QUÉBEC GEOSCIENCE CENTRE

ANNUAL REPORT
2021-2022

Resources and environment: Bridging two worlds

INRS
Institut national
de la recherche
scientifique

Canada

TABLE OF CONTENTS

MESSAGE FROM THE DIRECTORS

A year under the sign of renewal

QGC Working remotely and through virtual means has not prevented the members of the Québec Geoscience Centre (QGC) from standing out and continuing their quest for excellence. This year again, we have spared no effort to have a safe and healthy work environment.

Team We have seen a great evolution in the research teams, even if several members have chosen to leave us to enjoy a well-deserved retirement. These departures were an opportunity to bounce back and hire several new employees such as researchers, research professionals and technicians with varied and complementary expertise in geosciences to contribute to the partnership by collaborating on multiple projects.

Renewal It is a valuable asset to be able to work in collaboration with a federal research agency such as the Geological Survey of Canada (GSC), and a university such as the Institut national de la recherche scientifique (INRS). This asset is one that must be preserved and developed in order to respond to the current challenges of our society, while being at the forefront of geoscience research. This is why this year has been pivotal in renewing the QGC. Indeed, a task force composed of scientists and administrative staff from both institutions worked between Fall 2021 and Spring 2022 to reinvent the QGC and maximize its potential. Among other things, this task force has proposed more than 15 recommendations that are to be implemented during 2022-2023 by a new standing joint committee.

Thanks to all and congratulations!

Réjean Couture
Director of the Geological Survey of Canada in Québec

Louise Hénault-Ethier
Director of the Eau Terre Environnement Research Center

QUÉBEC GEOSCIENCE CENTRE

Who are we?

- A unique partnership between a university centre (Eau Terre Environnement Research Centre - ETE Center of the Institut national de la recherche scientifique - INRS) and a federal government agency (Quebec Division of the Geological Survey of Canada - GSC-Q of Natural Resources Canada - NRCan)

Our mission

- Respond to relevant socio-economic issues by developing knowledge of regional geology, georesources and environmental geosciences

Our vision

- Collaborate to be a focal point of excellence in geoscience, open to all, while ensuring the cooperation and participation of Canadian governments, agencies and universities

Our objectives

- Foster scientific collaboration between the ETE Centre and the GSC-Q
- Raise awareness of Earth Sciences within the general public and contribute to arouse the interest of the younger generations
- Train the next generation of scientists through the inter-university graduate program in Earth Sciences offered jointly by INRS and the Department of Geology and Geological Engineering of Laval University

One of Canada's largest multi-disciplinary earth science research clusters

THE QGC IN A FEW FIGURES

Our members

Postdoc (2)
Administration (12)
Research Support (18)
Researcher (21)
Administration (9)
Student (24)
Postdoc (5)
Research Assistant (6)
Research Support (18)
Research Support (18)
Professor (21)
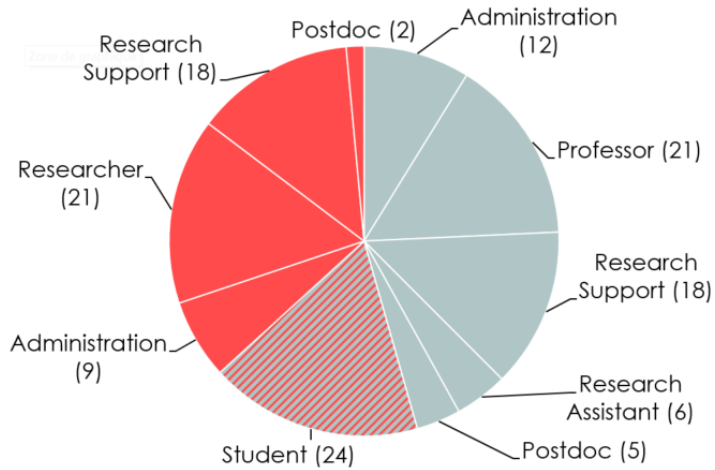
Country of origin of our students
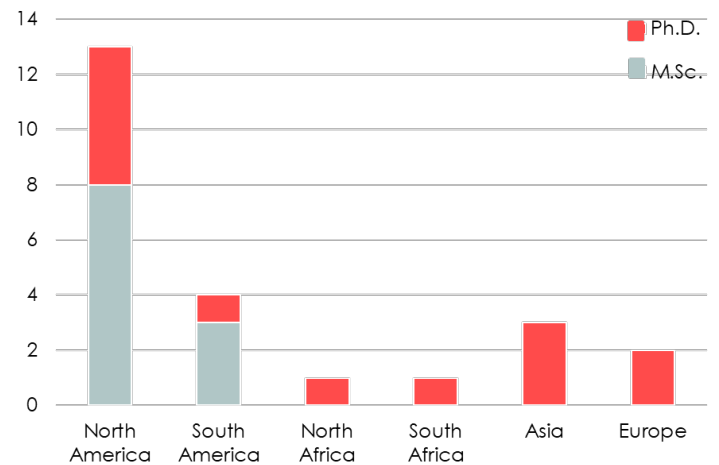
- **3** Research Chairs
- **1** New GSC Researcher
- **22** Joint Projects

HIGHLIGHTS

New joint committee to reinvent the QGC and maximize its potential

Return of field work in the summer of 2021

Retirements:

Benoit Dubé
Kathleen Lauzière
Marc Luzincourt

GEOSCIENCES AT THE SERVICE OF ECONOMIC DEVELOPMENT AND THE ENVIRONMENT

GSC Team	INRS Team	Expertises	For more information
Define the geological framework to guide mineral exploration			
Jean Bédard	**Lyal Harris**	Tectonics	**Bédard, J. and Harris, L.** (2021) A mantle overturn model for the Archean Earth, with possible implications for mineral exploration strategies. GeoHUG, virtual, 7 may (1)
Patrick Mercier-Langevin, Benoît Dubé, Jean-Luc Pilote, Kathleen Lauzière, Valérie Bécu	Pierre-Simon Ross, Liam Maw (M. Sc.), Émile Boily-Auclair (M.Sc.), Alexander Moses (M.Sc.), Octavio Vite Sanchez (Ph.D.)	Metallogeny Gitology Volcanology	**Boily-Auclair, É. et al.** (2022) Alteration and ore assemblages of the LaRonde Zone 5 (LZ5) deposit and Ellison mineralized zones, Doyon-Bousquet-LaRonde mining camp, Abitibi, Quebec; Geological Survey of Canada, Open File 8867, 48 pages. doi:10.4095/329637 (2)
Patrick Mercier-Langevin, Benoît Dubé, Sébastien Castonguay, Kathleen Lauzière, Valérie Bécu	Michel Malo, Brayden St-Pierre (M.Sc.)	Metallogeny Gitology Structural geology	**Project:** Un examen plus approfondi de la chronologie relative et de la nature de la minéralisation aurifère du gisement Tiriganiaq associé au BIF, district de Meliadine, ceinture de roches vertes de Rankin Inlet, Nunavut. (3)
Patrick Mercier-Langevin, Kathleen Lauzière, Valérie Bécu	Pierre-Simon Ross, Simon Tremblay-Hébert (M.Sc.)	Metallogeny Volcanology	**Project**: Géologie des indices aurifères de la zone Caniapiscau-Koksoak de l'Orogène du Nouveau Québec (Fosse du Labrador) (3)
Shiva Tirdad, Nicolas Pinet, Mathieu Duchesne, Karine Bédard	**Erwan Gloaguen**, Mojtaba Bavandsavadkoohi (Postdoc)	Geophysics Artificial Intelligence	**Project:** Les réseaux adverses génératifs pour augmenter la résolution des images aéromagnétiques (5)
Nicolas Pinet	**Erwan Gloaguen**, Victor Silva Dos Santos (M.Sc.)	Artificial Intelligence	**Project:** Reconnaissance automatique des fractures à partir de photos de forage : développements méthodologiques et applications géologiques (6)
Support the development of sustainable energy solutions			
Stéphanie Larmagnat	**Jasmin Raymond**, Michel Malo, Mirah Rajaobelison (Ph.D.)	Geothermal energy Structural geology Petrography Petrophysics Thermostratigraphy	**Rajaobelison, M. et al.** (2022) Understanding heat transfer along extensional faults: The case of the Ambilobe and Ambanja geothermal systems of Madagascar. Geothermics 104, 102455 doi.org/10.1016/j.geothermics.2022.102455 (7)
Stéphanie Larmagnat	**Jasmin Raymond**, Maria José Oviedo Valencia (M.Sc.)	Geothermal energy Petrophysics Tomodensitometry	**Project:** Tester les effets des fractures artificielles sur les propriétés des roches (porosité, perméabilité, conductivité thermique) (8)
Daniel Paradis	**Erwan Gloaguen**, Jasmin Raymond, Benyamin Shariatinik (Ph.D.)	Geothermal energy Hydrogeology Geophysics Data assimilation	**Project:** Optimisation des systèmes de géothermie (9)
Christine Rivard, Stéphanie Larmagnat, Vincent Tremblay	Jasmin Raymond, Pierre Francus, Damien Pham Van Bang, Félix-Antoine Comeau, Mathieu Des Roches, Louis-Frédéric Daigle, Philippe Lettelier, Abdelkader Hammouti, Violaine Gascuel (Ph.D.), Oleksandra Pedchenko (Postdoc)	Geothermal energy Structural geology Petrography Petrophysics Thermostratigraphy Tomodensitometry Physical and numerical modelling Hydraulics	**Larmagnat, S. et al.** (2022) Correlating med-CT density and thermal conductivity of sedimentary rocks: a new insight into thermofacies. GAC-MAC-IAH, 10-12 May (10)

Christine Rivard, Michel Parent, Vincent Tremblay	Jasmin Raymond, René Lefebvre, Jérôme Comte, Felix-Antoine Comeau, Geneviève Bordeleau, Victoria Lee (M.Sc.), Charis Wong (Ph.D.), Oleksandra Pedchenko (Postdoc)	Geothermal energy Hydrogeology Geochemistry Microbial ecology Numerical modelling	Wong, C. et al. (2021) The spatial-temporal variability of an aquifer's microbiological-geochemical characteristics as resulted from the operation of a groundwater heat pump system. Graduate Climate Conference, virtual, 29-31 October (11)
Stéphanie Larmagnat, Josué Jautzy, Mathieu Duchesne	Louis-César Pasquier, Bernard Giroux, Mathieu Des Roches, Arnault Baldassari (Ph.D.), Ehsan Vosoughi (PhD.)	CO_2 sequestration	Project: Captage, utilisation et stockage du carbone (12)

Understand the impact of human activities on the environment

Jason Ahad, Jade Bergeron, Marc Luzincourt, Hooshang Pakdel, Anna Smirnoff, Leah Mindorff	Valérie Langlois, Richard Martel, Luc Trépanier, Scott Hepditch (Ph.D.)	Isotopic geochemistry Organic geochemistry	Project: Impact environnemental du bitume dilué (13)
Jason Ahad, Jade Bergeron, Hooshang Pakdel, Anna Smirnoff, Leah Mindorff	Pierre Francus, Claude Fortin, Arnaud De Coninck, Léo Chassiot (Postdoc)	Environmental sedimentology Geochemistry of metals Organic geochemistry	Project: Dynamiques spatio-temporelles des contaminations anthropiques au sein des sédiments de la rivière Saint-Charles (Québec, QC, Canada) (14)
Mathieu J. Duchesne	Bernard Giroux, Pierre Francus, Mathieu Des Roches, Philippe Letellier, Louis-Frédéric Daigle, Ehsan Vosoughi (Ph.D.)	Applied geophysics Environmental sedimentology	Vosoughi, E. et al. (2021) Simultaneous acoustic, electrical and X-ray computed tomography laboratory measurements of partially-saturated permafrost degradation. SEG Technical Program Expanded Abstracts, pp. 2258-2262 (15)
Mathieu J. Duchesne	Jasmin Raymond, Félix-Antoine Comeau, Nicolò Giordano (Postdoc)	Applied geophysics Geothermal energy	Project: Caractérisation géothermique pour la simulation numérique de la dégradation du pergélisol sous-marin (16)
Daniel Paradis	Erwan Gloaguen, René Lefebvre, André St-Hilaire, Lemuel Carlos Ramos Arzola (Ph.D.)	Hydrogeology Hydrology Heat transfer Numerical modelling Digital inversion	Project: Modélisation hydrothermique couplée des ressources en eau de surface et souterraine (bassin de la rivière Yamaska) (17)
Christine Rivard, Vincent Tremblay	Claudio Paniconi, Geneviève Bordeleau, Bernard Giroux, Laura Isabel Guarin-Martinez (M.Sc.), Barbara Javiera Meneses Vega (Ph.D.)	Hydrogeology Geology Geochemistry Geophysics	Guarin-Martinez, L.I. (2022) Characterization and numerical modeling of the bedrock aquifer in the Fox Creek area, Alberta – Mémoire de maitrise INRS, 148 pages (18)

Characterize water resources

Daniel Paradis	Erwan Gloaguen, Xiao Xia Liang (Ph.D.),	Hydrogeology Hydrology Data assimilation by artificial intelligence	Project: Assimilation de données hydro-climatiques pour la prédiction de l'état et la qualité des ressources en eau (Yamaska et Mercier) (17)
Daniel Paradis	René Lefebvre, Raphaël Mathis (M.Sc.)	Hydrogeology Geochemistry Numerical modelling	Project: Modélisation des patrons d'écoulement et du temps de résidence de l'eau souterraine pour un système aquifère rocheux et de vallées enfouies (19)
Daniel Paradis	René Lefebvre, Jasmin Raymond, Jean-Marc Ballard, Cynthia Lee (M.Sc.)	Hydrogeology	Project: Caractérisation et modélisation des ressources en eaux (20)
Daniel Paradis	René Lefebvre, Aymen Nefzi (Ph.D.)	Hydrogeology Numerical inversion	Project: Évaluation du potentiel de la tomographie hydraulique oscillatoire pour la caractérisation de l'hétérogénéité des aquifères granulaires (9)

Michel Parent	**Richard Martel**, Thomas Robert, Luc Trépanier, Marco Boutin, Jean-Sébastien Gosselin, Marc-Alexandre Fillion (Ph.D.), Jean-Philippe Drolet (Postdoc)	Hydrogeology Quaternary	**Project:** Caractérisation des eaux souterraines des champs canadiens d'entrainement de tir (21)

Adapt to natural hazards

Didier Perret	**Damien Pham Van Bang**, Marc Richer-Laflèche, Jacob Stolle	Coastal engineering Hydraulics Soil mechanics Seismic geotechnics	**Project:** INtercomparaison d'Échelle et de Dimensionalité d'outils de prévision multi-risques: érosion, submersion côtière, Inondation par Embacle (INÉDINE) (22)

In bold: project leader(s)

(#): Project location number on the map

Location of our projects for the year 2021-2022
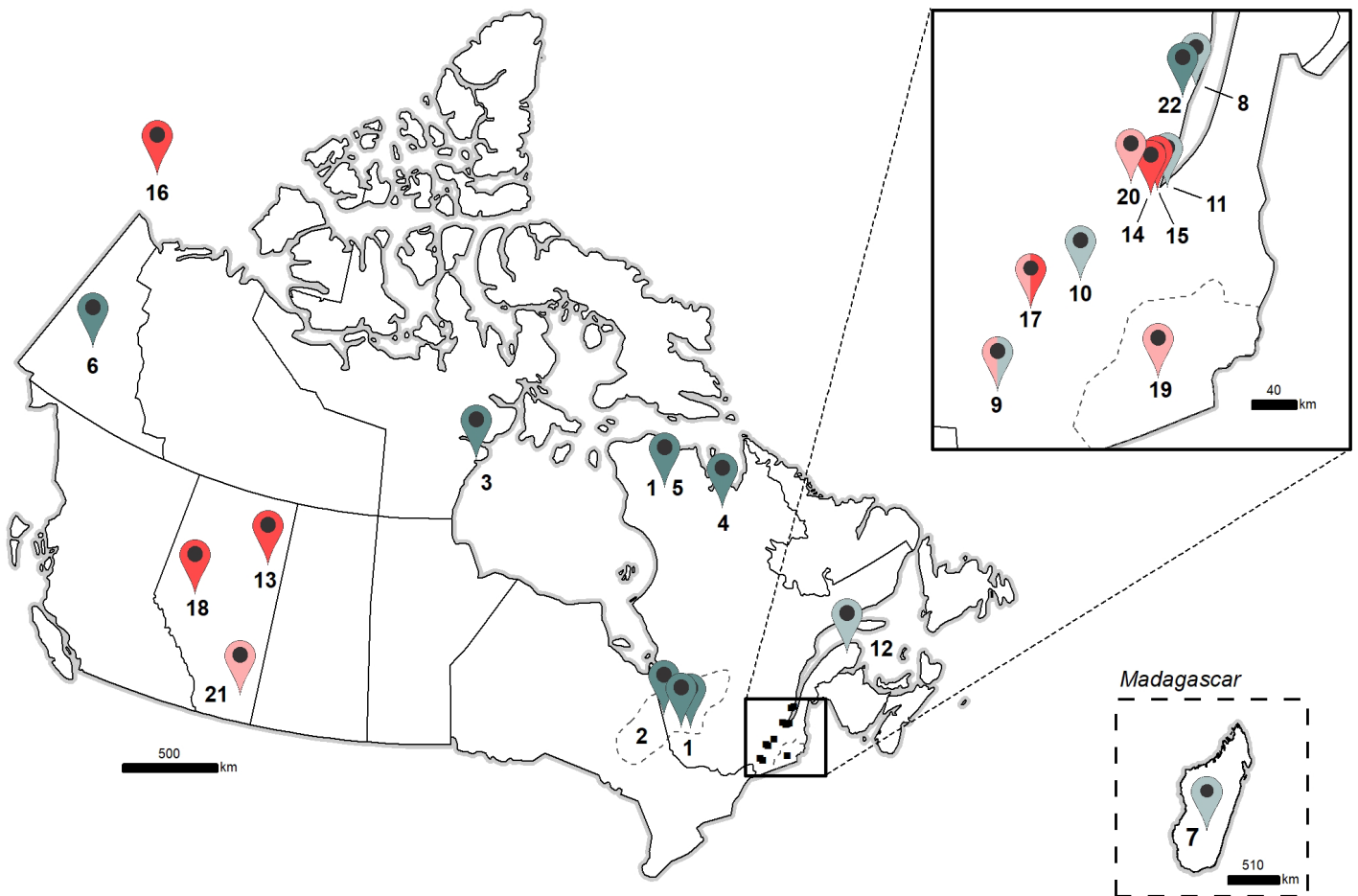
Supporting mineral resource exploration while helping environmental protection

KNOWLEDGE DISSEMINATION

Define the geological framework to guide mineral exploration

Geochemical and petrogenetic evolution of volcanic rocks in the Abitibi Greenstone Belt: Implications for VMS exploration (#2)

Context Volcanogenic massive sulphide (VMS) deposits are a source of copper, zinc, gold, silver and lead in Canada and elsewhere in the world. Our understanding of their formation is based primarily on scientific studies performed within the mine and mining district scales and on the seafloor as it is now. However, we do not know why some greenstone belts and volcanic assemblages within them are notably richer in VMS than others.

Objectives This study aims to understand the variability of volcanic assemblages of the Abitibi greenstone belt. It is part of the Metal Earth program and is carried out in collaboration with four other universities in Canada and the United States. Under the co-supervision of Professor Pierre-Simon Ross (INRS) and researcher Patrick Mercier-Langevin (GSC), candidate Octavio Vite is currently working on comparing the geochemistry and petrogenesis of Abitibi volcanic assemblages.

Method Several previous studies on Abitibi volcanics have focused on felsic rocks. In the present study, all subalkaline volcanic compositions were compiled and special attention has been paid to basalts, which are abundant in all assemblages and relatively easier to interpret. More than 10,000 analyses were compiled, and the two oldest assemblages were sampled during a field season in 2021 to obtain a better distribution of the data in relation to geological timing.

Results The results of the study that are currently available pertain to the geochemistry of mafic to intermediate volcanic rocks of the Blake River Group and allow to consider a link between the level of crustal contamination of the magmas and the abundance of VMS.

Octavio Vite and an intern (Enza Magnier) are sampling Archean volcanic rocks from the Abitibi belt, Summer 2021.

Adversarial generative networks to increase the resolution of aeromagnetic images (#5)

Context Currently, aeromagnetic geophysical surveys are one of the most cost-effective methods for mapping geological formations and detecting the concentration of magnetic minerals in support of mineral exploration. These surveys quickly cover large areas that are usually inaccessible or dangerous and do not require line cutting; hence, their cost is lower than that of terrestrial geophysical surveying. However, data resulting from aeromagnetic surveying are generally low resolution and high-resolution data are of low spatial coverage which limits robust geological interpretations.

Objectives For these reasons, the GSC team (Shiva Tirdad, Nicolas Pinet, Mathieu Duchesne, Karine Bédard) is collaborating with the INRS Geoscience Interpretation and Acquisition Laboratory team (Erwan Gloaguen, Mojtaba Bavandsavadkoohi) in order to provide new strategies to improve the resolution of existing aeromagnetic data. The main objective of the project is to develop digital artificial intelligence tools using super-resolution generative adversarial networks (GAN) to improve the resolution of aeromagnetic data. This approach will allow the generation of high-resolution maps from low-resolution maps by limiting information loss.

Method GANs include two competing neural networks that improve on each other. Since both networks are based on training data, this technique allows the generation of new data with the same characteristics. Indeed, the first network (generator) generates a sample (image), while the second one (discriminator) tries to detect if a sample is real or whether it is the result of the generator. This way, the generator is trained to fool the discriminator.

GAN Workflow
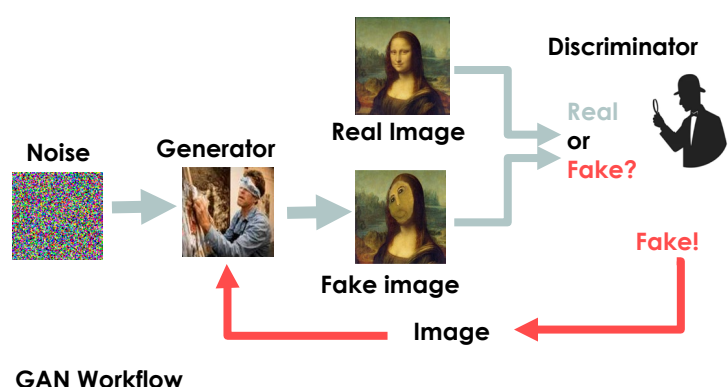
Support the development of sustainable energy solutions

Laboratory characterization of the effects of CO_2 injection on the rocks of sedimentary basins (#12)

Context Climate change related to the increase of greenhouse gas emissions such as carbon dioxide (CO_2) and methane (CH_4) are a phenomenon that society must now face. It is more important than ever to reduce greenhouse gas emissions, particularly CO_2. Although one of the best approaches remains to reduce our dependence on fossil fuels, governments will not be able to achieve and respect reduction targets in time without considering the use of carbon capture, utilisation, and storage technologies. However, despite the fact that this method has been under study for many years and employed around the world, geoscientific knowledge is still lacking in this area.

Objectives GSC (Stéphanie Larmagnat, Josué Jautzy, Mathieu J. Duchesne, Nicolas Pinet) and INRS (Louis-Cesar Pasquier, Mathieu Des Roches Pasquier, Mathieu Des Roches, Bernard Giroux, Pierre Francus) teams, along with two co-supervised doctoral students, have developed a project to test the changes in physical and chemical properties of sedimentary rocks of varying reservoir properties resulting from CO_2 injection scenarios. The observed changes will contribute to the development of new geophysical and geochemical tools to monitor the effects of injection on the surrounding rock. In addition, the results of this project will be used to determine whether there are preferential pathways for the movement of CO_2 in rocks, which will help establish optimized injection and sequestration scenarios on a larger scale within sedimentary basins.

Method To do this, the scientists use five types of sedimentary rock, of varying granulometry and porosity, and vary different injection parameters such as pressure, temperature, or the chemical composition of the brine saturating the rock. The observed changes are detected by X-ray imaging (XRD) and/or by electrical and acoustic measurements.

Understand the impact of human activities on the environment

Understanding the environmental impacts of permafrost degradation (#15)

Context In Canada, approximately 50% of the landmass has a permafrost sublayer, including coastal and offshore zones. In many regions, climate change is causing a rise in ground temperature resulting in thawing and thinning of the permafrost layer. As the permafrost thaws, it releases heavy metals, greenhouse gases and organic carbon into the environment.

Objectives The GSC (Mathieu J. Duchesne) and INRS (Bernard Giroux) teams are collaborating with other organizations to 1) develop methods for detecting and monitoring permafrost degradation; 2) quantify greenhouse gases and heavy metals emitted by permafrost degradation; 3) better understand the geological processes involved in permafrost degradation; and 4) assess the environmental considerations of permafrost degradation in the general context of human health.

Method To address some of these objectives, doctoral student Ehsan Vosoughi has been working to develop and adapt geophysical methods. For example, he participated in the development of laboratory equipment for real-time monitoring of degradation of permafrost samples of different granulometry and salinity using joint measurements of electrical resistivity, acoustics and tomodensitometry.

Results The results of his work suggest that the attenuation of the acoustic signal is a function of the salinity of the sample. Electrical resistivity monitoring also highlighted that temperature variation has a greater influence on low salinity samples. The CT images also showed that permafrost degradation reduces sediment cohesion, which in turn increases porosity and acoustic attenuation. These results facilitate the interpretation of geophysical field measurements used to detect areas of permafrost degradation.

Assessment of potential impacts of oil and gas activities on shallow aquifers in the Fox Creek area (AB) (#18)

Context Hydrocarbon development projects raise many environmental concerns, including overexploitation and contamination of water, and disturbance of wetlands and forest habitats. In this context, the Fox Creek area of Alberta, which has been one of the most active areas for hydrocarbon production in Canada for the past 50 years, is currently the focus of a multidisciplinary project.

Objectives In this large-scale project, the GSC-Québec (Christine Rivard, Vincent Tremblay) and INRS (Geneviève Bordeleau, Claudio Paniconi) teams are collaborating to evaluate the cumulative effects of hydrocarbon exploitation on the water resources in a 700 km² sub-watershed. The team's work will allow characterization of this regional shallow aquifer, to study the integrity of the intermediate zone, and to evaluate the current regional cumulative effects assessment process.

Method Since 2019, field work, laboratory analysis, and numerical modeling have been conducted. Currently, the team is working on the development of hydrogeological, coupled (surface and groundwater) and geomechanical models to study the potential effects of hydraulic fracturing. The different components of the hydrological cycle are also being evaluated at different locations of the area to study the impact of forest fragmentation on aquifer recharge. Changes in the landscape over the past few decades are also being studied and quantified.

Results Preliminary results show that groundwater quality does not appear to be affected by oil activities, which is excellent news. The results of the geomechanical model confirm that the induced fractures generally do not extend beyond the top of the geological formation targeted by the industry. On the other hand, the fragmentation of the forest resulting from the construction of roads and platforms for gas wells, as well as the construction of numerous seismic lines and the installation of tens of kilometers of pipelines, has clearly affected the ecosystems.

Installation of a piezometer in the riverbed

RESEARCH FACILITIES

A diversified range of first-class geoscience laboratories

Laboratory	Contact(s)	Expertise
Delta-Lab	Jason Ahad	Analysis of stable isotopes (H, C, N and O) applied to hydrogeological, environmental and mineral studies.
Dendrochronology and Dendrogeochemistry	Christian Bégin	Analysis of the physical and geochemical parameters of tree ring sequences.
Geochemistry, Imagery and Radiography of Sediments (GIRAS)	Pierre Francus	Non-destructive radiography analyses coupled with micro-x-ray fluorescence chemical analysis of rocks, soil and sediment.
Contaminant Hydrogeology	Richard Martel	Study of soil and groundwater contaminants and development of *in situ* treatment processes at the intermediary level between the laboratory and the field.
Hydrogeology and Environmental Characterization	Daniel Paradis	Field equipment for groundwater characterization and numerical modelling equipment.
INRS-GSC joint laboratory	Stéfane Prémont and Kathleen Lauzière	Geochemical characterization of rocks, sediments, soil horizons and tree rings.
Digital Cartography and Photogrammetry (LCNP)	Kathleen Lauzière	Acquisition, management, analysis and dissemination of geoscientific data.
Applied Geoscience (LGA)	Marc Richer-Laflèche	Geophysical studies applied to mineral, gas and oil exploration, geotechnics and archaeology.
Environmental Hydraulics (LHE)	Damien Pham Van Bang	Large-scale flume simulations of waves, tides and strong river currents for the development of sustainable approaches to coastal management.
Interpretation and Acquisition of Geoscientific Measurements (LIAMG)	Erwan Gloaguen	Applied work mainly for the characterization of reservoirs for CO_2 sequestration, hydrogeology and oil.
Geothermal Energy (LOG)	Jasmin Raymond	Open laboratory for measuring the thermal and hydraulic properties of geological materials.
Physical, Numerical and Geophysical Simulation	Lyal Harris	Numerical analyses combining CT-assisted analog simulation methods with geophysical, remote sensing and field data interpretations.
Multidisciplinary CT-Scan	Pierre Francus and Damien Pham Van Bang	Non-destructive dynamic 4D measurements of internal density variations on static bodies (internal structure, porosity, etc.) or of dynamic phenomena, mainly in hydrology.
Environmental Technologies	Jean-François Blais et Louis-César Pasquier	To test and demonstrate, at low cost, new processes for the treatment and recovery of liquid, solid and gaseous effluents before their implementation on a full scale.

For more information: cgq-qgc.ca/en/facilities

COMMUNICATION AND FACILITATION

Joint participation in geoscience conferences

October 25-28: XPLOR 2021 (virtual)
October 24-26: EMP 2021 – New Brunswick Mining and Petroleum Exploration and Exploitation Conference
November 22-25: Québec Mines + Énergie 2021

Joint participation in internal and external activities

November 6: INRS Open House (virtual)
January 19: Career Day in Science and Engineering at Laval University (virtual)
February 18: INRS Scientific Day (virtual)
March 22: World Water Day: Presentation of the documentary *La goutte de trop*
April 13: Science Storm at Cégep Garneau

MANAGEMENT, KNOWLEDGE DISSEMINATION AND PUBLICATIONS

INRS Eau Terre Environnement Research Centre

INRS Specialized Documentation and Information Service (SDIS - link)
Reports and theses (link)

Scientific articles (professor profiles - link)

Geological Survey of Canada

Federal Science Libraries Network (link)

Geoscan database (link)

Natural Resources Canada publications and reports (link)

Directory of scientists and professionals (link)

STUDENT PORTAL

Inter-university programs in Earth Sciences

Masters and Ph.D. programs at the ETE Centre (link)

Masters and Ph.D. projects available at INRS (link)

University internships

INRS undergraduate summer research internships (link)

INRS research internships (link)

Federal Student Work Experience Program (link)

Federal Research Affiliate Program (link)

Postdoctoral internships

INRS postdoctoral fellowships (link)

Federal Postdoctoral Research Program (link)

INRS-GSC Graduates 2021-2022 codirection
MSc.
Émile Boily-Auclair
(Pierre-Simon Ross, Patrick Mercier-Langevin)

Ph.D.
Mirah Rajaobelison
(Jasmin Raymond, Stéphanie Larmagnat)

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