously reported, although to date, the concentrations are still minimal and respect the recommended environmental standards in all cases. The work demonstrated the usefulness of

coupling isotopic analyses of carbon and hydrogen on PAH for source apportionment studies and the importance of petroleum coke in the anthropic cycle of PAH in the development of an environmental monitoring tool. The innovative character of this work ranked it among the top 10 scientific breakthroughs in Quebec for 2015 in the newspaper *Le Soleil*.



Jason Ahad and his team took sediment core samples from the bottom of a lake located 150 km northeast of the main oil sands zone. The accumulated sediment made it possible to go nearly a century back in time.

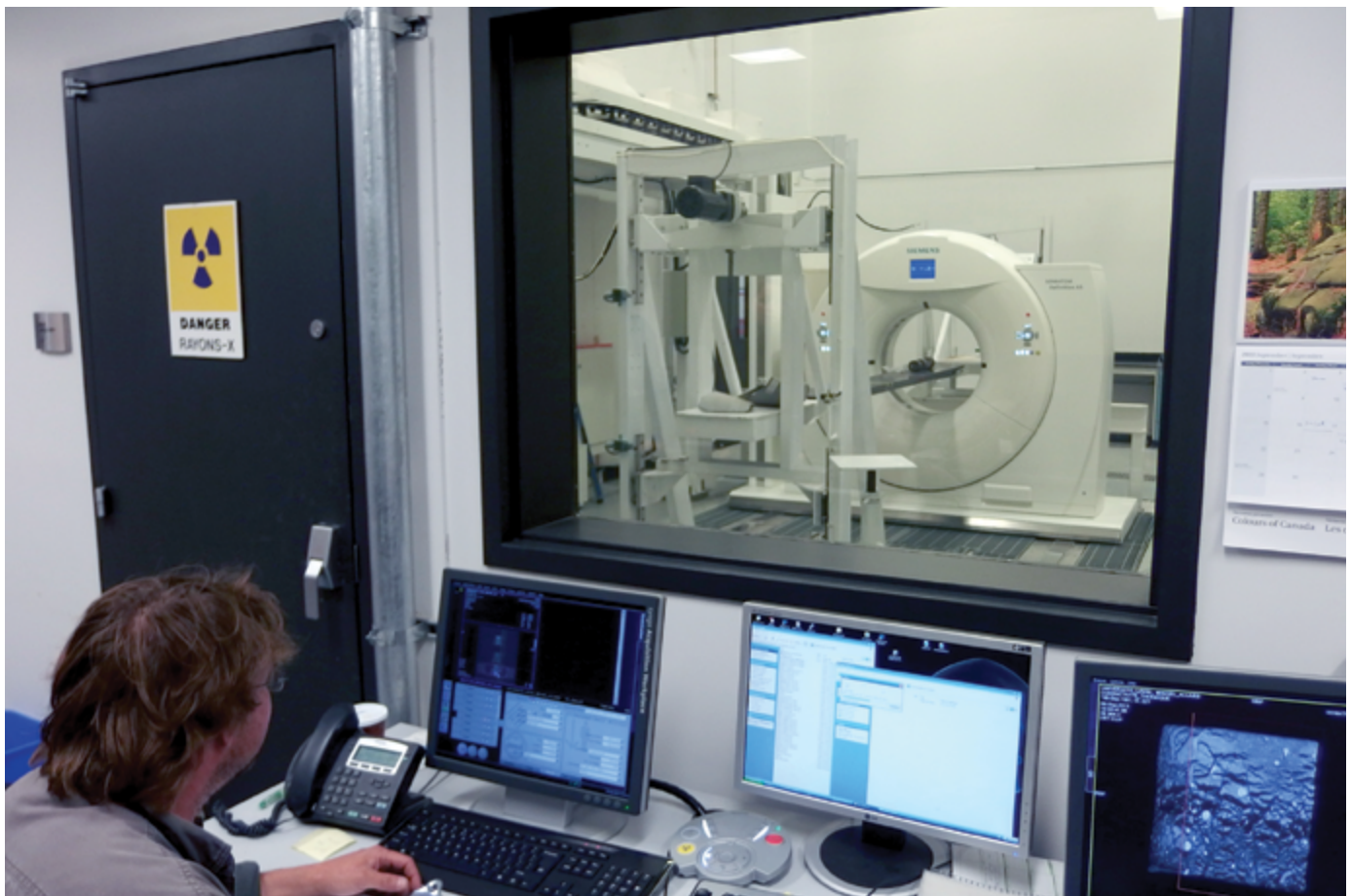


Geological Survey of Canada Samples Help Calibrate the INRS's CT Scanner

In 2013, the INRS acquired a new CT scanner. Computerized axial tomography is an imaging technique that consists of measuring the absorption of x-rays by objects then using a computer to digitize and reconstruct images of the internal structures in 3D. In order to calibrate the CT scanner, the Geological Survey of Canada lent the lab team 40 mineral samples for which the density is precisely known. Such density

measurements had been completed more than 15 years ago with the INRS's first CT scanner. The new measurements made it possible to conduct a comparison with the previous data and thereby define standards that will be used in future work. There are many fields of application for computerized axial tomography and they are quite varied, ranging from civil engineering to ecology to archaeology.

To find out more go to: ctscan.ete.inrs.ca/en



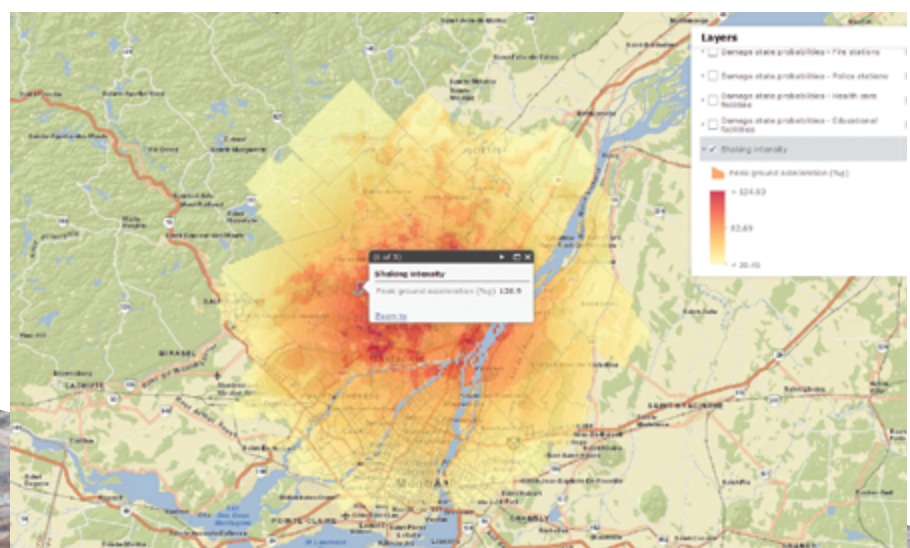


Virtual Fieldtrips for Teaching Structural and Tectonic Geology

Two field classes in Alpine Corsica (September 2015, photo) and Southern Quebec (September 2016) will serve as a basis for developing two virtual geological fieldtrips that will be accessible online using Gigapan images incorporated into Google Earth. Last year, Quebec students (INRS and Université Laval) greatly benefitted from their exposures to the spectacular geology of Corsica. This year, the Quebec fieldtrip will focus on the metamorphic rocks of the Canadian Shield, the sedimentary rocks of the St. Lawrence platform and the Appalachians. The pedagogical goal is to enable 1) participating students to revisit sites to better understand the structures and links between the geological units, to complete summarizing schematic views and structural cross-sections, etc. and 2) future students to benefit from geological fieldtrips that will be integrated into the teaching curriculum. INRS researchers Lyal Harris and Michel Malo are involved in this project in collaboration with the Université de Montpellier 2 in France. Jean Bédard, Sébastien Castonguay and Léopold Nadeau from CGS-QC will participate in the teaching during the Quebec fieldtrip.

Natural Geological and Hydro-meteorological Disasters – Scientific Approaches for Helping Communities

Every year, natural disasters cause significant damage to property, socio-economic activity and sometimes even injuries and loss of life. The disasters targeted by this project are of the geological and hydro-meteorological variety. Scientific approaches to risk reduction and disaster management may help communities and governments increase their resilience and reduce the economic and human impact of natural disasters. That is why the GSC, in partnership with the INRS and other university institutions (Western, New Brunswick, Waterloo, Ottawa, the École de technologie supérieure and UQAC), has undertaken to develop standardized methods and tools for evaluating risk and promoting their understanding, acceptance and use. This continuing work has made it possible to complete a geological map of the surficial formations in the Quebec-Ottawa region as well as a 3D geological/geophysical model of the surficial formations. The next objectives are to develop: (i) an automated system for rapid risk assessment, nearly in real time, following a major natural disaster and (ii) a user-friendly web application for conducting risk assessments based on likely scenarios. This web application is being designed to be used by public safety frontline responders (non-experts) and the aim is to make it a Canadian focal point in seismic and flooding risk assessment.



Shakemap of a magnitude 7.25 earthquake.

Methodological and IT Developments for Estimating Aquifer Recharge Rates

Groundwater plays a major role in supplying drinking water to populations. The responsible and sustainable management of this resource is therefore essential. The aquifer recharge rate is a key element in ensuring the sustainability of the resource and avoiding overuse. Recharge also plays an important role in the base flow of waterways, the vulnerability of aquifers and the ecology of peat bogs (wetlands). Even though there are several methods for estimating the recharge rate, it is still difficult to evaluate it with precision. It is also important, although a complex matter, to consider the impact of climate change on the recharge rate. A groundwater inventory project has focused on methodological and IT developments in order to make it easier to estimate the recharge rate and to monitor it over time. It has developed an estimating method using water level measurements in the observation wells and easily-available weather data (precipitation and air temperature). In addition to estimating the recharge rate, this approach makes it possible to simulate groundwater levels, which could make it possible to anticipate, over the short and medium term, the impact of climatic events on groundwater levels and their contribution to waterways, namely in connection with severe low-water levels. This work will provide managers with dynamic and easy-to-use tools to better understand, manage and use Quebec's groundwater resources.

Piezometric level
measurements
in the field.



Internal Activities and Communications

August 31, 2015

Welcome Day for new students at the INRS Eau Terre Environnement Research Centre.

September 2, 2015

Joint GSC-INRS talk to geology students of the Université Laval presenting the projects, programs and online resources provided by the two partners.

October 7 and 8, 2015

Joint GSC-INRS information kiosk at XPLOR 2015, the annual convention of the Quebec Mineral Exploration Association, to present the projects, programs and online resources provided by the two partners.

November 1 to 3, 2015

Joint GSC-INRS information kiosk at EMP 2015, the Exploration, Mining and Petroleum New Brunswick Conference, to present the projects, programs and online resources provided by the two partners.

November 4 to 6, 2015

First student conference at the INRS Eau Terre Environnement Research Centre with the theme "Past, Present, Future: 3 Perspectives on the Environment" with guest speaker Jean Bédard from the GSC.

November 23 to 26, 2015

Joint GSC-INRS information kiosk at Quebec-Mines, the Quebec annual meeting for geoscience and mineral resources, to present the projects, programs and online resources provided by the two partners.

March 3, 2016

Guided tour for regional college and university students of the INRS Laboratories for Scientific and Technological Innovation in Environment (LISTE).

March 12, 2016

Les filles et les sciences, un duo électrisant! Participation of INRS students to a day of scientific activities for young girls including a kiosk, workshops and the guiding of groups.

March 18, 2016

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.

April 23, 2016

12th edition of the joint MRNF-Université Laval-INRS-GSC activity to mark Earth Day with the general public at the Carrefour Beauport shopping centre.

International Outreach

The INRS and GSC played an active role in organizing the ICTMS 2015 (2nd International Conference on Tomography of Materials and Structures) which was held in Quebec City from June 29 to July 3, 2015. The conference drew nearly 150 specialists in the computerized analysis of the tomography of materials and structures. The applications of this technique in the Earth Sciences are many and varied. They can determine the mineralogical composition of drill cores

or conduct nanometric analyses of 3D structures that are better than with electronic microscopy. In petroleum geology, this technique makes it possible to not only analyze the structures, but also complete hydrocarbon extraction measurements from drill cores and thereby predict the potential production of oil fields, determine the quantity of CO₂ trapped in a rock and study gas hydrates in the lab. Soil and rock deformations can be characterized in 4D as part of geotechnical studies.



Mid-conference fieldtrip participants in Cap Santé on an outcrop of calcareous shale from the Upper Ordovician, which contains an abundance of graptolites.



The INRS and GSC sat on the organizing committee presided by the University of Ottawa for the 5th International Symposium on the Silurian System and the 5th annual meeting of International Geoscience Program Project 591 (IGCP). This international meeting was held in Quebec City and drew 65 participants from 14 countries. The purpose was to clarify the history of the Lower Paleozoic as well as the evolution of life on our planet in order to improve knowledge on the definition, stratigraphic correlations and chronostatigraphic resolution of this geological time period on a global and regional scale. Three fieldtrips to see the carbonate and siliciclastic rocks in the St. Lawrence Lowlands in the Quebec City region (photo), the successions of the Lower Paleozoic in the Gaspésie region as well as the Upper Ordovician and Lower Silurian on Anticosti Island completed the program.

The INRS and GSC also actively participated in the implementation of a France-Quebec International Associated Laboratory (IAL) with the Université de Rennes and the Bureau de recherches géologiques et minières (BRGM) [French Geological Survey], bringing together some 50 researchers working under the theme: “Development of deep resources and protection of surface resources: links between science and decisions.” Several activities have already taken place as part of this partnership, including 1) special sessions as part of conferences, 2) an annual course on the field work completed, given on a rotating basis in Quebec and Brittany and 3) joint scientific work in geochemistry, cyclic tomography and geothermal energy. A master’s program as part of a dual diploma should begin in 2017.



IAL field camp,
September 2015, France

Student Portal

Interuniversity MSc and PhD programs in the Earth Sciences at the INRS Eau Terre Environnement Research Centre

- Study programs:
inrs.ca/english/research-centres/ete/graduate-studies
- MSc and PhD projects:
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

Postdoctoral Internships

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

Student Recruiting

- Summer internships at the INRS Eau Terre Environnement Research Centre:
stages.ete.inrs.ca
- Federal Student Work Experience Program:
jobs-emplois.gc.ca/fswep-pfete/index-eng.php
- Federal Research Affiliate Program:
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
- Scientific articles (in the professor profiles):
ete.inrs.ca/les-professeurs/liste/3

Geological Survey of Canada

- GEOSCAN database:
geoscan.rncan.gc.ca
More than 70,000 publications authored by scientists in the Earth Sciences Sector (ESS).
- Directory of scientists and professionals:
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.

