



**QUÉBEC
MINES
2012**

CROSSROADS OF GEOSCIENCE
AND MINERAL RESOURCES

ABSTRACTS OF ORAL PRESENTATIONS AND POSTERS

November 26 to 29, 2012



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INVITATION FROM THE HONORARY PRESIDENT

Québec's history is closely linked to the development of its natural resources. The first settlers who arrived in the continent were quick to understand that our territory contained resources that distinguished it from all others. Even today, mineral resources occupy an important, and even crucial, position in collective wealth creation in Québec society. We must look to the rest of the world and we seize this key moment to raise the profile of Québec's mining sector.

Québec Mines 2012 provides an opportunity to review, together, the current situation of our mining sector and to continue to think strategically about ways to successfully link the knowledge-based economy and the mining industry, which creates shared wealth and vital resources for society. We must make the choices that will allow us to respond in a sustainable way—whether in economic, environmental or social terms—to new demand from countries experiencing strong growth, and also from the so-called developed nations.

I personally invite you to attend this key event to discuss the concrete strategies that must be defined to respond to issues and take advantage of opportunities for maximizing the positive impact of mineral resource development in Québec, from exploration to extraction.

Québec Mines 2012 is the ideal place to enjoy productive meetings, witness the unveiling of new exploration results, obtain privileged information on structural projects, and, above all, to learn, discuss and do business.

Dominique Dionne
Honorary President



MESSAGE FROM THE MINISTER OF NATURAL RESOURCES

QUÉBEC MINES 2012

OF MINES AND MEN: AN INDUSTRY WITH A HUMAN DIMENSION

I am delighted to invite you to the Québec Mines 2012 Conference, the crossroads of geoscience and mineral resources, to be held on November 26 to 29 at the Québec City Convention Centre. The theme of the Conference is: *"Of Mines and Men: The Human Aspect of the Mining Industry"*.

The men and women who have been involved in the development of Québec's mining industry have written an important page in our history. Through their dreams and hard work, they have made a significant contribution to the economic, social and territorial development of Québec. Mining activity first began to flourish in Québec in the early 1920s. First through gold, and later, through copper and iron, combined with industrial growth, Québec was able to earn a reputation throughout North America as a major supplier of ore.

Since then, many other sites with mining potential have been developed. With the current growth in the mineral resource sector and current plans to develop the North, the future looks promising. Several new mines should be opened in the coming years. They will be a source of diamonds, gold, nickel, iron, lithium, niobium, apatite, zinc, rare earths and many other sought-after substances. The use of these resources in compliance with the principles of sustainable development will help, in turn, to foster the economic and social development of Québec.

This is what you will discover at Québec Mines 2012: A mining industry of the future, based on knowledge and leading-edge technology, local community involvement, sustainable mine development, social acceptability, respect for the environment and the creation of collective wealth. Above all, however, you will discover an industry with a human dimension, composed of competent, dynamic men and women of vision, whose expertise is recognized throughout the world!

It is my pleasure to invite you to attend this unique event!

Martine Ouellet
Ministre des Ressources naturelles

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Session 1

2012-2013 geoscientific programming and new exploration targets based on work by the BEGQ

Patrice Roy, Charles Maurice and Claude Dion (MRN)

The *Bureau de l'exploration géologique du Québec* (BEGQ) has an annual budget of \$12M to carry out geoscience knowledge acquisition work across Québec. This work is designed to increase our basic geoscience knowledge in under-explored areas, and to deepen our knowledge in more mature regions, namely by looking at the third dimension.

Since November 2011, the BEGQ has worked on 22 geoscience knowledge acquisition projects that namely resulted in the identification of more than fifty new exploration targets, listed in the promotional document PRO 2012-05. Inventory work included six geophysical projects, six geological mapping projects, eight Quaternary geology projects, and two lake sediment sampling projects. Two mineral potential studies and three 3D geological models were also completed. This work is also complemented by several studies and analyses conducted in cooperation with our academic and institutional partners.

The impacts of BEGQ work on geoscience knowledge and mineral potential in Québec are significant. With the geophysical surveys, the aeromagnetic coverage of the Baie-James region, the Labrador Trough and the Eastern Churchill Province was completed and coverage of the Grenville Province and the north part of the Ungava Orogen was initiated. These geophysical data will prove very useful for future mapping surveys, in particular the Outardes project in the Grenville Province. In the Labrador Trough, geophysical surveys have already been used to reinterpret existing geological maps. We continued reconnaissance-scale mapping (1/250,000) of the Churchill Province and began, in parallel, the mapping of Quaternary deposits in this area. The Octave-Wawagasic project was in the final phases and served to enhance the geological and Quaternary maps of an extensive area overlain by a thick cover of lacustrine sediments. In the Baie-James region, we continued mapping along the boundary between the La Grande and Opinaca subprovinces. East of Chapais, outcrops exposed along new logging roads were examined to perfect our geological understanding of the area. In Malartic, a high-precision helicopter-borne magnetic survey and new mapping will have a profound impact on our geological understanding of the area.

Session 1

Overview of Quaternary projects in Québec

Hugo Dubé-Loubert, Guillaume Allard, André Brazeau and Mohamed El Amrani (MRN)

In recent years, Géologie Québec has inserted into its annual programming a number of projects focussing on Quaternary geology. These projects cover very diverse sectors and have led to the development of various partnerships with other government ministries, universities, or with the private sector.

For 2012, eleven different projects were carried out across Québec. Under the Groundwater Knowledge Acquisition Program headed by the *Ministère du Développement durable, de l'Environnement, de la Faune et des Parcs* (MDDEFP), six new projects were launched in the Outaouais, Charlevoix, Abitibi, Vaudreuil-Soulanges, Chaudière-Appalaches, and Bas-Saint-Laurent regions. These projects, jointly conducted with the MDDEFP, are intended to build a profile of groundwater resources in each region.

In an effort to prevent potential problems related to climate change and thawing of permafrost, an aggregate inventory project was carried out near the town of Kuujuaq. Most of the town's infrastructure are built on aggregate pads and are thus very sensitive to surface changes and destabilization of permafrost. The search for and characterization of new sources of aggregate in permafrost areas thus becomes a critical issue.

The drilling program combining Quaternary stratigraphy and bedrock sampling, in order to document new exploration targets, continued in northwestern Abitibi. Nearly 60 new drill holes were logged and analytical results will be used to develop a more robust time-stratigraphic framework, thus facilitating exploration efforts in this area with a thick Quaternary cover.

In collaboration with the Université de Nancy (ENSG), a project aimed at modelling the thickness of Quaternary deposits over the Abitibi greenstone belt was completed. The objective is to produce an isopach map of Quaternary sediments and a map of the bedrock topography, to highlight areas where ancient sediments or altered bedrock are more likely to be preserved.

Finally, the first phase of an esker and glacial sediment sampling project was undertaken in the Lac Saffray area south-east of Kuujuaq. This three-year project will combine glacial prospecting tools with bedrock mapping, in the search for mineral targets. The Ungava Quaternary project will result in a regional overview of the diamond and gold potential of investigated areas.

Session 1

Assessing the Quaternary cover and bedrock topography of the Abitibi greenstone belt: Implications for mineral exploration

Guillaume Rongier (U. Lorraine-ENSG), Olivier Rabeau and Guillaume Allard (MRN)

The Abitibi region exhibits evidence of multiple advances and retreats of the ice margin in the Labrador Sector of the Laurentide Ice Sheet. Recent glaciations have led to the deposition of extensive layers of Quaternary sediments. In areas with a thick cover, maps showing the depth to bedrock and the bedrock topography can prove useful in many domains: for hydrogeology, geotechnical studies, geophysical surveys, mineral exploration, etc. In the mining field in particular, these maps may be used to outline zones where weathered bedrock (saprolite) has been preserved. These zones of weathered bedrock – where certain elements representing a potentially economic resource may be concentrated – may have been protected from glacial erosion in certain areas, where the bedrock topography provided favourable conditions for preservation. The presence of a few saprolite zones has recently been documented within the study area. Work to define potential zones for the discovery of saprolite under the Quaternary cover was undertaken in the western part of the Abitibi greenstone belt. Maps showing the depth to bedrock were generated over a surface area of 23,000 km² based on data from outcrops, thin till cover and drill holes. These data come from a variety of sources: the Geological Survey of Canada, the *Ministère des Ressources naturelles*, mining companies, and the *Ministère du Développement durable, de l'Environnement, de la Faune et des Parcs*. Following a validation process, a standardized database was generated in ArcGIS format. The 416,984 depth-to-bedrock data points present an exponential distribution and their spatial distribution is mainly clustered around inhabited areas and mining centres. After a few attempts, kriging was selected as the preferred interpolation technique to estimate the depth to bedrock across the entire study area. The bedrock topography was then determined by subtracting this depth from the surface topography. The best-fit model was selected through cross-validation and comparisons with known geomorphological and structural features (eskers, faults). Zones of potential saprolite preservation were interpreted in areas of great depth to bedrock that did not correspond to known esker structures. The relationship between deep troughs and the various gold-bearing faults in the Abitibi can be used to focus on potential areas to explore for supergene deposits.

Session 1

Implications of the reanalysis of lake sediments in the Northeastern Superior Province for the development of new exploration models

Charles Maurice (MRN)

Nearly 18,000 lake sediment samples covering a surface area of more than 260,000 km² in the Northeastern Superior Province (NESP) were reanalyzed. These samples were initially collected in 1997, at a spacing of one sample per 13 km², within the scope of a regional survey encompassing more than 26,000 samples (survey 1997520¹). About 2,000 of these, mostly samples located west of Ungava Bay, were reanalyzed in 2004 to determine their precious metal content². In 2009, 4,000 samples collected further east, in an area underlain by the Churchill Province, were reanalyzed for a large suite of elements³. The new data available today consist of analyses carried out at the same laboratory as in 2009, using the same analytical protocols³.

The database has now been upgraded with analytical results for which more than 95% of previous results were below or equal to detection limits (e.g., Be and Se). Certain elements had not been analyzed previously (e.g., Hg, In, Nb, Sn, Ta, Te, Tl), whereas others were simply unusable. This is the case for Bi notably, which shows a correlation coefficient of 0.09 between ICP-MS and ICP-AES results, a scatter inferred to result from interference with Cr in ICP-AES analyses.

In the Goudalie Domain and the La Grande Subprovince, the new data reveal metal associations typical of porphyry systems associated with felsic intrusives derived from a sedimentary protolith. Thus, we see, from north to south, several domains where lake sediments are successively enriched in Bi-In (Sn), Bi-W (Sn-In), Mo, Sn-W-Mo, then W-Sn. Collectively, these domains are aligned along a NNW-trending axis some 350 kilometres long, similar in size to the 300-kilometre W-Sn Jurassic Nanling Province in China. Further north, in the Utsalik Domain (Nantais Complex), the combination of high Bi and Te concentrations in lakes proximal to known gold showings may suggest the presence of mineralized systems involving bismuth tellurides. The new lake sediment data may be used to further define existing exploration models, but may also contribute to outlining geological settings previously unrecognized in the NESP.

1. 35 elements by ICP-AES, partial digestion in nitric acid (0.5 g) and 9 elements by neutron activation (10 g)
2. Au, Pd, Pt by fire assay with ICP-MS (5 to 15 g)
3. 53 elements by ICP-MS, partial digestion in *aqua regia* (0.5 g)

Session 1

Preliminary results of recent geological mapping in the Baie-James region

Hanafi Hammouche, Pénopée Burniaux, Jean Goutier, Claude Dion and Daniel Bandyayera (MRN)

Since 2009, the area around the La Grande 3 and La Grande 4 reservoirs (Baie-James) has been the focus of geological mapping at a scale of 1/50,000. This work is also supported by new high-resolution aeromagnetic surveys.

The map area is mainly underlain by rocks of the La Grande Subprovince, locally spilling into the Opinaca Subprovince. It is dominated by Archean rocks, mostly tonalitic gneisses and foliated tonalites. Some of these rocks belong to the Langelier Complex and are interpreted as basement rocks, whereas others crosscut volcano-sedimentary sequences and are syntectonic. Archean (Keyano, Magin and Marbot formations) and Proterozoic (Sakami Formation) sedimentary basins formed atop these basement rocks. Volcanic belts, albeit generally dismembered, were recognized during mapping (eastward extension of the Guyer Group, Corvette Formation).

Archean sedimentary formations and volcanic belts contain centimetre-scale to metre-scale beds of iron formation and massive to semi-massive sulphide bands. Ultramafic sills and dykes, from one to ten metres in thickness, crosscut the latter and locally host sulphides.

In the south part of the map area, the Opinaca Subprovince is represented by the Laguiche Complex, mainly composed of migmatitic paragneisses.

Late Archean magmatism resulted in the emplacement of vast felsic to intermediate intrusions. Archean and Proterozoic gabbro and gabbro-norite dyke swarms crosscut all of the above.

The dominant structural fabric is roughly E-W. Major lithostratigraphic assemblages are separated by ductile deformation zones. The metamorphic grade reaches the amphibolite facies in the La Grande Subprovince, and the granulite facies in the Opinaca Subprovince.

Recent mapping has namely contributed in redefining the boundary between the two subprovinces. It has also led to the identification of several types of mineral occurrences with promising potential:

- Iron formations associated with gold and base metal occurrences. These are generally interbedded with volcanic rocks of the Guyer Group;
- Volcanogenic base metal and precious metal occurrences including sulphide-facies formations and disseminated sulphides (PY-PO $\pm$ CP) in alteration zones;
- Cu-Ni-PGE and Cr-PGE occurrences in ultramafic intrusions crosscutting rocks of the Guyer Group and the Corvette and Keyano formations;
- Mo-Cu occurrences associated with granitoids similar to those in the Lac Tilly area, north of the map area;
- Gold occurrences associated with deformation zones at the boundary between the La Grande and Opinaca subprovinces;
- Vein-type Cu-Ag $\pm$ Au occurrences, generally consisting of rectilinear quartz veins in shear zones.

Session 1

Geophysical surveys in the Labrador Trough and the Churchill Province: Results and preliminary interpretation

Isabelle D'Amours and Thomas Clark (MRN)

Géologie Québec carried out in 2011 two new high-resolution magnetic and gamma-ray spectrometry surveys over the New Québec Orogen, also known as the Labrador Trough, and the west part of the Core Zone in the Southeast Churchill Province. These new surveys cover a surface area of 27,000 km², *i.e.* 38 map sheets at 1/50,000 scale. Additional surveys are underway to complete the geophysical coverage of the Churchill Province. Aeromagnetic and spectrometry surveys have become indispensable tools for regional mapping and contribute to a better understanding of this area where the diversified mineral potential remains poorly known given its geographic isolation. Based on a preliminary review of these new data, combined with data from recent surveys carried out by the Earth Science Sector of Natural Resource Canada, we will present a few observations and interpretations made to date, while attempting to put these into the context of the tectono-stratigraphic model currently used for the Labrador Trough. Examples will focus on the geometry and the nature of major faults and regional fold systems, the link between deformation in the Trough and its hinterland, the distribution of iron formations, and the potential causes of gamma-ray spectrometry anomalies.

Session 1

A new look at the Churchill Province: Tectonic evolution and implications for exploration of mineral resources in northern Québec and Labrador

David Corrigan (GSC-Ottawa)

A large amount of new data has been generated and new concepts developed since the publication, more than 20 years ago, of the last synthesis on the evolution of the Churchill Province. This province represents the final configuration of a Wilson cycle, which saw the opening and closure of one or many oceanic basins, among which the Manikewan basin, during the formation of the Nuna supercontinent from ca. 2.07 to 1.80 Ga. Convergence began with the progressive accretion of Archean sedimentary basins, continents and microcontinents, juvenile continental and oceanic arcs, and back-arc basins, from the southeast margin of the Rae craton toward the southeast. This accretionary period was followed by the final collision with the Superior craton and ultimately with the North Atlantic (Nain) craton. After this collisional period, tectonic activity migrated to the south margin of the Superior and North Atlantic cratons, adding new juvenile crust until the onset of the Grenville Orogeny resulting from the collision with the continent of Amazonia. Given the intimate link between tectonic processes and metallogeny, we are now in a better position to understand, at least in part, the distribution of ore deposits across the Churchill Province and to better assess their prospectivity in under-explored areas. The Churchill Province namely hosts world-class Paleoproterozoic VMS ore deposits (Flin Flon, Snow Lake), orogenic gold (Seabee mine, McLellan mine, Snow Lake), nickel (Thompson, Raglan, Lynn Lake, Rottenstone) and iron ore deposits (Schefferville). It also includes a few prospects at the development or advanced exploration phase [diamondiferous kimberlite in Fort-à-la-Corne; Bravo Formation (Homestake-type)]. In terms of tectonic setting at the time of formation, juvenile supracrustal belts in the Circum-Superior, including the Cape Smith Belt and the Labrador Trough, share a few common points with the mineralized terrains mentioned above. The Core Zone (banded microcontinent wedged between the Superior and North Atlantic cratons) also shares some common characteristics with the Sask craton that hosts the Fort-à-la-Corne kimberlite in Saskatchewan. Another area of interest is the Athabasca area and its uranium, derived from a complex relationship between late- to post-orogenic extension faults and deposition of reducing sedimentary layers. These observations outline the importance of the Churchill Province in terms of its mining prospectivity, and consequently, the Labrador and Ungava troughs (Cape Smith Belt) as areas with tremendous potential for the discovery of future ore deposits.

Session 2

Classic substances / new substances: Challenges and constraints in the beneficiation of new ores

Normand Grégoire (Genivar)

Growing demand for both classic substances and new substances has accelerated the development of increasingly complex mining projects and has emphasized the importance of the beneficiation of polymetallic ores through new and innovative processes. The depth of required scientific knowledge (particularly in exploration and mineral processing), expertise provided by laboratories and consultants, and consultation processes and environmental authorizations are also determining factors. Contemporary projects, from right here, that break from conventional ideas in exploration and mineral processing, will be used to briefly illustrate this situation. The presentation will also provide a brief summary of new substances that will become part of our mining profile in the short and medium term.

Session 2

Applied mineralogy: A tool to better understand iron ore concentration processes

Sylvie Lévesque, Marilène Renaud, Daniel Michaud
and Simon Goudreau (COREM)

It is essential to determine the mineralogical characteristics of iron ores to optimize valuable iron ore concentration processes and to predict their performance.

Growing demand in recent years for the production of iron concentrate has stimulated the mining of new ore deposits and the arrival of new concentrators. Existing iron ore concentrators must also increase their production to meet demand. To do so, zones of lesser interest in mines, which had not been targeted before due to specific metallurgical issues, are now being considered. The need to reach basic grade and recovery characteristics for produced concentrates may represent a technical challenge to maintain the economic viability of mineral processing.

To this end, increased knowledge of ore mineralogy constitutes a major, if not crucial asset. Applied mineralogy is used to study the characteristics of ores and compare them with concentration processes so as to understand the resulting outcome. Mineralogical characteristics include the mineral composition, liberation, and texture of ores. Modifications may then be proposed based on this information, to improve existing processes or to maintain the performance level following a change (current or future) in the mineralogical characteristics of processed ores.

Examples of ores with various mineralogical characteristics will be presented during this presentation, and existing (or proposed) concentration processes used to treat these ores will be discussed along with existing (or predicted) recoveries.

Session 2

85 years of development at the Horne Smelter

Yves Prévost (Xstrata Copper)

The Horne Smelter in Rouyn-Noranda will be celebrating this year its 85 years of operation. Originally built to process ore from its own copper mine, the smelter quickly carved out its share of the custom-smelting market, becoming entirely dependent on the latter when the Horne mine ceased operations in 1976. Over the years, concentrates have become increasingly complex and the proportion of recycling material has increased. This presentation will provide an overview of developments introduced at the smelter over the years, and will focus on its outlook for the future.

Session 3

Permafrost and climate change in northern Québec, challenges for regional development

Michel Allard (Université Laval)

In Québec, permafrost extends below the surface over vast expanses of land in the northern parts of the province. Sporadic lenses of permafrost may be found across the landscape starting at 51°N, generally in peat bogs where it is only a few metres thick, but also at the top of barren rocky hills. The discontinuous permafrost zone extends approximately between latitudes 56° and 58°N. Here, permafrost occurs in patches in peat-rich and clay-rich soils, in both valley bottoms and tundra-covered hills. Beyond 58°N, the continuous permafrost zone takes over, overlain by tundra, and temperatures in the subsurface are considered to be below 0°C over at least 90% of the surface area. The thickest section of permafrost measured to date is 630 m, on the Katinniq plateau. However, permafrost does not develop under lakes, which are very abundant in northern Québec, and this explains the presence of transition zones and vertical contacts between frozen and non-frozen areas, which may generate problems for the mining of ore deposits. In the continuous zone, temperatures in the permafrost are very cold (about -3°C to -7°C), but in the discontinuous and sporadic zones, temperatures are now on the order of 0°C. Since 1992, temperatures in permafrost have gone up by about 2°C across Nunavik (at 4 m depth) and this trend will continue. All unconsolidated Quaternary deposits present in this area are likely to contain ice. Some, like post-glacial marine deposits, contain more than others. The presence of ground ice, which upon melting triggers settling and instability of terrain and infrastructure, represents a challenge for the construction and maintenance of roads, landing strips, and buildings. It is critically important to understand the properties of permafrost (texture, ice content, thickness of active layer) and the local factors that affect its thermal regime (weather, differential snow accumulation, organic and plant cover) in order to select the most appropriate construction methods. Finally, in the case of mining operations, it is important to realize that mining waste and tailings will be exposed to the cold and that permafrost forming in waste piles (which we call industrial permafrost) will have specific properties depending on the texture and geochemical composition of the waste material. The engineering solutions selected upon opening a mine will have an important impact on operating costs and maintenance costs, and on the environmental performance of mining companies.

Permafrost: soil and rock that remains below 0°C for an extended period of time.

Session 3

Xstrata Nickel's Raglan Mine: The challenges for a mining operation in northernmost Québec

Pierre Barrette (Xstrata Nickel)

This oral presentation will focus on the challenges faced by operations in an Arctic climate and in isolated areas. The issues to be discussed namely include the complex logistics, power generation, management of support infrastructure, partnerships with Inuit communities, and issues related to mining in permafrost.

For companies, mine development in the Far North involves its fair share of challenges and Xstrata Nickel's Raglan Mine is no exception.

Located in northernmost Québec, Xstrata Nickel's Raglan property extends over nearly 70 kilometres and includes a series of rich deposits of high-grade nickel and copper ore. The facilities include four underground mines, a concentrator, a power plant, administrative offices and residential buildings, a source of fresh water, and fuel tanks. A road network open year-round links the mining complex to a landing strip located in Donaldson as well as warehouses and port facilities located in Deception Bay.

This presentation will outline some of the *savoir-faire* developed by Xstrata Nickel's Raglan Mine to ensure the success of its mining operations.

Session 3

The challenges associated with project development in northern settings: the Meliadine project case study

Michel Julien (Agnico-Eagle Mines)

Agnico-Eagle Mines (AEM) is developing the Meliadine project in Nunavut. This is a gold mining project being developed as an open pit and underground mining operation. When production commences, sometime after 2017, the Meliadine project will be AEM's second mining operation in Nunavut after Meadowbank. It is clear that developing a mining project in a northern setting involves very unique challenges, namely in terms of logistics, manpower, health & safety, and permitting. Drawing on its experience in Meadowbank and its team of experts, AEM has a good understanding of how complex this type of project can be and is well prepared to face the challenges that come with this new project.

This presentation will discuss the distinctive characteristics of the Meliadine project: a northern environment characterized by extreme temperatures, continuous permafrost, innumerable lakes, and complex socio-economic issues related to personnel recruitment and community relations with the Inuit. An overview of the permitting process in Nunavut will also be provided to show the impact permitting issues can have on the overall planning and scheduling leading to production. We will also discuss a few technical issues relating to mine development in an extremely cold setting, particularly the impact of short material shipping seasons on the construction schedule, the impact of temperatures on the performance of mining equipment, and global water management (surface water, groundwater, process water, etc.). Finally, the challenges and the risks associated with the preparation of a cost estimate for a project in this type of environment will be discussed.

Session 3

The Strange Lake heavy rare earth deposit: Building a world-class mine in Québec's far North

Peter Cashin (Quest Rare Minerals)

Quest Rare Minerals' Strange Lake B-Zone project is located in Northeastern Québec, approximately 220 km northeast of Schefferville and three km northwest of the Quebec-Labrador border. As the largest heavy rare earth resource outside of China, the deposit is expected to play a critical role in meeting the long-term supply needs for the growing technological economy. Quest is addressing the sustainable development challenges of building a world-class rare earth mine in Northern Québec. Issues related to creating new mine infrastructure, to the development of responsible aboriginal relations, and the assurance of mitigation of impacts of mining in a sensitive ecosystem will be addressed by this presentation.

Session 3

The mineral resources of Northern Québec: How do we convert the potential into an economic reality?

Jean-Marc Lulin (Azimut Exploration)

More than 300 economic ore deposits, 550 mineral deposits and 6,700 mineral occurrences of all types of commodities have been discovered to date across Québec. After a first wave of 19th century discoveries in the Eastern Townships, exploration in the 20th century moved north, mainly into the Abitibi and North Shore regions. The same trend can be seen today as exploration and mine development activities are moving into the James Bay region and Nunavik, even further north from the dominant active mining regions.

This current expansion phase is driven in part by external factors (greater global demand related to strong metal prices) and in part by internal factors in Québec, particularly the existence of high-quality geoscience data and a legal and fiscal regime favourable for investments. Unprecedented challenges must be faced, however, given the sheer size of the territory at stake (1,200,000 km²), the lack of infrastructure, and weather constraints. This land remains at a very early stage of economic development, as illustrated by the presence of only eight active mines, which represent only 0.003% of its surface area.

The development of Northern Québec must be approached in two complementary ways:

1. In the short term (1-5 years), with advanced projects in the pre-feasibility, feasibility or development stage. These projects correspond either to earlier discoveries that are not yet in production namely due to adverse market conditions (for iron notably), or to discoveries of new ore deposits that took place in the last fifteen years (gold, lithium and diamonds in the James Bay region; nickel and rare earths in Nunavik).
2. In the medium to long term (5-50 years), with exploration projects located along the extensions of known deposits or conceptual exploration projects testing targets over vast and under-explored or never-explored territories. In the latter case, discoveries will need to be sufficiently important to justify the creation of new infrastructure as stand-alone projects. These «founding ore deposits» may eventually become centres of gravity for new mining camps.

Northern Québec can provide considerable strategic depth for the economic development and prosperity of Québec. Considering the sheer size of the territory at stake, and the occurrence of economic cycles, it is wishful thinking to believe that 30 years from now, or even 50 years from now, its mineral potential will have been fully assessed. Securing land access in the long term and maintaining a favourable legal and fiscal framework appear to be two essential conditions that will make it possible to eventually convert this potential into an economic reality.

Session 4

Critical Materials for a Sustainable Future: Lithium, Graphite and the Rare Earths

Gareth P. Hatch (Innovation Metals Corp.)

The future success of sustainable global energy production will depend on our ability to locate, extract and utilize a number of lesser-known but critical materials. Materials such as lithium, graphite and the rare-earth elements (REEs) will be vital for the production of the electrical machines, energy-storage batteries and other high-tech devices that will be required for a sustainable future. This presentation will review the present supply and demand drivers for these materials, the global challenges faced in developing associated projects, and the important role that Quebec could play in the development of the industries associated with these materials.

Session 4

The Kipawa deposit: Development of a heavy rare earth project in the Témiscamingue region and related challenges

Paul Blatter (Matamec Explorations)

The Kipawa deposit is located in the Témiscamingue region in Québec, about 140 km south of Rouyn-Noranda and 60 km northeast of the town of Témiscaming. More specifically, it is located on the Zeus property, wholly owned by Matamec and covering more than 22,000 hectares. The Kipawa deposit (51% Matamec, 49% TRECan) is characterized by the presence of key rare earth elements, mainly heavy rare earths such as dysprosium, terbium, yttrium, europium, and neodymium. Eudialyte and mosandrite are the main rare earth-bearing minerals, but no industrial process for these minerals has been developed to date.

A positive preliminary scoping study was publicly released in January 2012, namely indicating a mineral potential of 19 million tonnes at an average grade of 0.428% TREO (total rare earth oxides). The results of this study led the company to fast-track the development of the project and a feasibility study was undertaken last April.

This presentation will initially focus on the global market for rare earth elements and how this projects fits in. Then, in the technical description of the project (including mining, metallurgical and environmental aspects), the challenges associated with the project will be outlined and discussed.

Session 4

Quebec's Graphite: Unlocking its Extraordinary Potential for Humanity Through Graphene Applications

Gary Economo (Focus Graphite)

Quebec's natural graphite is now the subject of universal investigation by the scientific community. Graphene, the world's new wonder material, holds the key to the current global technology revolution. Producing the highest quality graphene at the lowest possible cost will transform our lives. Focus Graphite's Lac Knife, Quebec technology graphite source and Grafoïd's industrial graphene application solutions developments are about to change the material world.

Session 4

Extraction, purification and recycling of minor metals for the semiconductor industry

Frédéric Bélanger and Denis Shink (5N Plus)

5N Plus is a leading producer of specialty metals and chemical products. The fully integrated company has closed-loop recycling facilities and is headquartered in Montréal (Québec, Canada), with production facilities in many countries across Europe, North America and Asia. Using a range of proprietary and proven technologies, 5N Plus manufactures products for use in a variety of pharmaceutical, electronic, and industrial applications. Typical products include purified metals such as bismuth, gallium, germanium, indium, selenium and tellurium, inorganic chemicals based on these metals, and compound semiconductor wafers. Many of these products are critical precursors and key enablers in certain markets such as solar modules, light-emitting diodes, and environment-friendly materials.

This presentation will summarize the various applications and growth opportunities for minor metals such as tellurium, germanium, gallium, and bismuth. We will also focus on the metallurgical processes involved in the extraction, purification, and recycling of tellurium and germanium.

Session 4

Extraction of metallurgical alumina from clayschist: A new technological approach

Marc Filion (Orbite Aluminae)

Canadian company Orbite Aluminae is the owner of unique green technologies that are setting the new standard in the aluminium industry. These technologies make it possible to extract smelter-grade alumina (SGA), high-purity alumina (HPA) as well as other valuable products such as rare earths and other uncommon metals, from a variety of sources like aluminous clay and bauxite, without generating the toxic red mud residue associated with the traditionally used Bayer process. Orbite also holds eleven different families of intellectual property rights across the world, pertaining to its unique alumina extraction process.

The company also holds 100% of the mining rights on a total surface area of 60,984 hectares, including the 6,665-hectare Grande-Vallée property, which hosts an aluminous clay deposit in Québec, Canada. The latest 43-101 report dated May 30, 2012, entitled *Reviewed Preliminary Economic Assessment*, establishes the amount of indicated mineral resources in part of the deposit at more than one billion metric tonnes of aluminous clay.

In addition, the process developed by Orbite does not generate the infamous and caustic red mud associated with the Bayer process which has been used for over 100 years to extract alumina from bauxite. This red mud generally requires long-term impoundment to protect the environment and there are currently 3 billion tonnes of this red mud on the planet. Orbite's process, on the other hand, separates the various components of clay in sequential fashion and recycles the acid used in the process to leach metals.

Session 4

A non-exhaustive review of processing technology development for graphite and lithium

Claude Gagnon (COREM)

The new tendencies in every day technologies can be summarized as portable and green. Demand for portable electronics and production of energy from renewable sources has triggered a demand for elements such as lithium, graphite and rare earth elements, for some of which availability has or may become critical. COREM, a research center located in Quebec City, Canada, specializes in process development for the mineral industry. In this regard, demand for projects on upgrading those value minerals is on the rise. Throughout the years, COREM has participated in the development of new processes for beneficiation or transformation of the above mentioned resources for end users. In a non-exhaustive review of processing of those materials, a few examples of past COREM work on spodumene beneficiation, graphite and lithium carbonate purification for electronic applications and even fabrication of materials from those elements for battery application are given.

Session 5

Gaining a better understanding of the social impacts of mines on Native communities in Nunavik and Eeyou Istchee, an overview of legal, political and social issues

Thierry Rodon (Université Laval)

We are seeing an unprecedented level of mining development on lands subject to the James Bay and Northern Québec Agreement (JBNQA) covering Eeyou Istchee (Cree) and Nunavik (Inuit). Mines are not a novelty in the area however, and it is important to review their past history and the social conditions that prevail in Native communities in this region to gain a better understanding of the potential impacts of mining development.

In this presentation, we will summarize the legal and political framework that governs relationships between mines and communities (JBNQA, environmental assessment process, Impacts and Benefits Agreements, and the notion of “social licence”). We will then present an overview of current knowledge on the social impacts of mines on Native communities in the Canadian Arctic based on case studies and scientific literature, and we will propose a few potential solutions.

Session 5

ArcelorMittal, the North's largest mining project

Éric Tétrault (ArcelorMittal Mines Canada)

ArcelorMittal announced in May 2011 a \$2.1 billion expansion project, the Plan Nord's most important mining project, and one of the most important private economic development projects in Québec's history.

The economic impact will be felt not only in the Côte-Nord region but across all regions of Québec. The more ArcelorMittal invests, the richer Quebecers become.

Session 5

Economic, environmental and social development of the Renard Project

Patrick Godin (Stornoway Diamonds)

The Renard project is on the verge of becoming the first diamond mine in Québec. Several important milestones were successfully reached over the past year to progress toward this goal. At the end of last year, we published the feasibility study on the Renard diamond project and submitted our environmental and social impact study to government authorities. This year, we: signed an Impacts and Benefits Agreement with the Cree Nation in the Baie-James region; signed a Declaration of Partnership with the towns of Chibougamau and Chapais; successfully completed both the federal and provincial public hearing process; transferred our head office to Montréal; and finally, announced the execution of a Mandate Letter with seven financial institutions concerning a debt financing of \$475M for the Renard project. The main regulatory authorizations enabling us to proceed with construction of the project are expected shortly.

In its **social** approach, Stornoway has always considered it a priority to maintain consistent dialogue with host communities and other stakeholders in the project. This approach, based on integrity and respect, enabled us to fully explain the issues related to the development project we are considering, and the numerous challenges it entails at each step of the process. The fact remains that the support of our stakeholders for the development of the Renard project through each phase of the process played a major role in advancing the project to completion.

The **environmental** approach on the Renard project resulted in the definition of a project whose environmental footprint will not exceed 3.1 km² (including the landing strip) over the 20 years of operation anticipated in our long-term plan. Our approach was based on the need to minimize the environmental footprint, as well as the desire to develop an innovative approach for water management on the mine site. The creation of environmental exchange groups played a key role by making it possible to take into account the concerns of stakeholders throughout the process to optimize the mine site and to integrate changes that will make Renard a socially acceptable project.

The long-term plan at Renard demonstrates that this project will bring important **economic** benefits for the region, over a period of at least twenty years. In addition, the potential to significantly increase the mine life of this operation remains very high based on our current knowledge. For the population of Québec, this means major benefits in terms of taxes, jobs, contracts, and operational expenditures. Renard will diversify Québec's mineral production and will enable the Nord-du-Québec region to count on yet another economic driving force that will be developed in a manner respectful of its environment and its communities.

Session 6

Of Mines and Men: Mining workers, towns and environments of yesterday and today

Marc Vallières (Université Laval)

Today, the working conditions in mineral exploration and mining, the organization of isolated mining communities, and the natural environment on mining sites respect and comply with the most modern standards. But this has not always been the case over the 150-year history of the mineral industry in Québec. Using old illustrations, this presentation will retrace the historical footsteps of an industry long considered as hazardous for its workers, of residential and urban communities highly dependent on the mines that operated nearby, and of a natural and living environment that was seriously disturbed by the tailings derived from the mining and processing of mineral substances.

The presentation will show that working conditions evolved as exploration techniques and open pit and underground mining methods changed, while being influenced by provincial legislation on occupational health & safety. In addition, mine workers and their families needed, from the very start, homes, businesses and public utilities near the mines, such that rustic mining camps in the woods were transformed into mining towns and even mining regions as mining operations expanded and were established permanently. Finally, mines and mills, smelters and refineries released in the atmosphere, in watercourses and on the ground emissions, tailings, and effluents that over time, greatly disturbed the natural environment of affected areas. Much like any other type of economic activity, it took time to become aware of the hazards and the negative repercussions of the industry on the people, the communities and the environment, to stop considering these as the inevitable price to pay for economic development and job creation, and to take the necessary measures to ensure the sustainable development of mineral resources in Québec, in a manner respectful of its workers, its communities and the natural environment.

All of this is part of the legacy that the mining industry in Québec is passing on to current and future generations, who are much more sensitive to their quality of life and less inclined to favour economic development at any cost. This legacy also includes an industrial heritage attesting to a very wealthy past for industry players and local communities, which must now take a new direction as its useful life comes to an end.

Session 6

Innovation in mineral exploration in Québec – 50 years of history

Marc Boivin (MB Geosolutions) and Gérald Thériault (technician and prospector)

The Province of Québec has a rich history of mine discoveries and remains as attractive as ever for exploration companies. This success has been spurred by 50 years of innovation in mineral exploration; innovation taking place in the form of new geophysical and geochemical tools being developed such as the IP SWP-1 receiver, the Beep-Mat, the EMAL airborne system, mass balance modelling of precursors, and normative mineral calculations (NORMAT index and CONSOREM standard). It has also translated into innovative initiatives such as regional stream sediment geochemistry surveys or INPUT surveys. Many of these developments or initiatives contributed to the discovery of mineral occurrences that eventually became mines, and to the birth of service companies based in Québec, some of which are still in business today. Research agencies such as IREM, CONSOREM and DIVEX also played a role as catalysts boosting creativity in Québec in the search for mineral ore deposits. To prepare the future, it is important to take a look at the past and at the surprising contributions of our innovators.

Session 6

Geomatics in the service of mining

Jacques Charron (K2 Geospatial)

In today's competitive and complex environment, geomatics and geographic information systems (GIS) offer a multitude of approaches, techniques and tools to the mining industry, enabling it to acquire, structure and store, process and disseminate spatial data.

However, to support enlightened decision-making, GIS must be integrated with management systems in use, which are usually independent from one another and generally operate in silos, so as to provide a global perspective on mining operations. In addition, data and systems thus connected must be accessible on a daily basis for non-technical decision-makers. These challenges relating to integration and user-friendliness are faced in a variety of sectors, namely in municipal organizations, government ministries and agencies, public utilities and in the mining industry.

The objective of this presentation is to outline the benefits of using GIS in mining organizations, with a particular focus on mining operations. Examples of applications will be provided.

Session 6

The survival of Niobec through its mining and metallurgical innovations

Steve Thivierge (Niobec)

Since its discovery in 1967 and the start of production in 1976, men and women have contributed in developing this economically significant project. This oral presentation is a retrospective of the major technological advances that have marked the evolution of the Niobec mine and that show just how far we have come. Niobec is what it is today essentially because it has been able to innovate to survive. Our ability to face changes has enabled us to take a leading position in growing markets. A major project is looming on the horizon and you will have the opportunity to glimpse into future technological issues. The know-how of our dedicated people remains our greatest asset and our guarantee of success.

Session 6

Space exploration: The door to tomorrow's mines

Martin Picard and Jean-Claude Piedbœuf (Canadian Space Agency)

Humans have always shown an interest in space. For several millennia, space could only be observed from afar. Only recently, barely more than 50 years, have human beings been able to "step" into space. Initially spurred by scientific curiosity, exploration of the Earth's orbit rapidly generated benefits, as interesting as they were unexpected. We now take for granted weather forecasts, our ability to communicate wherever and whenever, and global positioning systems.

After having conquered Earth's orbit and made a few incursions into the solar system, the Earth is now on the verge of extending its frontiers to include the Moon, the asteroid belt and Mars. This new phase in space exploration is based not only on scientific interest, but also on the possibility of expanding the Earth's economic sphere in the field of space tourism and the mining of extraterrestrial resources.

Since the Moon is most likely the result of a collision involving the Earth and a small planet, it offers the same potential resources as the Earth itself. Asteroids are the remains of the creation of the solar system and present a tremendous resource potential. Recently, the company Planetary Resources announced its intent to initiate mining activities to recover resources on asteroids as they pass near Earth. Imagine a future where humanity has conquered the solar system and can mine its resources.

In the short and medium term, the main resource we can extract is one of the most abundant on Earth: water. This may seem like a paradox, but water is critical for human life in space. It is an effective shield against solar radiation, and can be used to generate oxygen and hydrogen and is thus a source of fuel for our rockets to explore the solar system. Knowing that the bulk of a rocket's mass is its fuel, one may quickly understand how interesting it would be to be able to generate this fuel in space, either on the Moon or from an asteroid. The first "space mines" thus will most likely be water mines!

As a country well endowed in a variety of mineral resources, Canada is in a good position to take part in this type of space mining. In recent years, the Canadian Space Agency has been working with NASA to develop drilling technology and "rovers" (mobile minirobots) that will make prospecting possible, as the first and essential step prior to mining.

Session 7

Giant sulphide bodies in the South Iberian Pyrite Belt in 2012: Current knowledge and outlook for mining

Eric Marcoux (Université d'Orléans)

The South Iberian Pyrite Belt (in Spain and Portugal) is the heaviest sulphide deposit belt in the world, with more than 1,800 Mt of sulphides distributed in at least 86 Zn-Pb-Cu-(Ag-Au) deposits, eight of which contain more than 100 Mt (Rio Tinto, Neves Corvo, Tharsis, etc.). All the deposits are Visean in age and are related to extensive subaqueous volcanic activity dominated by rhyolites.

Its mining history, dating back 4,000 years, is chaotic. The modern period begins with the discovery, in 1977, of Neves Corvo, a polymetallic deposit of more than 280 Mt still being mined in 2012 by Lundin Mining. From this date on, exploration campaigns and discoveries came one after another, but mine start-ups were halted by a drop in metal prices at the end of the 20th century. Over the past decade, a certain renewal has been taking place and mines are opening (Las Cruces) or reopening (Aguas Teñidas) and reserves are being significantly expanded (Neves Corvo).

Although geophysics, and especially gravity, was the most successful tool, the results of scientific studies by international teams accompanied and supported these last three decades of exploration. A detailed study on rhyolite geochemistry demonstrated the existence of two successive but well-constrained episodes (351.5 ± 0.4 and 345.7 ± 0.6 Ma) derived from superficial crustal melting and indicated a geodynamic pull-apart setting. Sulphide deposits are interpreted as being almost exclusively related to the second episode. A detailed structural study showed the predominance of thrust faults in the region, opening up to exploration vast areas previously considered barren.

A better understanding of ore deposit models prevented the restrictions of the massive sulphide model *sensu stricto* and opened the search for and the discovery of other types of deposits. The emergence of volcanism led to the formation of Au-Ag-Hg epithermal deposits (La Zarza: 9.8 Mt @ 1.6 g/t Au). Understanding Miocene paleosurfaces made it possible to recognize the Las Cruces deposit (14.7 Mt @ 6.2% Cu), brought into production in 2009 by Inmet and consisting of an iron cap and cementation zone over a sulphide body. The presence of cassiterite at Neves Corvo is now recognized as being indicative of a perimagmatic event predating the volcanic rocks associated with sulphide deposition.

The combination of successful exploration methods and a thorough understanding of the geological setting remains, in 2012, the best course of action leading to major discoveries.

Session 7

Trace elements in magmatic sulphides and oxides: Implications for petrogenesis, exploration and exploitation

Sarah-Jane Barnes, Philippe Pagé and Sarah Dare (CRC-MM-UQAC)

Most elements that are exploited from magmatic ore deposits; Ni, Cr, Ti, V, Platinum-group elements (PGE) are present only as minor or trace elements in silicate magmas. In order to form an ore deposit they need to be concentrated by factors of 20 to 1000 times. The minerals concentrating these elements are commonly sulphide or oxide minerals. Understanding; how these minerals form, how the minerals themselves can be concentrated, and identifying which are likely to contain the elements of interest helps in developing models of magmatic systems and models for the formation of the ores. The trace element concentrations in the oxides and sulphides combined with textural studies of the minerals can indicate the conditions under which the minerals formed. This information can then be used in provenance studies. Trace element concentrations are particularly important in exploitation of PGE and Au as these may be present in a number of sulfides at the ppm level. Finally the presence of some trace elements such as As and Cd are important because they may poison the extraction circuit or they may leak from mine waste and pollute the area.

The development of laser ablation combined with ICP-MS allows us to determine the concentrations of trace elements in minerals down to the ppb level. Work at LabMaTer, UQAC, shows that in quenched sulphides all of the PGE (except Pt) and Re are present as trace elements in pyrrhotite and pentlandite. In systems that cooled more slowly only 30-40% of the PGE are in the sulphides. The remainder are found in platinum-group minerals (PGM). CT-scans show and SEM studies show that these minerals are generally associated with sulfides, suggesting that the PGM exsolved from the sulphide minerals or in some cases crystallized from the sulphide liquid. In metamorphosed rocks some PGM are completely isolated possibly due to remobilization of the S resulting in rocks that contain ore grade PGE with no obvious collector phase present.

Trace element studies of chromite show that it is possible to distinguish chromites from the mantle, boninites, komatiites, MORB, layered intrusions and OIB, with incompatible element concentrations increasing from mantle chromites to OIB chromites. A wider range of trace elements can be determined in magmatic Fe-oxides and it is possible to distinguish magnetites from different magmatic environments, e.g. layered intrusions, anorthosites, magmatic sulphides.

Session 7

The behaviour of metals (Au-Cu-Zn-Pb-Mo) under stratovolcanoes

Olivier Nadeau (UQAM)

In California, the Sulphur Bank and McLaughlin (Au-Hg) mines are directly associated with the Clear Lake volcanic field. Cinnabar, pyrite, alunite and kaolinite continue to crystallize near geysers and thermal springs. This illustrates that in a broad sense, magmatic reservoirs, volcanoes and porphyry systems are genetically related.

It is by studying porphyries in South America that Sillitoe (1973) established a vertical continuity between porphyries, epithermal deposits and stratovolcanoes. The Bingham gold porphyry (Utah) hosts syngenetic mineralization in a stratovolcano (Hattori and Keith, 2001), where multiple magma injections evolved from a mafic to monzonitic composition, ultimately reaching the surface and erupting. The Pinatubo volcano (Philippines) erupted in 1991, releasing 20 Mt of SO₂ in a plume that traveled around the Earth twice. Since then, it has been the focus of studies aimed at understanding the behaviour of sulphur in magmatic-hydrothermal systems. The Satsuma-Iwojima calc-alkaline volcano (Japan) releases about 0.1 to 10 t/year of Cu, Zn, Pb and Mo, and 10 g to 1 kg/year of gold through its fumaroles. A world-class gold deposit, containing 100 t of gold, could thus form in this location over a period of 1,000 to 100,000 years. These examples illustrate the links existing between volcanoes and metalliferous deposits.

At the Merapi volcano (Indonesia), a mafic magma, reduced and saturated with sulphide melt, was injected into a felsic oxidized magma. Chalcophile metals segregated into the immiscible sulphide melt, which was then dissolved by a magmatic fluid newly segregated from the mafic magma (Nadeau et al., 2010). Although the two magmas did not mix, the hydrothermal fluid transferred metals from the mafic magma to the felsic magma, thereby causing a volcanic explosion and massive metal deposition (Nadeau et al., under review). The injection of reduced mafic magma resulted in a volcanic explosion, a sharp drop in pressure to hydrostatic values, and a pulse of reduced hydrothermal fluid enriched in Cu and Pb (Nadeau, 2011). After the eruption, the magmas evolved through assimilation and crystal fractionation. The felsic magma and its hydrothermal fluid became more oxidized and enriched in incompatible metals (molybdenum deposition). The system was sealed and the pressure climbed to lithostatic values, until the next injection.

The study of volcanoes is critical to help us understand the mechanisms of mineralization such as differentiation of volatile elements and metal compounds between the various phases present in these environments. Volcanoes are indeed windows looking into magmatic hydrothermal processes.

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Session 7

Chrome and nickel occurrences in the McFaulds Lake greenstone belt, Ontario: Current knowledge and outlook for the Superior Province

Michel G. Houlié (GSC-Q), Riku Metsaranta (OGS) and C.M. Leshner (Laurentian University)

The associations of Ni-Cu-PGE-Cr-V mineralization with mafic-ultramafic magmatic systems are well-known, but world-class deposits are becoming more and more difficult to find and operate, requiring a global perspective and understanding of their multiple geological and magmatic settings, diverse mechanisms of sulfide/alloy/oxide saturation, and complex processes of ore transport, deposition, and modification. Canada has long been one of the world's leading nickel producers with numerous world-class nickel districts (e.g., Sudbury, Thompson, Raglan), but except for minor production from small podiform chromite deposits from Appalachian ophiolite complexes has not been a major Cr producer. However, with the recent discoveries in the McFaulds Lake area (i.e., Ring of Fire) in northern Ontario, Canada is poised to become a major producer. This area contains numerous mafic-ultramafic intrusions that have been shown to contain world-class chromite deposits (e.g., Black Thor, Black Label, Black Creek, Blackbird), major Ni-Cu-(PGE) deposit (e.g., Eagle's Nest), and minor (thus far) Fe-Ti-V mineralization (e.g., Thunderbird).

The high level of current exploration activities in this emerging area provides unparalleled access to new, high-quality geoscience data sets and provides an ideal environment to test genetic and exploration models for Cr-(PGE), Ni-Cu-(PGE), PGE, and Fe-Ti-V deposits in ultramafic to mafic systems under the auspices of and in collaboration with the TGI-4 program of the Geological Survey of Canada. This Canada-wide project focusses on district- and deposit-scale studies in the McFaulds Lake area, outlining the key components for detecting hidden or deeply buried orthomagmatic mineralization by using and developing methods to characterize the fertility of intrusions, expanding target indicators, and improving the geological knowledge of the ore environments. Other areas are also targeted within the Bird River greenstone belt (southern Manitoba) and the La Grande–Eastmain domains (Québec), both of which are potential geological extensions of the Oxford–Stull domain (Ontario) of the Superior Province. Together, these domains appear to define what appears to be a major new Cr-Ni-Cu-PGE super-domain (metallotect) that is fundamentally different from the Ni-Cu-(PGE)-dominated systems in the Abitibi greenstone belt or, thus far, the relatively unmineralized North Caribou terrane and Goudalie domain.

A thorough understanding of the geological context combined with the main characteristics of these new Cr-(PGE), Ni-Cu-(PGE), PGE, and Fe-Ti-V orthomagmatic deposits will hopefully highlight the likelihood of discovering additional major deposits within the Superior Province and in other frontier areas throughout the Canadian Shield in Canada.

Session 7

Geophysical signature of late Archean gold-bearing intrusions in the Abitibi in their geodynamic setting

Noémie Fayol, Christophe Azevedo, Ludovic Bigot, Michel Jébrak (UQAM) and Lyl B. Harris (INRS-ETE)

The Abitibi Subprovince encompasses numerous calc-alkaline to alkaline intrusions associated with major gold deposits. With ages from 2685 to 2670 Ma, in southern Abitibi they are located in late Archean sedimentary basins. The highly variable petrology of these plutons, their emplacement dynamics and their magmatic hydrothermal evolution have been the focus of studies in an effort to renew our understanding.

The study of geophysical data, particularly the magnetic signature of these intrusions, enables us to attempt an early diagnostic on their metallogenic potential. These data may be used to illustrate the tectonic setting, the relative timing of events and possibly the oxidation state of magmas. For instance, the presence or absence of certain sets of faults may suggest a transtension or transpression basin setting; the shape of the intrusion and of regional fabrics may be useful to determine if the intrusion is pre-, syn- or post-tectonic. Finally, zoning of magnetic susceptibility values may indicate the presence of a redox front with, more specifically, the transition from a magnetite zone to a hematite zone. The latter is critical in terms of mineral potential, since the gold potential is particularly influenced by the oxidation state of magmas.

Although most of these basins are considered as pull-apart basins occurring in E-W-trending deformation zones, others such as the Desmaraisville basin associated with a NE-SW-trending structure, appear to have formed in a transpression regime. This stress localization phenomenon related to variations in crustal density was highlighted by studying gravity and aeromagnetic data of the area and by experimenting with analogue modelling.

Finally, a comparative study of mineralized intrusives reveals contrasts between the Beattie district in Duparquet and the O'Brien district at Bachelor Lake, respectively located in a pull-apart basin and a transpression basin. Although the metallic paragenesis, with pyrite, gold, magnetite and hematite, is very similar, the Beattie ore deposit is characterized by the presence of arsenopyrite. Also, at the Beattie deposit, gold is mainly disseminated in the pluton and remobilized along its edges, whereas the bulk of gold mineralization recognized at the Bachelor Lake mine is localized in an extremely altered tuff unit bordering the intrusion.

The metallogeny of late Archean alkaline intrusions thus reflects significant variations where the geodynamic emplacement setting controls the development of mineralized zones.

Session 8

Strategic disposal of waste rock to improve the geotechnical and geochemical behaviour of rock piles during construction and through mine closure

Michel Aubertin (École Polytechnique) and Bruno Bussière (UQAT)

Waste rock piles generated on mining sites can reach significant proportions. They can also contain reactive minerals likely to interact with water and atmospheric oxygen and thus contaminate seeping water. These rock piles must be designed and built so as to ensure their long-term physical and chemical stability.

The technique used to build a rock pile is usually governed by practical and economic considerations. It is also possible, and often beneficial, to plan the construction of rock piles so as to minimize geotechnical and environmental hazards during operation and closure of the site. This requires detailed planning of the construction sequence however, and controlling the deposition of waste rock based on a configuration that differs from conventional approaches. This approach may for example involve construction in benches, with specific individual bench heights. The overall slope angles of the rock pile should also be constrained, and the surface of each bench should slope outward and be compacted so as to limit water seepage. When part of the waste pile contains reactive minerals likely to contaminate percolating water, selective deposition must be used to minimize exposure of these minerals.

These various aspects will be discussed during the presentation, by illustrating the proposed approach using numerical models and actual case studies.

Session 8

Investigating the beneficiation of processing sludge to prevent and control acid mine drainage

Mamert Mbonimpa, Isabelle Demers, Médard Bouda (UQAT), Mario Gagnon (IAMGOLD) and Mostafa Benzaazoua (UQAT)

Lime is commonly used as an active treatment method against acid mine drainage (AMD). This treatment generates sludge that mainly contains metals precipitated in the form of hydroxides, gypsum, and the excess lime that was not consumed. This sludge has a high water content and is generally deposited in ponds that must be restored once mining operations cease. However, in certain cases, vegetation fairly quickly covers sludge basins, which illustrates their potential as a plant-growing substrate. The sludge may also have interesting geotechnical and geochemical properties that would allow its use as a component in cover systems to control AMD in accumulation areas (tailings ponds or sulphide-rich waste piles).

The objective of this project is to study the use of processing sludge for the restoration of AMD-generating mining sites. The main objective is to establish, based on a robust experimental program, if processing sludge may be used as a cover material in tailings management and mining site restoration. Various possibilities will be investigated, namely using sludge mixed with tailings, with waste rock or with natural soil, with or without added cement.

This work was undertaken in part at the laboratories of the *Unité de recherche et de service en technologie minérale* of the *Université du Québec en Abitibi-Témiscamingue* (URSTM-UQAT) (detailed characterization of materials, column tests) and in part on site at the former Doyon mine (experimental cells to test specific scenarios). The use of sludge-tailings and sludge-waste mixtures (with or without binders) was investigated using kinetic column tests and humidity cell tests to study their chemical stability. The hydrogeotechnical behaviour of selected mixtures was then studied to choose the optimal formulations that would ultimately be tested in experimental cells in the field. In addition, the hydrogeotechnical behaviour of sludge-soil mixtures was studied to assess their possible use as a cover material. Once the optimal mixtures were determined, their chemical stability was assessed in column tests, to select the optimal mixture that would ultimately be tested in field experimental cells. The experimental cells, built in the summer of 2012, will make it possible to assess, in actual field conditions, the performance of single-layer covers composed in part of lime treatment sludge.

Session 8

CO₂ sequestration in mine tailings: A component of green mining

Georges Beaudoin (Université Laval)

Mine tailings enriched in calcium, iron and magnesium possess a carbon sequestration potential that should be better known and put to good use. The divalent cations Ca, Fe and Mg can form carbonates to trap CO₂ permanently and with no environmental impact. Fe and Mg carbonates in particular are resistant to dissolution by meteoric water and so can be considered as a permanent CO₂ sequestration solution. CO₂ is captured in a chemical reaction to form carbonate minerals, which begins with the dissolution of Ca-, Fe-, or Mg-rich minerals such as silicates. Carbonate precipitation occurs when cations are released into solution in the presence of dissolved or gaseous CO₂. The CO₂ storage capacity depends not only on the total cation content in the mine tailings, but also on the mineral structure that is dissolved to release cations into solution. Mineral dissolution must not be inhibited by the precipitation of neoformed phases on surface, and dissolved cations must remain available to react with CO₂. CO₂ may be derived from a high-grade localized source such as a pipe, or a low-grade diffuse source such as the atmosphere. The reaction kinetics are determined in part by the CO₂ content in the reactive gas or liquid, but also by several other parameters controlling seepage, diffusion, mineral dissolution and chemical passivation of reactive surfaces. It has been demonstrated that the mineral carbonation reaction spontaneously takes place in tailings from chrysotile mines in southern Québec. It is the only method that allows simultaneous capture and storage of CO₂ directly from the atmosphere. Mineral carbonation of mine tailings thus shows significant potential for CO₂ sequestration, which may be ten times greater than the greenhouse gas (GHG) emissions produced by the mine. CO₂ sequestration may enable mines to entirely offset their GHG emissions and even generate new income from GHG emission credits.

Session 8

Searching for economic substitutes for traditional binders in paste fill

Mostafa Benzaazoua and Olivier Peyronnard (UQAT)

Backfilling of underground openings during mining operations was introduced in the 1930s and is now a widely used technique. Backfilling using cement fill (the most widely used) consists in injecting in openings a mixture of mine tailings, cement (or cements) (3 to 7% of the solid fraction) and water (in large amounts to facilitate paste flow). This technique is particularly interesting as it makes it possible to extract a greater proportion of mineral resources while reducing the volume needed to store mine tailings on surface.

The cost of backfilling varies from \$2 to \$20 per tonne of backfill; the cement component represents the most important cost item. The large amount of energy needed to manufacture cement, combined with the fact that mines are farther and farther away leads to a particularly unfavourable context for backfilling. The beneficiation of industrial waste for use as binders thus constitutes an interesting substitute. Not only does it lower the cost of cement-based binders, this type of re-use involves major environmental benefits (including lower greenhouse gas emissions, less waste to manage, etc.).

This study was aimed at developing alternative byproduct-based binders to provide suitable mechanical resistance development. The various binders tested include a combination of pozzolanic byproducts (ash, scoria, glass, etc.), hydration activators (cement dust, anhydrite), and traditional binders (Portland cement and blast furnace slag). Up to 50% of traditional binders may be replaced: anhydrite and cement dust help accelerate resistance development, whereas pozzolanic byproducts make it possible to reduce the need for traditional binders. Nevertheless, to obtain very high mechanical resistance, the addition of blast furnace slag is necessary. The excellent cementation properties of slag may be explained by a combination of its optimal characteristics. Consequently, the optimization of byproduct-based binders relies on obtaining those characteristics. The combination of different byproducts may be considered to obtain an optimal composition. Thus, glass could be used as a source of silica, and lime-rich byproducts (waste lime notably) as a source of calcium. The reactivity of byproducts derived from thermal processes (ash, scoria) may be increased by rapid quenching (in water) to give them an amorphous structure.

Session 8

Sludge dewatering and continuous operation

Philippe Authier (ASDR Environnement)

ASDR Environnement specializes in finding environmental solutions for the management and treatment of various types of wastewater and sludge.

As the exclusive distributor of the Geotube process in Eastern Canada and an expert in the optimal operation of this technology, ASDR has been using this technology for more than a decade in the municipal field and for more than five years for mining and industrial projects.

This technology requires very little energy, is a simple and passive method that makes dewatering easier and reduces disposal costs. It is based on a simple principle. Through the addition of reactants, adequately analyzed and controlled, solids are agglomerated and separated from the water component pumped into the Geotube, resulting in more than 90% captured solids; clear water simply seeps out with no added pressure and returns to the process water stream and/or discharge, while respecting natural environmental standards.

After some preliminary laboratory testing, treatment protocols are drawn up and prepared so as to process the sludge in an appropriate manner.

Certain processing operations were developed to meet specific sequential or continuous treatment requirements for various underground mining pumping systems. Usually used in vast working areas, Geotubes were adjusted for smaller workspaces. This filtration technology has certainly evolved since the first lab tests.

For this type of installation, we sought to optimize our sequential and/or monitored treatment system into a continuous, automated treatment system.

The main objectives, in this type of installation, are to process sludge on a continuous basis, to allow water to be reused in operations, to retain the solid-state sludge and re-expedite it via ore chutes, while facilitating operational requirements and reducing maintenance costs for the various pumping systems.

Based on the principle behind our technology, we examined a few dewatering methods and we designed a new dewatering equipment that is more mechanical and modular, that removes water more rapidly and leaves a reduced operational footprint, in an effort to meet the needs of the mining industry.

Session 8

Continuous monitoring of hoisting cables

Sylvain Ouellette (CanmetMINE), Marc-Antoine Jetté (MEGLAB), Eric Leung and Raymond Gaëtan (CanmetMINE)

Hoisting cables are a critical component of underground mining operations. The cost of cables is high and the cost associated with production stoppages required for their maintenance and replacement is even higher. Cable replacement is a complex task that requires specialized material and personnel. An unplanned replacement is much more costly than a planned replacement. In the extreme case where a cable breaks, the overall loss may be very significant.

A continuous monitoring system for hoisting cables is about to be launched on the market by a manufacturer from Québec. This system allows real-time assessments of the condition of cables by producing three types of signals, namely detection of local defects, a measure of the metallic section, and a measure of the length of coiling. In the event one cable or more suddenly deteriorates, the system triggers an alarm and may even automatically immobilize the hoist, depending on the expected result.

Since February 18, 2011, article 305 of Québec's Regulation respecting occupational health and safety in mines allows the replacement of daily visual inspections by electromagnetic inspections. As opposed to visual inspections, a magnetic inspection may detect significant defects, regardless of the amount of lubricant or its position (on the outside or inside the cable). It requires no production stoppages, except for the visual inspection of any newly detected major defect.

For deep mines, article 288.1 of the Regulation respecting occupational health and safety in mines allows for the use of a reduced safety factor, provided South African standards SABS-0293 and SABS-0294 are applied. These standards respectively cover cable inspections and hoisting infrastructure with the reduced safety factor. SABS-0294 namely requires a measure of the dynamic load as well as continuous magnetic monitoring of cables. The reduction of dynamic loads and cable monitoring make it possible to safely and substantially increase the payload.

The regulation also requires that magnetic cable inspections be performed at intervals not exceeding six months. Operationally, inspections are more frequent near the end of the cable's useful life. Safety is always the priority, such that the inspector may shorten the interval before the next inspection if the cable integrity is called into question. It is very easy to transfer files by email to the inspector in charge, enabling the latter to monitor the condition of cables and to determine if and when a new inspection is needed.

Session 9

Seafloor Massive Sulphide Mining – The dawning of a new industry

Steven Scott (University of Toronto)

First observed 34 years ago, high-temperature hot springs (black smokers) on the deep ocean floor are precipitating mounds and columnar edifices (chimneys) of copper, zinc, lead, iron and silver sulphides, gold and other major and minor elements. Some deposits are of sufficient size and metal content to be considered for mining. Canadians have played important roles in their geological and geophysical exploration and evaluation.

Steven Scott is a pioneer in the study of these seafloor massive sulphide (SMS) deposits and is the co-discoverer of the Solwara site in the Manus basin of the Bismarck Sea offshore eastern Papua New Guinea. Nautilus Minerals, incorporated in Canada, intends to mine the large Solwara 1 deposit by the end of 2013 pending resolution of a contract dispute with the PNG government that is presently under arbitration in Australia and the acquisition of a suitable surface mining platform.

Steven Scott will present an overview of this new type of mineral resource, emphasizing exploration strategies, proposed robotic mining methods, environmental issues unique to these deposits and future prospects for continued commercialization.

Session 10

Research on the restoration of abandoned mining sites in Québec

Bruno Bussière (UQAT) and Michel Aubertin (École Polytechnique)

Over the past few years, substantial research has been conducted to develop methods to control acid mine drainage (AMD) production from tailings accumulation areas. Most of these methods aim to eliminate, or reduce to very low levels, the presence of air (or oxygen), water, or sulphides. These three elements are the main components involved in the oxidation reactions that generate AMD, such that eliminating one or the other may reduce acid generation to very low levels. Developed techniques are particularly effective for active sites.

When AMD-generating tailings have been exposed for several years (even several decades in certain cases) to natural ambient conditions, these techniques are not always successful in reaching the targeted environmental objectives, due to the presence of contaminants in the porosity of mine tailings, certain bacterial strains, and iron contents sufficiently high to trigger indirect oxidation (without oxygen) of sulphides. In recent years, research studies have been undertaken to better understand the specific characteristics of abandoned mining sites. The objective of this work conducted in partnership with universities, the *Ministère des Ressources naturelles et de la Faune*, responsible for mining sites, and government agencies that fund research, is to develop restoration technologies that will be effective even under the conditions prevailing at abandoned sites.

After a brief introduction on the scope of environmental problems associated with abandoned mining sites, the main differences relating to restoration of AMD-generating mining sites, whether active or abandoned, will be discussed. A summary of research studies carried out in recent years on restoration methods for AMD-generating abandoned sites will focus on laboratory studies and numerical modelling based on hydrogeological or hydrogeochemical models. The presentation will also include some of the results typically obtained at abandoned mining sites such as the Lorraine, Manitou and Aldermac mine sites. Finally, an overview of upcoming research will be presented.

Session 10

The Gaspé Mines rehabilitation project from 2007 to 2010

L. Jacques Moulins (Xstrata Copper Canada)

Xstrata Copper maintains its commitment to communities once its activities have ended. After 50 years of mining and metallurgical operations in Murdochville, Québec, we implemented a detailed plan to rehabilitate and secure reclaimed areas to allow the site to be re-used in the future.

In light of our consultations with the local population and after numerous assessments and authorizations from the *Ministère du Développement durable, de l'Environnement, de la Faune et des Parcs*, the *Ministère des Ressources naturelles* and public health authorities, we developed a definitive closure and rehabilitation plan.

This plan included the dismantling of 38 buildings, securement and vegetation of tailings ponds, excavation and rehabilitation of soils, reconfiguration of surface water flow and consolidation of water management infrastructure, removal of power lines, dismantling of pipelines, and landscaping of the site. We also built a more effective water treatment plant.

We were particularly careful to collect and recycle equipment and demolition materials and to dispose safely of waste and contaminated soil. We excavated all soils affected by hydrocarbons and submitted them to bioprocessing. Organic soils affected by metals were used to cover mine tailings ponds. We stored large volumes of hazardous waste on site, in a safe confinement cell built specifically to this end. Other hazardous waste was sent to approved facilities off-site. We focused on recovering materials for re-use or recycling. For example, we shipped construction steel, reinforcement bars and electrical cables to recycling plants and crushed concrete on site to use it as fill material. We also treated soils showing high copper concentrations at our Horne smelter in Rouyn-Noranda.

In Murdochville and near the port of Gaspé where we shipped copper concentrate, we launched, of our own accord, a soil characterization program on 795 private, commercial and industrial properties. After analyzing 10,000 samples, we restored 736 properties with the owners' consent.

We held open-house days and published news bulletins to maintain regular communications with the local population. We explained our plan to citizens, we invited them to share their comments with us, we set up a phone line for the population, and we named a Community Relations Coordinator. The Citizen's Environmental Committee we created when the mine was in operation continued to meet. This committee is formed of municipal employees and elected officials, members of the community and regional representatives from various provincial ministries such as the MSSS, the MDDEFP and the MSP.

Whenever possible, we hired local and regional personnel and businesses and provided training on Xstrata practices in environmental and health & safety matters. We are proud to report that after more than 670,000 hours of work, not a single lost-time accident took place!

We maintained our support to the municipality by making a donation of equipment to the Copper Interpretation Centre. We built a viewpoint that provides access to the restored metallurgical site so as to enhance the experience of visitors. We also contributed to the financing of a retirement home, to embellish all the town's entrances and to create a bike path near Gaspé.

Since 2010, the Murdochville site is under the constant surveillance of an Xstrata employee who is responsible for care and maintenance and who is making sure our restoration measures are successful. His responsibilities namely include inspecting water management infrastructure and ensuring all equipment remains in good working order. The restoration project cost a total of CAN\$130 million and was completed on schedule and under budget.

Session 10

Fonds Restor-Action Nunavik: 5 years already and what an achievement!

Nancy Dea (KRG) and André Gaumond (Virginia Mines)

The *Fonds Restor-Action Nunavik* (FRAN) was created in 2007 to participate in a collaborative effort involving the provincial government, the mining industry and local Inuit communities, to restore former mining sites and abandoned outfitters in Northern Québec. After five years of work, 18 of the most important sites have all been cleaned up. This means that more than 40,000 barrels of fuel, hundreds of propane tanks, tires, batteries, and mattresses have been removed from Nunavik. Several tens of tonnes of metal have also been recycled.

Just recently, a second five-year agreement was signed by all stakeholders to pursue restoration efforts on secondary sites. More than \$2.6 million have been invested to date on this restoration project, and a budget of \$2.8 million is planned for Phase II (2013-2017).

Session 10

Restoration project at the Principale mine in Chibougamau

Alain Philibert, Anderson Santos (SMI) and Alexandre Couturier-Dubé (MRN)

The Principale mine was one of the most important mines in the Chibougamau area. Mining operations at the copper-gold deposit began in the 1950s. The mining complex included a headframe¹, an open pit, workshops, administrative offices, a laboratory and an ore concentration plant. The plant processed ore from close to a dozen different mines in the vicinity. Tailings were deposited in three different accumulation areas covering about 270 hectares, including a polishing pond. The processing plant ceased operations in 2005. In May 2010, when the owner went bankrupt, the State became responsible for the site. The *Ministère des Ressources naturelles* (MRN) immediately launched a stability assessment study in certain parts of the site to ensure the safety of people accessing the site in the short term. Securement work was rapidly performed. Subsequently, a site characterization study was undertaken, looking at three different aspects: environment, geotechnical engineering, and stability of the site. These studies enabled the MRN to begin preparations for a site restoration plan, with the collaboration of SMI Consulting Group.

Given its extent, the site to be restored was divided into distinct homogeneous zones with specific problems to be addressed, either acid mine drainage (AMD)-generating tailings, structures, contaminated soils, groundwater depth, or surface water quality. For each zone, various technically viable scenarios were developed and analyzed to reach the MRN's restoration objectives.

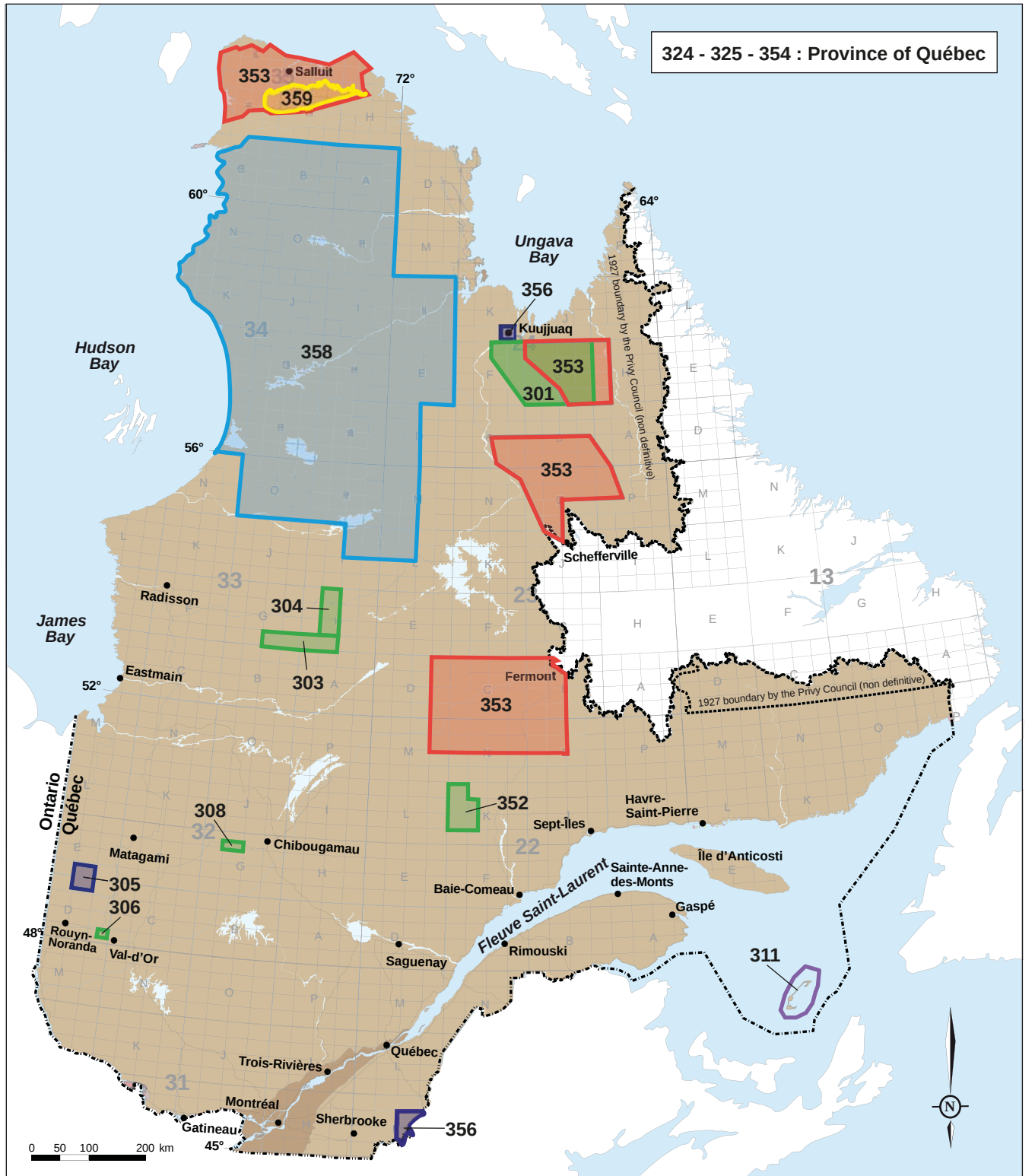
These scenarios were assessed using criteria based on the three (3) components of sustainable development (environmental, social, economic). Environmental and social criteria were addressed by taking into account the concerns of local communities, particularly in Chibougamau and Oujé-Bougoumou, expressed during information sessions and discussion meetings. A multi-criteria assessment grid was then used to compare scenarios and to choose the solution that provided the best fit with MRN and community objectives.

This is a vast and complex site, which means that proposed restoration solutions combine a variety of techniques to stabilize steep slopes, minimize erosion, confine AMD-generating tailings, and reduce contamination of surface water and groundwater, keeping in mind the possibility that the site may eventually be used for other purposes.

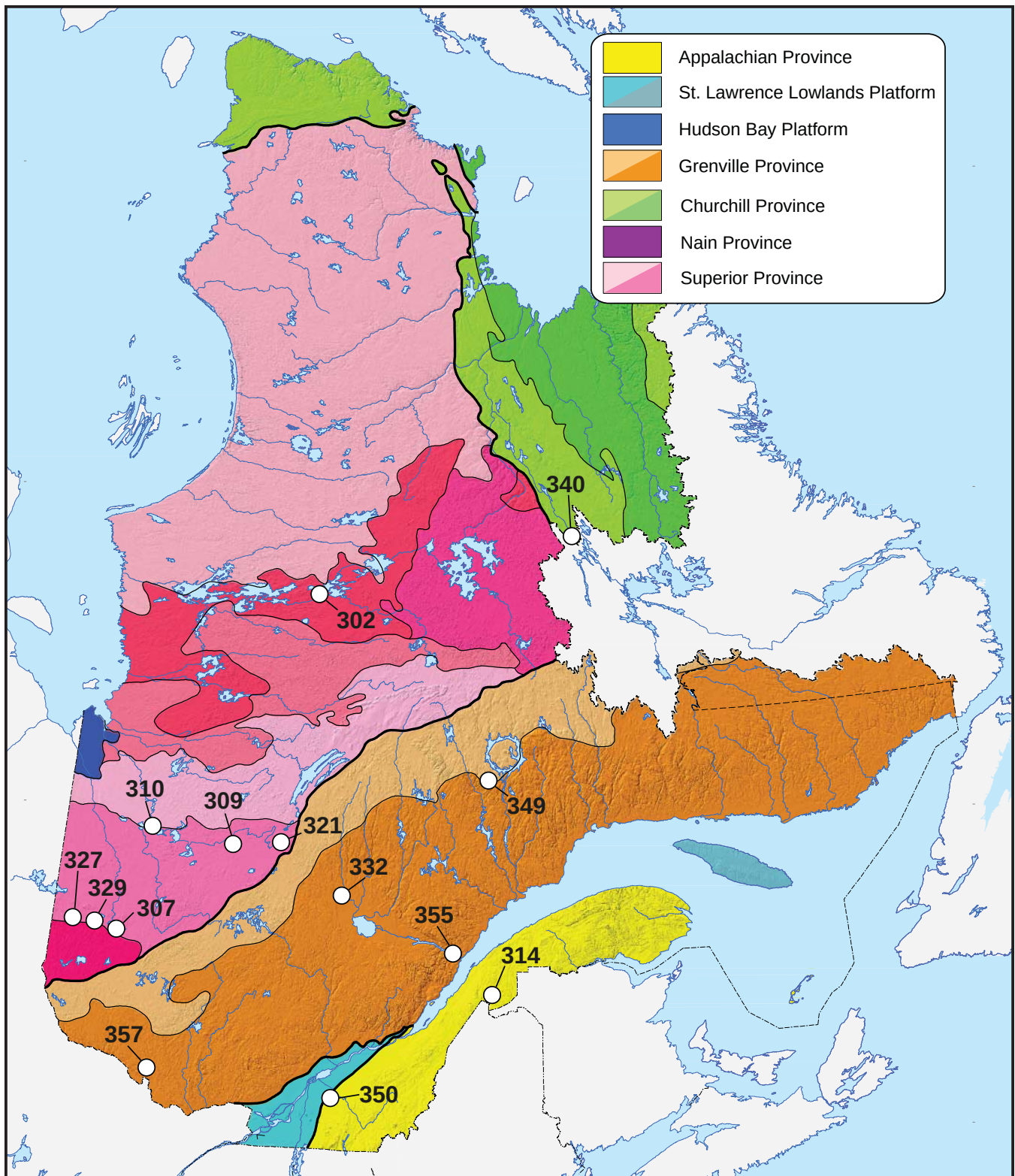
1. Headframe: structural frame made of metal, or occasionally concrete, installed at the top of a mine shaft to support the sheaves for the hoisting cables.

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LOCATION OF UNIVERSITY PROJECTS



301

Geology and economic potential of the Lac Saffray region, Southeast Churchill (NTS 24G and 24F-East)

Isabelle Lafrance, Daniel Bandyayera, Martin Simard (MRN)

This new geological survey at 1:250,000 scale, carried out during the summer of 2012 in the Lac Saffray area, 100 km southeast of Kuujuaq, comprises the Core Zone of the Southeast Churchill Province as well as the Rachel-Laporte Zone, which is considered the metamorphosed equivalent of the Labrador Trough.

In the mapped area, the Core Zone corresponds to an Archean craton, deformed and remobilized during the Proterozoic as part of the Nouveau-Québec Orogen. It consists of complex assemblages of gneiss, often migmatitic, intercalated with slices of paragneiss and amphibolite several kilometres long. Our work revealed the presence of a large unit of migmatitic paragneiss in the west part of the Core Zone that may correspond to an ancient sedimentary basin of Archean or Proterozoic age. Numerous syn- to late-tectonic Proterozoic intrusions of granodiorite, granite and pegmatite cut the older rocks. The largest is the DePas Batholith, which extends for more than 600 km in the heart of the Core Zone and crosses the east part of our study area. The Rachel-Laporte Zone is dominantly composed of metasediments and amphibolites with decametre-scale layers of marble and calc-silicate rocks. The NW-SE regional structural grain is overturned to the west, defined by a subhorizontal foliation, recumbent or overturned folds, and thrust faults.

Many decimetre- to decametre-scale sulphide zones were discovered in the Rachel-Laporte Zone. These are of particular interest because the contexts are similar to those of showings in the less metamorphosed equivalent rocks of the Labrador Trough. Most of the mineralized zones are found within layers of fine-grained schistose amphibolites and, to a lesser extent, in metasediments, at the contacts between ultramafic intrusions and metasediments, and within metre-scale layers of graphitic argillite. Mineralization is most commonly in the form of finely disseminated sulphides, mainly pyrrhotite, although semi-massive zones associated with silica and chlorite alteration were also observed at the contact between the metasediments and amphibolites. Metre- to decametre-scale mineralized zones were also observed in the Core Zone. These were mainly found in amphibolitized gabbros and diorites, as well as in migmatized paragneiss and in diatexites. Some of these zones can be traced over several hundred metres in length.

302

Petrochemical study of sedimentary basin in the La Grande Subprovince (Baie-James)

Quentin Duparc, Pierre A. Cousineau (UQAC), Daniel Bandyayera, Jean Goutier (MRN)

Following the 1:50,000 mapping of part of the Baie-James region (33H13, 33H12, 33H08 and 33G05), the BEGQ collaborated with UQAC for a Master's project that aims to test potential correlations between the Magin, Brune and Keyano formations. Located in geographically separate basins, these three formations are characterized by strongly metamorphosed conglomerates and sandstones. These rocks will be studied from a sedimentological, petrographic and geochemical perspective. U/Pb dating on zircons will also be carried out to provide a temporal framework.

The work began in the summer of 2011 and continued in the summer of 2012. The first step was to choose the most representative sites and build stratigraphic columns. We selected places where these formations are the least deformed to facilitate the study and interpretation of their environment. We performed bed-by-bed surveys of sedimentary structures, including the determination of paleocurrents directions and the nature of the contacts, both vertical and lateral, in order to document facies changes. For the conglomerates, clast size, roundness and composition were also noted. The findings of our sedimentological field work support a Timiskaming-type fluvial environment common to all three formations and no notable distinctions between them.

The ongoing petrographic study of the sandstones, initiated in 2011-2012, has revealed near-total metamorphic recrystallization, thus precluding the use of classic sandstone classification diagrams. The main minerals are quartz, feldspar, biotite and muscovite, and amphiboles. Accessory minerals are magnetite, pyrite, pyrrhotite and arsenopyrite, zircon, apatite and allanite. The metagraywackes and conglomerates of the three formations contain mainly felsic fragments (tonalites). The Brune Formation is different from the other two due to the absence of iron formation fragments. The chemical study confirms the petrographic findings and supports a continental island arc paleogeographic context for all three formations according to the diagrams of Batia (1983, 1986), based on immobile element (Th, La, Sc and Al_2O_3) and mobile element contents (CaO , Na_2O , Fe_2O_3 and MgO). Particular attention will be given this year to the identification to the mineral phases for elements of interest. A study of the heavy mineral suite will be performed using LA-ICP-MS and possibly by cathodoluminescence. Statistical analysis should yield sets of factors that can be used as correlation tools.

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The Lac Pelletan ultramafic intrusion (Baie-James): metasomatism or magmatism?

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A new ultramafic intrusion with textures and mineralogical assemblages never before seen in the northern part of the Baie-James region was discovered during regional mapping work covering NTS map sheet 33H04 in the summer of 2012. This Archean intrusion crosscuts paragneisses belonging to the Laguiche Complex of the Opinaca Subprovince. The intrusion displays a dominant metamorphic crystallization texture and is only weakly deformed, whereas the paragneisses are strongly deformed and migmatized. The intrusion comprises three main units: a porphyroblastic peridotite, a heterogeneous banded unit, and biotite horizons. The peridotite is characterized by a texture of round centimetre-scale porphyroblasts. The banded unit is composed of an assemblage of prismatic amphiboles (2 mm to 6 cm), biotite that may be very coarse, and variable amounts of feldspar. The mineral arrangement in this unit suggests magmatic segregation. The biotite, centimetres thick, is observed at the peridotite-paragneiss contact. The arrangement of these units suggests a magmatic process, whereas the abundance of biotite in the banded unit indicates a metasomatic process. The objective of this study is to characterize the intrusion using detailed mapping, petrographic study, and geochemistry. These studies should allow us to determine the nature of the different facies.

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Geology of the Lac Pelletan region, Baie-James

Jean Goutier, Claude Dion, Francis Talla Takam (MRN)

The Lac Pelletan area lies within the Baie-James region, about a hundred kilometres south of the La Grande 4 Reservoir. This geological survey (1:50,000) covers NTS map sheets 33G01, 33G02 and 33H04. Previous geological work was limited to geological reconnaissance mapping (1:506,880) carried out in the 1950s by the Geological Association of Canada and some more recent prospecting work for gold and uranium. The Lac Pelletan region is part of the Northeast Superior Province and is underlain by the La Grande and Opinaca subprovinces. It comprises Archean rocks and swarms of Archean (Mistassini) and Proterozoic (Lac Esprit) gabbro-gabbro-norite dykes. From north to south, the Archean metamorphism ranges from amphibolite facies to granulite. The rocks of the Opinaca Subprovince are the most abundant in the region and consist primarily of biotite paragneiss and migmatites, injected by a considerable volume of granite as centimetre- to metre-scale bodies. The paragneiss and migmatites are also cut by magnetic plutons of quartz monzonite to monzodiorite. The rocks of the La Grande Subprovince only occur in the northeast part of the study area. The mafic to intermediate volcanic units were transformed into banded amphibolites. Volcanic structures are rarely recognizable. In some places, the amphibolites are intercalated with layers of silicate and magnetite iron formations. These rocks are cut by gold-bearing felsic dykes and foliated to gneissic tonalite. Small ultramafic intrusions were injected in the rocks of both subprovinces. They are much less deformed than the country rocks, but were metamorphosed to the same facies. Our work this summer, the recent aeromagnetic survey of Géologie Québec, and a compilation of outcrops visited by companies collectively provide a better definition of the boundary between the La Grande and Opinaca subprovinces. This boundary is an important metallogenic for gold in the Baie-James region. A new gold showing (2.17 g/t Au in a grab sample) was identified within the shear zone separating amphibolites and paragneisses.

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The angular unconformity of Timiskaming rocks in the Rouyn-Noranda region

Jean Goutier (MRN) and Howard Poulsen (consultant, Ottawa)

The Timiskaming Group is the youngest unit of the Abitibi Subprovince. An erosional unconformity separates this sedimentary unit from the underlying volcanic and sedimentary rocks. In 1962, M. E. Wilson was the first person to interpret the contact between the metasedimentary rocks of the Timiskaming Group (La Bruère Formation) and the volcanic rocks of the Blake River Group (Rouyn-Pelletier Formation) as an angular unconformity. He described and photographed the erosional contact at the base of the Timiskaming at a small outcrop northwest of McWatters. This outcrop, since overgrown by vegetation, was located and cleaned. In the 1970s, Dimroth and his team documented a second outcrop 2 kilometres to the southwest that also illustrates the Timiskaming angular unconformity.

These two outcrops occur along the northern contact of the La Bruère Formation. This formation, overturned to the south, abuts against the Cadillac Fault. Dimroth's outcrop, to the southwest of Wilson's, displays an angular unconformity between northeast-facing pillowed metabasalts and sedimentary rocks (a polygenic conglomerate and a wacke) overturned to the southeast. The latter are strongly deformed, resulting in stretched clasts and a moderate plunge to the north. This lineation has a similar orientation to the stretched variales observed further west. The rocks at Wilson's outcrop, to the north, are much less deformed. The conglomerate unconformably overlies south-facing pillowed metabasalt. The conglomerate is composed mainly of angular to subrounded clasts of basalt and gabbro without any internal tectonic fabric. Also found are rounded pebbles and cobbles of spherulitic rhyolite and intermediate to felsic porphyritic rock. The conglomerate locally contains thin discontinuous horizons of weakly bedded sandstone and mudstone of mafic composition.

These outcrops shed light on an important aspect of the Timiskaming unconformity: the reversal of facings in the rocks below the unconformity. The observations demonstrate that large folds formed prior to the deposition of the Timiskaming Group. The absence of pre-depositional cleavage indicates that these early folds are not associated with the many cleavages present in the region. The notion of pre-Timiskaming folding is not new, but this direct evidence within such a small area at Rouyn-Noranda is matched only by examples in the Timmins and Duparquet regions. In these places, the Timiskaming Group was deposited on opposing flanks of folds. The unconformity separates two distinct folding events. In the McWatters region, the older folding event is not related to the tectono-metamorphic fabric that dominates the numerous outcrops in the region.

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Geology and mineral potential of the Lac Carmoy region (Baie-James)

Pénélope Burniaux, Hanafi Hammouche (MRN), Abdelali Kharis (URSTM), Pierre-Luc Deschênes (MRN)

A geological survey at 1:50,000 scale was carried out in the summer of 2012 in the Lac Carmoy region (Baie-James, near the La Grande 4 Reservoir), covering map sheets 33H06, 33H11 and 33H14. The mapped area is part of the La Grande Subprovince. The work is supported by new high-resolution aeromagnetic surveys with lines spaced 250 metres apart.

The Lac Carmoy region is predominantly underlain by Archean rocks. The basement consists of tonalitic gneiss, tonalites, and foliated diorites belonging to the Langelier Complex (3360-2788 Ma). Sedimentary basins of Archean age (Keyano and Magin formations, minimum age of 2721 Ma, and Marbot Formation) and Proterozoic age (Sakami Formation, 2510-2216 Ma) were formed on this Archean basement. Dismembered volcanic belts, already known west of the study area through previous work, were also identified (Guyer Group, 2820-2806 Ma, Corvette Formation). Ultramafic sills and dykes, metres to decametres thick, cut the volcanic rocks and contain sulphides in some places. Late Archean magmatism is expressed as very large felsic to intermediate intrusions, some of which are likely syntectonic. The most important intrusions are: 1) the Nochet intrusion, consisting of weakly foliated to nonfoliated tonalites cross-cutting Archean volcano-sedimentary sequences; 2) felsic to intermediate porphyritic intrusions of the Bezier Suite (2674 Ma); and 3) the Vieux Comptoir Granite (2618 Ma), often pegmatitic. Proterozoic gabbro and gabbro-norite dyke swarms cut through all these rocks.

The structural grain is dominantly E-W, with major lithostratigraphic assemblages separated by ductile shear zones. Metamorphism generally reached amphibolite facies, but locally attained granulite conditions.

Several iron formations, mostly oxide facies, occur within the metasedimentary package. Sulphide zones (PY-PO ± CP assemblage) are locally observed. Bands of semi-massive sulphides are present in the metavolcanic rocks of the Guyer Group. Partial results reveal anomalous gold values in some places, up to 0.85 g/t.

The region has the potential to host the following types of mineralization:

- gold and base metal mineralization associated with iron formations;
- precious metal or base metal volcanogenic mineralization, including sulphide-bearing formations and disseminated sulphides (PY-PO ± CP) in alteration zones;
- Cu-Ni-PGE and Cr-PGE mineralization in ultramafic intrusions;
- Cu-Ag ± Au vein-type mineralization, generally consisting of quartz veins in shear zones.

Quaternary stratigraphy of the Rivière Wawagosic region (parts of NTS 32D15, 32E02)

Guillaume Allard and Pierre-Luc Deschênes (MRN)

Quaternary stratigraphy

The northern Abitibi is characterized by the presence of a thick clayey layer related to the Ojibway proglacial lake. The bedrock crops out very little in this region and the area yields evidence of multiple ice margin advances and retreats in the Labrador part of the Laurentide Ice Sheet (Veillette *et al.*, 1999, Parent *et al.*, 1995). These movements were characterized by significant variations in ice flow directions, which affected glacial dispersions (Parent *et al.*, 1995), producing highly complex stratigraphy and glacial transport patterns. It is therefore essential to review the stratigraphic framework of the northern Abitibi in order to determine the number of glacial units present and to elucidate the chronological succession of glacial advances.

Method and objectives

A drilling program, combining the study of Quaternary deposits and systematic sampling of the underlying bedrock, was carried out to better define the geology of an area near Rivière Wawagosic. The area covered by the project, representing a surface area of about 615 km², is located about 50 km northeast of the town of La Sarre.

The objectives of the new survey are:

1. To establish the stratigraphy of Quaternary sediments in the region and the associated glacial dynamics;
2. To assess the mineral potential of the area by defining favourable geological contexts for discovering new mineral deposits.

The source of the glacial deposits (tills) will be interpreted using field observations and laboratory studies focusing on sedimentology, mineralogy, petrology and geochemistry.

A total of 58 rotasonic holes were drilled and 1,208 metres of Quaternary sediments collected. The rotasonic drill rig produced a relatively continuous and intact core 10 cm in diameter, which made it possible to perform a complete stratigraphic study and a reliable interpretation of the depositional environment. After fully describing the core from each hole, we sampled the till and fluvio-glacial sand units. At least one sample of 8 to 10 kg (for heavy mineral concentrates) and two 1-kg samples (geochemical analyses + witness core) were taken from each stratigraphic interval encountered. The fine fraction in the tills (<63 µm) will be analyzed by INAA (neutron activation) for trace elements and by XRF (X-ray fluorescence spectrometry) for major elements. The heavy mineral concentrates will be used to determine the presence of indicator and accessory minerals. More than 300 till samples were collected for analytical purposes.

The rotasonic drilling program defined nine (9) new stratigraphic units. The depth to bedrock varies between 2 and 68 metres (average of 20 metres) and the recovery rate ranged from 75% to 100%.

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Geological reconnaissance of the Rivière Wawagosic region (parts of NTS 32D15, 32E02)

Pierre-Luc Deschênes and Guillaume Allard (MRN)

A drilling program combining the study of Quaternary deposits with systematic sampling of underlying basement rocks was carried out near Rivière Wawagosic to better define the area's geology. The study area, covering approximately 615 km², is situated about 50 km northeast of the town of La Sarre. A total of 58 rotosonic drill holes were completed over the course of the project.

This study follows a drilling project carried out by the *Ministère des Ressources naturelles* in the Rivière Octave area during the winter of 2011.

The objectives of the new geological survey are to:

1. Document the geology of a band of volcanosedimentary rocks to the south of the Mistaouac Pluton and distinguish the different phases composing the pluton;
2. Evaluate the mineral potential of the area by identifying favourable geological contexts for discovering new mineral deposits.

With the exception of some Proterozoic dykes, the rocks of the mapped region are Archean. The volcanic rocks, mainly basalts, andesites and tuffs, belong to the Vanier-Dalet-Poirier Group, the Desboues Formation, and the Clermont-Disson Formation. These volcanic rocks are unconformably overlain by siliciclastic metasedimentary rocks belonging to the Glandelet Formation. The geological units of the study area are cut by numerous deformation zones, likely related to the emplacement of various plutons, including the Mistaouac Pluton, the Nissing-Oditan Pluton, and the Lac de la Perdrix Pluton. The units are also injected by several types of intrusives, including gabbros and felsic quartz±feldspar porphyry intrusions. The largest deformation zones in the area are Laflamme-Sud and Laflamme-Nord. Regional metamorphism reached greenschist facies, locally attaining mid-amphibolite conditions around plutons.

The presence of the Vior deposit, favourable alteration assemblages, and synvolcanic intrusions collectively underscore the region's potential for volcanic-related deposits. The extension of two deformation zones into the area and the presence of widespread carbonate alteration zones and gold vein showings also indicate the region's potential for orogenic gold deposits.

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Geology of the Malartic region (32D01-NE)

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The Malartic region is located in the southern Abitibi Subprovince. This project, which spans three years (2012-2014), covered the northeast quadrant of NTS map sheet 32D01 this past summer, at a scale of 1:20,000. The project will provide a link between the mapping work in the western Malartic Group (2006-2009) and the MRN's historical work in the Val-d'Or area.

The Malartic region is underlain by alternating volcanic (Malartic, Louvicourt, Blake River and Piché groups) and sedimentary rocks (Cadillac, Kewagama and Pontiac groups) of Archean age. This region represents the extension of volcanic units found in the Val-d'Or region, which is renowned for its wealth of volcanogenic massive sulphide, gold, and nickel deposits (Marbridge mine, NTS 32D08). The Malartic and Louvicourt groups contain the La Motte-Vassan (2714 $\pm$ 2 Ma), Dubuisson (2708 $\pm$ 2 Ma), Jacola (2706 $\pm$ 2 Ma), Val-d'Or (2704 $\pm$ 2 Ma) and Héra formations (2702 $\pm$ 2 Ma). All these formations occur in the Malartic region where they have variable thicknesses and continuities. The general lithological trend is NW-SE. Stratification (S0) is generally oriented WNW-ESE to locally N-S, and dips are typically steep and to the north or east. Stratigraphic tops are to the southwest or west. S1 schistosity, subparallel to S0, is locally discernible. An important structural feature in this region is a major F2 Z-fold associated with an axial planar cleavage (S2) oriented E-W to ENE-WSW, which cuts the earlier schistosity (S1). This fold appears to continue eastward and disappear along the trajectory of certain faults. The Malartic region is bound to the south by the Cadillac Tectonic Zone. It is also affected by numerous shear zones and longitudinal faults, the most important of which are La Pause, Parfouru, Norbenite and Marbenite.

The Malartic region hosts six major gold mines, each of which has produced more than 1 tonne of gold metal over their mining history: Canadian Malartic (in production, Osisko Mining Corporation), Barnat-Sladen, East Malartic, Malartic Goldfields, Camflo and Malartic Hygrade. Other deposits, such as Marban, First Canadian, Norlartic and Kiena, have also produced significant amounts of gold and are located in the east part of the region, towards Lac De Montigny. Many of these gold deposits and showings are spatially associated with longitudinal faults and with multiple generations of pre-tectonic tonalite and syn-/post-tectonic tonalite-monzonite dykes and stocks. During the study, a particular emphasis will be placed on the diversity of gold deposits in terms of variations in structural context, multiple episodes of emplacement, and associations with specific generations of felsic intrusions.

The project will enhance and better define the mineral potential of this region. It will also help guide the exploration for specific types of gold deposits in the Abitibi Subprovince or in comparable tectonometamorphic environments elsewhere in the Superior Province.

Geology and gold mineralization at the Malartic Hygrade mine – Orion No. 8 ore zone

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Michel Gauthier (UQAM)

This study focuses specifically on the Orion No. 8 ore zone, one of the mineralized zones of the former Malartic Hygrade mine, discovered in 1936. The work constitutes the basis of a Master's project carried out at UQAM in collaboration with and supported by the MRN and the company NioGold. The overall goal is to document the different episodes of gold mineralization in the Val-d'Or–Malartic region, while updating the local geology of the Malartic Hygrade mine area and investigating the importance of large fault zones, such as the Norbenite Fault. This study is part of the MRN mapping project (Pilote *et al.*, 2012) for the Malartic region (NTS 32D01-NE).

The Malartic Hygrade mine area is underlain by the Jacola Formation, which consists of massive to pillowed mafic lavas, ultramafic lavas, and dioritic to tonalitic intrusions. Stratification, S0, is oriented N-S to NW-SE at the regional scale, with a steep dip to the east. Stratigraphic tops are to the west or southwest. Schistosity, S1, is subparallel to S0 and locally discernible.

The Malartic Hygrade mine consists of seven separate gold zones that have been mined to various degrees. During the summer of 2012, our work focused on one of the gold zones, the Orion No. 8 orebody. Discovered in 1985, it was mined from 1987 to 1990 (131,000 tonnes of ore at 5.31 g/t Au; Trudeau and Raymond, 1992). At surface, mineralization crops out over nearly 100 metres and has been traced in drill holes down to a depth of 600 metres. It strikes 315° with a dip of about 45° to the east; this dip becomes steeper and reaches almost 80° at a depth of 300 metres below surface, where the mineralization joins the interpreted trace of the Norbenite Fault.

The hanging wall mineralization of the Orion No. 8 orebody consists primarily of coarse-grained basalt and ultramafic flows, whereas the footwall is composed of pillowed/brecciated aphanitic flows and felsic intrusions, mostly tonalitic. Mineralization is present as four facies: 1- pyritized pillowed basalts (5 to 20% pyrite), altered to actinolite-tremolite-carbonate; 2- pyritized fault breccias; 3- gold-bearing quartz breccias accompanied by albite; 4- quartz veins, mainly in the northeast part of the orebody, accompanied by albite, particularly near vein walls, and locally by visible gold. Some tonalite dykes appear contemporaneous with mineralization (Trudeau and Raymond, 1992), and one such dyke will be isotopically dated using the U-Pb zircon method to validate or refute an early age for the gold-bearing mineralizing system.

A key structural characteristic of the Malartic Hygrade mine and the Orion No. 8 orebody is that most of the stratigraphic package occurs within the core or along the flank of a major Z-fold (F2) associated with E-W schistosity (S2), which cross-cuts the earlier S1 schistosity. This structural interpretation is supported by some molar-shaped pillows and the perpendicular relationship between stratification (S0) and schistosity (S2). The S1 surface, generally trending SE, is commonly characterized by numerous faults that delineate the mineralized zone. Several reciprocally crosscutting S1-S2 relationships complicate the established chronology, indicating that the S1 fabric may have been re-activated.

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Geology of the Lac Lamarck region (southern half of NTS map sheet 32G14)

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The mapping revision of the Lac Lamarck region (southern half of NTS map sheet 32G14) is part of an ongoing survey of the Chapais and Chibougamau areas (Abitibi Subprovince, Québec). The main objectives of the project are to: a) refine the stratigraphy; and b) investigate the potential for VMS and lode gold mineralization.

The most favourable areas for VMS mineralization are located:

1. West of Lac Chrissie, where the upper member of the Chrissie Formation comprises mafic to felsic volcanoclastic rocks, and rhyolites (2791.4 $\pm$ 3.4/-2.8 Ma) with exhalative horizons and disseminated sulphides (Py-Po-Cp);
2. Northwest of Lac Dolomieu, in the form of disseminated sulphides (Mg-Py-Po-Cp) accompanied by strong chlorite-epidote alteration within volcanic rocks, medium to fine lapilli tuffs of mafic to felsic composition, and laminated siltstone-mudstone lenses of the Blondeau Formation;
3. In the Lac Sunrise and Lac des Trois Îles areas and south of Lac Pacifique, where the Scorpion Formation (overlying the Blondeau Formation) contains dacites (2716.4 $\pm$ 1.0 Ma) and volcanoclastic rocks of dacitic composition with disseminated Py-Po-Cp.

The most favourable targets for exploring for gold veins are:

1. The Kapunapotagen shear zone at the contact between the mafic volcanic rocks of the Obatogamau Formation and the rhyolites of the Waconichi Formation (Queylus member), which were transformed into SR-CL-AK $\pm$ MG schists. Primary textures and veins of smoky quartz with disseminated pyrite are strongly transposed in this zone where flattening dominates. The Jean-Luc and Fardoche syenite stocks also occur near the shear zone;
2. The Ventures sill (Cummings Complex) and the host volcano-sedimentary rocks south of Lac Pacifique, where the lithological and structural context is similar to that of Chapais in terms of the potential for copper-gold veins. Two phases of deformation affected the sill: the first corresponds to a phase of folding that produced an E-W syncline, and the second corresponds to another phase of folding generated by movements among sinistral NE-trending faults;
3. The area around the Dolodau syenite stock, injected by carbonatite dykes. The syenite and carbonatite dykes around the periphery of the intrusion are crosscut by NE- to NNE-trending sinistral and dextral shear zones with disseminated mineralization (Au-Ag-W).

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Discrimination of syenites associated with gold deposits of the Abitibi and Pontiac subprovinces

Marc Legault (Cégep de l'Abitibi-Témiscamingue) and Jean Goutier (MRN)

In the greenstone belts of Archean cratons, a well-established spatial association exists between major faults, Timiskaming-type sediments, gold mineralization, and felsic or syenitic intrusions. This association is interpreted as either a structural association in which the intrusion acts as a competency trap for late-stage mineralization, or a genetic relationship between gold and the intrusion. Even though there is a genetic link exists between some alkaline intrusions and gold mineralization, not all alkaline intrusions are mineralized with gold. The ability to distinguish between gold-bearing and barren alkaline intrusions would have significant repercussions on gold exploration and on hypotheses about the genetic link between alkaline magmatism and gold.

An inventory of syenites scattered across two regions was carried out in the summer of 2012. The two target areas were the Rouyn-Noranda and Chapais areas. The goal of the inventory was to test whether the fertility of a syenite can be determined by studying "fresh" samples from the intrusion. Previous findings have indicated that "fertile" and "barren" alkaline intrusions can be discerned using macroscopic, microscopic and geochemical observations. However, our recent findings reveal that the relationship is not so simple. In general, fertile intrusions tend to be small (<3 km²), elongate, E-W-trending, and spatially associated with major faults. They are porphyritic, locally brecciated, and non-magnetic. Barren intrusions are typically subcircular, equigranular, and magnetic. They are also coarser in grain size, and trachytic textures are often observed. Geochemical analyses reveal that fertile intrusions tend to be more felsic than barren intrusions. Several elements and normative minerals can be used to distinguish the two types. For cases in which there appears to be a genetic link between the alkaline intrusion and gold mineralization, this distinction indicates that the latter was related to incompatible hydrothermal fluids that became enriched during later phases following magma fractionation. In the case of intrusions that acted as structural traps, the greater the competency contrast with the host rocks, the greater the tendency of the intrusion to have fractured during subsequent deformation.

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Tectonometamorphic evolution of the Abitibi Subprovince (Québec, Canada): contributions of $^{40}\text{Ar}/^{39}\text{Ar}$ geochronology

Yannick Daoudene, Alain Tremblay (UQAM), Gilles Ruffet (Université de Rennes 1, France), Jean Goutier (MRN)

The Superior Province, which forms the northwest part of the province of Québec, consists of tectonostratigraphic units accreted between ~2.8 and ca ~2.65 Ga. One of these, the Abitibi Subprovince, is characterized by regional east-west folding and greenschist facies metamorphic conditions, locally reaching amphibolite facies (for example, at the contact with the Opatika Subprovince to the north). Even though regional metamorphism is collectively attributed to the period of accretion, its age remains uncertain due to a lack of suitable thermochronological data, notably $^{40}\text{Ar}/^{39}\text{Ar}$ ages. Such data are essential for retracing the region's thermal and tectonic history and shedding additional light on Earth's geodynamics during the Archean. Launched in the summer of 2012, our postdoctoral study aims to establish the regional metamorphic age of the Abitibi Subprovince.

To start off this ambitious project, we have studied the geology of a region northeast of Lac Goéland, which occupies a strategic position straddling the Abitibi and Opatika sub-provinces. Here, the volcanic rocks of the Abitibi, metamorphosed to amphibolite facies, are affected by generally steeply dipping NW-SE foliation marked by a down-dip mineral lineation. Field observations reveal that the Abitibi rocks structurally overlie igneous rocks of the Opatika Subprovince, and the entire assemblage is overprinted by NW-SE folds of variable wavelengths. Near the contact between the two subprovinces, the Abitibi rocks are clearly more deformed but the exact nature of the contact remains to be determined. A wide variety of metamorphic and igneous rocks were collected to extract micas and amphiboles. These minerals were then dated using the $^{40}\text{Ar}/^{39}\text{Ar}$ method. This method is ideal since the isotope closure temperatures for the analyzed minerals are between ~350 and ~600 °C, a range that matches the temperatures associated with greenschist and amphibolite metamorphism. The results, which will be available in a few months, should provide metamorphic ages for the region, in addition to a more accurate portrait of its tectonic evolution. To further improve our understanding of the tectonic and metamorphic history of the Abitibi, this type of study should be carried out in other parts of the sub-province, particularly further south, near the contact with the Pontiac Subprovince.

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3D geological modelling of the Îles-de-la-Madeleine archipelago

Olivier Rabeau and Robert Thériault (MRN)

The Îles-de-la-Madeleine archipelago relies almost exclusively on groundwater to supply its drinking water. This resource is threatened by overpumping, which leads to salt-water intrusion and upward migration of the freshwater-salt-water interface. As part of the 2006-2012 Climate Change Action Plan (CCAP) of the *Ministère du Développement durable, de l'Environnement, de la Faune et des Parcs* (MDDEFP), our work aims to precisely locate the freshwater-saltwater interface throughout the archipelago. To accomplish this, we carried out transient electromagnetic (TEM) surveys to better define the location of the freshwater-saltwater interface on most of the inhabited islands. Some of the data indicate the presence of conductive zones in the Havre-aux-Maisons and Fatima-Centre areas, where the detected depths do not correspond to the expected positions of the freshwater-saltwater interface. Drilling was carried out in the fall of 2012 to determine whether these anomalies are related to geological bodies. Géologie Québec was responsible for interpreting the drill holes. In addition, the MDDEFP's *Service de l'aménagement et des eaux souterraines* (SAES) called upon the expertise of Géologie Québec to develop a geological model for the entire archipelago. The geology of the archipelago is dominated by horsts formed by rising salt diapirs. The model incorporates all available geoscientific data and relies mainly on mapping work carried out in the late 1970s by the Québec government. This geological model will form the basis for the hydrogeological modelling.

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Highlights of advanced exploration and mine development work in the Abitibi-Témiscamingue region in 2012

Pierre Doucet and James Moorhead (MRN)

West of Rouyn-Noranda, production commenced in August at the Francoeur gold mine belonging to Richmont Mines. The company continues to explore its Wasamac Project, with a drilling program of 55,000 metres planned for 2012. Aurizon Mines and Typhoon Exploration announced a new resource calculation for the Fayolle Project. The deposit contains indicated resources of 1.814 Mt at 2.7 g/t Au (156,000 ounces gold) calculated at a cut-off grade of 0.8 g/t Au. West of Amos, Royal Nickel Corporation continues to advance its Dumont Nickel Project. The company filed the results of its revised pre-feasibility study and has begun a feasibility study. Aurizon Mines published a positive feasibility study for its Joanna Project. Nevertheless, the company decided to postpone development and continue exploration drilling on the Heva deposit in the west part of the project. In April, IAMGOLD announced a new resource calculation for its Westwood Project, as well as some of the parameters for mining the ore deposit. Production is scheduled to start up in early 2013, with a mine life of 19 years. In the Témiscamingue region, Matamec Explorations announced, in the first quarter, a positive preliminary economic assessment for the Zeus Rare Earth Project. The company also signed a joint venture agreement with Toyotsu Rare Earth Canada to finance the project's feasibility study.

In Val-d'Or, after interrupting mining of the GEZ Zone at the Goldex mine in October 2011, Agnico-Eagle Mines announced that production will start up again from the M and E satellite zones in 2014, which respectively contain indicated resources of 4.36 Mt at 1.84 g/t Au and 4.27 Mt at 1.69 g/t Au. Exploration drilling continues in the D Zone. At the Lac Herbin mine of QMX Gold Corporation, drilling and development work continue in the Bonanza, FL, LH and S1 zones. Over at the Kiena mine of Wesdome Gold Mines, drilling has continued on the Martin, VC, S-50 and Dubuisson zones, and this work led to the discovery of the Dubuisson North Zone. At Malartic, Osisko Mining Corporation continues to optimize production at its Canadian Malartic mine, which commenced production in 2011 and contains proven and probable reserves of 337.67 Mt at 0.99 g/t Au (10.72 Moz gold). At the Québec Lithium mine in La Corne, Canada Lithium Corporation is almost finished the construction of its ore processing plant. Commissioning is scheduled for late 2012, and the first shipments of lithium carbonate for March 2013.

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The Canadian Malartic mine, Abitibi: preliminary observations on geological characteristics and relative chronology of the low-grade, high-tonnage Archean gold mineralization

Stéphane de Souza, Benoît Dubé (GSC-Québec), Vicki McNicoll (GSC-Ottawa), Patrick Mercier-Langevin (GSC-Québec), Pierre de Chavigny, Donald Gervais, Louis Caron (Osisko)

The Canadian Malartic mine is exploiting a low-grade, high-tonnage gold deposit (proven and probable reserves of 10.9 Moz; 345 Mt at 0.98 g/t Au) in the Abitibi Subprovince. Mineralization is hosted mainly by metasedimentary rocks of the Pontiac Group and deformed porphyritic monzodioritic intrusions south of the Cadillac Fault Zone. The Pontiac Group consists of turbiditic greywacke (albite-quartz-biotite-chlorite) affected by a WNW to NW cleavage dipping to the NE (70-90°), whereas the mineralized intrusions trend E-W. The Sladen Fault, which marks the southern contact of one of these intrusions is oriented E-W with a dip (45-85°) to the south, in part controlled by the geometry of the intrusion. There are two known trends for the mineralized intrusions: E-W and NW-SE, with respective opposing dips to the south and north.

Mineralized rocks typically contain calcite and traces to 3% finely disseminated pyrite, and visible gold is rare. The majority of mineralization is found in metasedimentary rocks as replacement zones characterized by silicification accompanied by potassic alteration and/or carbonatization, along with veinlets of quartz - calcite ± pyrite, and biotitization along the vein walls. Laminated and/or brecciated mineralized veins of quartz ± pyrite are also locally present. In the intrusions, mineralization consists of zones silicification and potassic alteration with an envelope of carbonatization and hematization. This envelope contains millimetre- to centimetre-scale veins of quartz - calcite ± pyrite locally forming stockworks. Gold-bearing centimetre- to decimetre-scale pegmatitic veins of quartz - calcite - muscovite - biotite ± albite ± tourmaline ± pyrite ± galena ± scheelite, with potassic feldspar alteration of the vein walls, are present in the intrusions. Mineralization is preferentially developed along the Sladen Fault, in the hinge zones of folds, and along brittle-ductile deformation corridors trending NW-SE. The association of mineralization with porphyry intrusions, the mineralogy and textures of the auriferous pegmatitic veins, the omnipresent potassic alteration, the presence of mineralized stockworks, and the local occurrence of chalcopyrite and molybdenite, are compatible with a magmatic-hydrothermal footprint for the deposit. However, the geometry of the mineralized bodies, their spatial association with structural features, and the presence of laminated mineralized quartz veins indicate the existence of a syn-deformational phase of mineralization and/or the remobilization of pre-existing mineralization.

The working hypothesis is that the low-grade, high-tonnage Canadian Malartic gold mine and its current geometry were the result of syn-deformational mineralization superimposed on a gold-bearing magmatic-hydrothermal system associated with porphyritic intrusions.

The Dunnage Zone and the Gaspé Belt in the Appalachians south of the city of Québec – A synthesis

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Despite a significant increase in the amount of geological knowledge acquired for the Appalachians south of the city of Québec over more than 25 years, no new synthesis map has been published for this large region since the work of Slivitzky and St-Julien (1987). At the request of the MRN, a team from UQAM has been compiling and reinterpreting, since 2009, the geology of an entire series of NTS map sheets at 1:50,000 scale, covering the Estrie, Beauce and Bas-Saint-Laurent (St. Lawrence Lowlands) regions. The geological maps generated for the Estrie-Beauce region represent a surface area equivalent to about 24 NTS map sheets and are now available in SIGEOM. About 50% of this land area is underlain by Ordovician rocks of the Dunnage Zone (Tremblay *et al.*, 1995) and Siluro-Devonian rocks of the Gaspé Belt (Bourque *et al.*, 2000). The geological maps, combined with the results of mapping work carried out as part of PhD and M.Sc. studies since about 1995 (e.g., Castonguay, 2001; Schroetter, 2004; de Souza, 2012), were used to propose a synthesis map for rock units east of the St-Joseph Fault and the Baie Verte-Brompton Line.

The Dunnage Zone consists of ophiolites, the St-Daniel Mélange, the Magog Group, and the Ascot Complex. The ophiolites, of Lower Ordovician age, form a more or less continuous slab that is correlative between Thetford-Mines and Lac Brompton, and is in tectonic contact with the Mount Orford ophiolite to the south. The St-Daniel Mélange (465-455 Ma) and the Magog Group (461-455 Ma) represent a sedimentary basin unconformably overlying deeply eroded basement consisting of continental, ophiolitic and volcanic rocks. The “exotic” lithologies of the St-Daniel Mélange, previously interpreted as “mega-fragments” (i.e., the volcanics of Bolton, Ware, the Bunker Hill sequence, and some parts of the Ascot Complex), instead represent structural windows exposing lower units of the mélange or its basement, or stratiform volcanic flows in the core of the St-Daniel Mélange, or lateral facies variations between the St-Daniel Mélange and the Magog Group. The Magog Group corresponds to a series of various siliciclastic rocks of kilometre-scale thicknesses. U-Pb dating on detrital zircons from Magog Group rocks suggests that deposition continued into the Upper Silurian (de Souza, 2012). Regionally, the Magog Group forms an approximately 300-km sedimentary basin, extending from the borders with Maine in the NE and Vermont in the SW, which unconformably overlies the St-Daniel Mélange in the NW and the Ascot Complex (ca. 460 Ma) in the SE. The rocks of the Gaspé Belt unconformably overlie the Dunnage Zone (forming the Glenbrooke Group and the Lac Aylmer Formation) or are in tectonic contact with them in the hanging wall of the La Guadeloupe Fault (in this case constituting the St-Francis Group and the Frontenac and Clinton formations towards the Québec-Maine-New Hampshire border).

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Detection of mineral deposits buried under glacial cover using the MMI™ method: synthesis, case studies, outlook

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This project aims to assess the MMI™ (Mobile Metal Ion) method for mineral exploration in Canadian climatic, geologic and pedologic settings, which are very different than the Australian settings where the method was initially developed. Our in-depth documentation revealed several critical knowledge gaps: 1) inadequate experimental data about the processes involved in the transport of metals from their source, which precludes any possibility of assessing the favourability of different types of surveyed environments and thus the validity of the results; 2) the truly exogenic nature of the metal signal measured by the method, although theoretically recognized, has not been rigorously demonstrated in environments with transported glacial cover; 3) the current “fixed depth” sampling protocol does not take into account the pedologic nature of the sampled horizon, thereby constituting a source of uncertainty that leads to difficulties during the interpretation phase of the surveys.

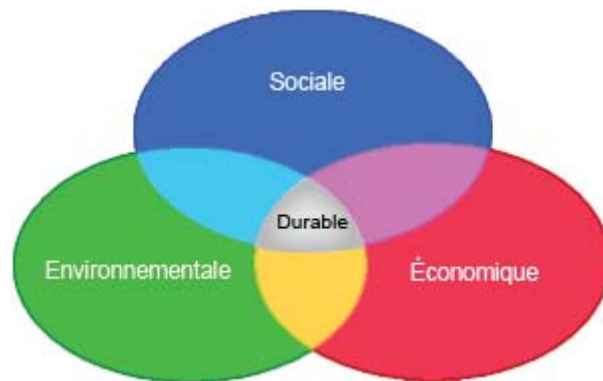
Our analysis of public data reveals that certain external factors (i.e., those not related to mineralization) exercise a strong control on MMI™ levels. First and foremost are background metal levels, which in the case of base metals are related to the soil phyllosilicate fraction and represented by the aqua regia response. We note a clear correlation between MMI™ metal and aqua regia responses when samples are taken from the same soil interval (10 to 25 cm below the humus), whether determined by qualitative direct observations during traverses or by statistical analysis (principal component analysis). This suggests that nearly 50% of total variation is related to a lack of consistency in the sampled pedogenic horizon as a consequence of the “fixed depth” sampling protocol. In addition, local changes in a soil's physico-chemical conditions can produce significant *in situ* metal remobilization, resulting in “indirect” anomalies that may be incorrectly interpreted as ion emanations derived directly from a buried source. In order to enhance a truly “direct” and “exogenic” component in the MMI™ signal, a correction (multivariate regression) must be applied to the external factors identified herein. However, this step is absent from the analyzed case studies. These results call into question the direct and exogenic nature of the MMI™ anomalies and demonstrate the need to apply corrections in order to exclude false anomalies produced by external factors (phyllosilicate-rich soils, carbonate-rich soils, pH changes, etc.).

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Sustainable development at Géologie Québec

Isabelle d'Amours, Pénélope Burniaux, Andrea Amortegui, Pierre Lacoste, Jean-Yves Labbé, Patrice Roy (MRN)

Sustainable development is more than just an environmental issue. What is sustainable development? Sustainable development is about meeting the needs of the present without compromising the ability of future generations to meet their own needs. It is based on a long-term approach which takes into account the inextricable nature of the environmental, social and economic dimensions of development activities.



The **environmental dimension** aims to protect and conserve our environment, our ecosystems, our resources, and our living environment; in short, it aims to keep our planet healthy.

The **social dimension** addresses our way of life as well as our desire to build a democratic and safe society that reduces inequality and inequity.

The **economic dimension** contributes to our prosperity and improves our standard of living.

Sustainable development is thus all of the above: a healthy planet, individuals living in harmony and safety, and a fair and prosperous society with long-lasting institutions and structures, where everything as a whole contributes to the quality of life of current and future generations.

In Québec, the Sustainable Development Act (Bill 118) has been in effect since 2006. Article 2 of chapter 1 of the Act specifies: “...development that meets the needs of the present without compromising the ability of future generations to meet their own needs”.

We look closely at these terms and issues in the context of activities and work carried out by the Ministry, particularly by Géologie Québec. We have tried to assess how our activities relate to each of the dimensions. For example, the geochemical sampling of lake-bottom sediments intersects two dimensions: economic (mineral prospecting) and environmental (environmental characterization). We have reached the conclusion that SIGEOM is at the heart of this mandate and our contribution to sustainable development.

The Sustainable Development Committee at Géologie Québec: Isabelle d'Amours, Pénélope Burniaux, Andrea Amortegui, Pierre Lacoste, Jean-Yves Labbé, Patrice Roy (MRN).

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The Lebel-sur-Quévillon (Abitibi) Metal Trend reinterpreted

Stéphane Faure (CONSOREM)

The Lebel-sur-Quévillon area, in the centre of the Abitibi, has specific geological characteristics, uncommon in the Abitibi region, that make it favourable for several types of mineralizing environments. They relate to a NE-trending segment of greenstone affected by several major structures, such as the Cameron, Casa Berardi and Lamarck faults. The segment contains fertile rhyolites with volcanogenic massive sulphide (VMS) potential, and an assortment of intrusions ranging from synvolcanic tonalites to late alkaline intrusions (syenites, carbonatites, kimberlites).

Following the discovery in 1989 of the Gonzague-Langlois deposit (1.9 Mt Zn), several companies carried out exploration work in the area during the early 1990s. The digital data archived by some of the companies on old computer systems were never made public. One of the objectives of this project is to integrate this information into the SIGEOM database to produce a new geological and structural map. Field descriptions and structural data, in addition to the interpretation of magnetic and electromagnetic (EM conductor) maps have better defined known deformation zones and revealed a dozen new ones. The Lamarck corridor is now traced over a width ranging from 2 to 4 km along a NE-SW direction, making it the only major fault in the Abitibi with this orientation.

VMS and orogenic gold targets were generated for the region. The VMS targets were identified using various criteria, namely volcanic rock geochemical affinity and fertility, geophysical signatures, volcanic assemblages and textures, and a paleovolcanic reconstruction, which collectively suggest an extension or equivalence to the fertile bimodal sequence of the Gonzague-Langlois mine. The paleovolcanic reconstruction proposes two cycles of opening volcanic basins: the first around 2718-2714 Ma, with the formation of one or more basins of transitional affinity and the deposition of Gonzague-Langlois VMS mineralization, and possibly a second around 2720-2722 Ma, with at least two basins of calc-alkaline affinity oriented NE-SW, parallel to the Lamarck Fault, and the formation of the volcanogenic gold mineralization of the Sleeping Giant mine. The Lamarck Fault thus acted as an important control very early in the volcanic history.

Two new deformation corridors explain some known occurrences of gold mineralization with no previously proposed relationship to regional structural geology. Based on field descriptions, the study identified 26 new syenites with surface areas of <2 km². The majority of these are spatially associated with the Lamarck Fault and its subsidiary faults.

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Fossil mantle rift controls on mineralization in the Quebec Abitibi during cratonic breakup and reassembly

Lyal B. Harris (INRS-ETE) and Jean H. Bédard (CGC-Q)

In the Abitibi Subprovince of the Superior Province in Quebec, extrusive sequences were formed in a volcanic plateau-like setting during plume-related rifting of older cratonic lithosphere that started at ca. 2.78-2.75 Ga. Mantle plume activity led to focussed thermal erosion, destruction, and assimilation of ancient lithosphere and formation of isotopically juvenile crust that now constitutes the Abitibi belt. 3D images of S-wave seismic tomographic data of the Superior Province illustrate that the Abitibi Subprovince overlies a symmetrical, generally E-W-trending rift in the sub-crustal lithospheric mantle (SCLM) of older Archaean lithosphere (N Superior Province and Minnesota River Valley domain). Seismic tomography shows no evidence for 'fossil' subduction zones. Enhanced aeromagnetic images of the central-northern Abitibi illustrate early, penetrative E-W dextral ductile shearing preceded formation of discrete ductile to brittle-ductile conjugate transcurrent and E-W reverse $\pm$ dextral shear zones. Offset and ductile deflection of dense, mafic crust along regional transcurrent shear zones in the Abitibi Subprovince and its continuation in the Grenville Province parautochthon is apparent on short wavelength Bouguer gravity images. An Archaean, NE-striking, sinistral shear zone (the proto-Grenville shear zone) is identified along the SE margin of the Abitibi and Opatika subprovinces. The displacement history and geometry of reverse and strike-slip shear zones is similar to that of structures developed during progressive lateral escape and indentation during impingement of a rigid body. We propose that southward migration of the old cratonic nucleus (N Superior Craton) in response to mantle flow acting upon its deep lithospheric keel, and not subduction-related processes, led to progressive southward accretion of crustal fragments and oceanic plateaux-like segments like the Abitibi. Terrane accretion led to shortening, and rift inversion in the Abitibi. Major epigenetic gold deposits are located above rift-bounding faults in the SCLM, suggesting that early rift structures localized subsequent deformation and hydrothermal fluid flow during N-S shortening in the ca. 2.7 Ga Shebandowanian orogeny. The 1.1 Ga Desmaraisville and 0.55 Ga Otish kimberlite clusters also coincide with interpreted rift structures in SCLM, highlighting the role of ancient mantle structures on localizing deformation and intrusion in the overlying crust.

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Multiparameter analysis of drill core from the Chibougamau region: preliminary results

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There are very few large databases of drill core physical, mineralogical and geochemical properties for mineral exploration camps in Québec. This is mainly because the methods for measuring these parameters are typically destructive. Such databases, however, would have many geoscientific applications, including hydrothermal alteration characterization, chemostratigraphy, reserve calculations, and geological modelling. LAMROC, the INRS' mobile laboratory for the physical, mineralogical and chemical characterization of rocks (*Laboratoire mobile de caractérisation physique, minéralogique et chimique des roches*), makes it possible to conduct several types of measurements on drill core, nearly simultaneously and at high spatial resolution: density by gamma ray attenuation, magnetic susceptibility, approximate concentrations of up to 25 elements by XRF, and alteration mineralogy by infrared spectrometry. The system also acquires a continuous image of the core to provide a complete virtual archive of the drill hole, thereby making it possible to match the rock's visual appearance to the data in order to better understand variations in the measured parameters.

The INRS received a mandate from the MRN to carry out a high-resolution multiparameter analysis of drill core from the Chibougamau region. Logistical support was provided by Cogitore Resources and Forages Chibougamau.

In contrast to other parts of the Abitibi, the Chapais-Chibougamau region is not particularly well known for its VMS deposits or its potential for this type of deposit. Nevertheless, the Chibougamau area contains the former Lemoine mine (the richest VMS deposit ever mined in Canada), the Scott deposit, and many significant showings that illustrate its potential. The relatively modest amount of VMS exploration work at the regional scale is partly due to an incomplete knowledge base for the favourable volcanic sequences. The INRS used LAMROC to analyze several drill holes from the Chibougamau region in order to improve the level of geological knowledge for the Waconichi Formation, the region's principal VMS metallotect. Two areas were examined: the former Lemoine mine area to the south of the Lac Doré Complex, and the Lac Taché-Lempira area to the north of the complex. The main goal is to compare the stratigraphy of the Waconichi Formation in both areas using the LAMROC data and already available information.

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Lithology and alteration modelling by multivariate statistical analysis using drill core measurements from the Matagami mining camp, Québec

Bastien Fresia, Alexandre Bourke, Pierre-Simon Ross, Erwan Gloaguen (INRS-ETE)

The Matagami mining camp (north of the Abitibi Subprovince) contains many volcanogenic massive sulphide (VMS) deposits. Little information is available concerning the physical and mineralogical properties of the host rocks, which hinders geophysical modelling, among other things. In 2010, the INRS launched LAMROC (*Laboratoire mobile de caractérisation physique, minéralogique et chimique des roches*), a mobile laboratory for the physical, mineralogical and chemical characterization of rocks. This physical and chemical analysis laboratory for drill core can be used directly at the core shack to perform in situ measurements. The INRS received a mandate from the *Ministère des Ressources naturelles du Québec* (MRN) to carry out a high-resolution multiparameter analysis of drill core from the study area. We have taken more than 25,000 gamma ray density, magnetic susceptibility, and infrared spectrometry and visible light (mineralogy) measurements, in addition to more than 12,000 geochemical measurements by X-ray fluorescence (XRF), along more than 7,000 metres of drill core.

The enormous amount of co-located physico-chemical measurements precludes analyzing and interpreting the data "by hand"; instead, multivariate statistical analysis methods must be applied so that the data and measurement points can be grouped based on the responses for each parameter. These methods proved to be very useful in simultaneously interpreting the overall collection of data. We present an approach based on principal components analysis (PCA) and cluster analysis. PCA is first used to determine the most discriminating factors (variables) for alteration or protoliths. Cluster analysis is then applied in order to group data points according to pseudolithology, as a function of their physical and geochemical signature. The geological pseudolog models obtained through this process allow us to study the alteration affecting each lithology while avoiding the issues imposed by variations due to lithological changes and magmatic affinities. For this last step, the results of the mineralogical study are combined with PCA and single-precursor methods in order to establish the evolution of alteration along the core and provide some degree of quantification.

Thus, by combining statistical and classic processes, we will be able to use the data obtained from LAMROC to spatially discriminate, at high resolution and across the entire drill core assemblage, any lithologies and alteration related to the emplacement of VMS deposits.

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Geological map of Québec – 2012 Edition

Robert Thériault and Stéphane Beauséjour (MRN)

A new geological map of Québec at a scale of 1:2 000 000 was produced by the *Ministère des Ressources naturelles* (MRN) during the last year. This new map, which represents an update of the 2002 edition, was produced in order to incorporate the results of the numerous geological mapping projects carried out throughout the Province of Québec during the last ten years. The digital map is viewable and searchable through the ArcGIS platform. Furthermore, an interactive map is distributed on Internet, and enables to put in relation geological (e.g. stratigraphic unit, mineral deposit, drill hole) and geographical (e.g. satellite imagery, hydrography, topography) information. The new geological map of Québec will serve as a promotional tool for the diffusion of the geological knowledge of the territory of Québec, for the benefit of school, college and university institutions, research centers and the general public, among others.

Compared with the previous version published in 2002, the new geological map of Québec contains the following features:

- The level of detail of the geology increased significantly, as reflected in the increase in the number of units making up the geological legend, which went from 106 to 165, as well as the number of geologic zones (i.e. polygonal elements), which is in the order of about 6500 relative to 4400 for the previous version;
- In addition to including the age and lithological description, the ArcGIS database attached to the geological map now includes the stratigraphic unit of the digitized geologic zones. Thus, over 900 different stratigraphic units are present in the database;
- A box in a corner of the map presents, in addition to the limits of the geological provinces, a subdivision at the level of subprovince, zone, belt and orogen.

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Geochemistry of the Blake River Group, Abitibi Subprovince: Compilation and preliminary results

Sarane Sterckx, Pierre-Simon Ross (INRS-ETE), Jean Goutier, Claude Dion (MRN)

The Abitibi Subprovince is one of the best areas in the world to explore for volcanogenic massive sulphide (VMS)-type polymetallic deposits. The Blake River Group, in the Rouyn-Noranda area, encompasses two major VMS mining camps, the Noranda camp and the Doyon-Bousquet-LaRonde camp. Since the emplacement of VMS deposits is controlled in part by stratigraphy, it is worthwhile to gain a better understanding of the stratigraphy of submarine volcanic rocks in the Blake River Group. In addition, very few marker horizons are known at the regional scale. In recent years, thousands of geochemical analyses including immobile trace elements have become available following government mapping programs, thematic studies by universities and government agencies, and exploration work by mining companies. Numerous U-Pb ages have also been determined, and these provide a timeframe for volcanic events and mineralization.

These geochemical data have not been used in an optimal manner however to decipher the stratigraphy of the Blake River Group, and this is the main objective of a Master's project undertaken this fall at the INRS-ETE with the support of the MRN. The first step consisted in compiling existing information to build a database of geochemical analyses deemed to be the most reliable and complete, and clearly distinguishing between lavas and intrusive rocks. The second phase consisted in collecting new samples in the field to fill gaps in the geochemical coverage at a regional scale. We also submitted several pulp samples for re-analysis to determine their trace element content. Our poster will show the geographic distribution of data and a few preliminary results. Upcoming work will aim to establish the geochemical signature and homogeneity of stratigraphic units and to assess the spatial coherence of potential geochemical associations.

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The Westwood deposit, Abitibi, Québec: an Archean magmatic-hydrothermal gold system?

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The Westwood gold deposit (3.715 Moz) occurs in the Doyon-Bousquet-LaRonde mine camp in the Abitibi. The mineralization is hosted by metavolcanic rocks of the Bousquet Formation (~2699-2696 Ma), which form a thin, subvertical homoclinal band trending E-W with tops toward the south. The Bousquet Formation is subdivided into a lower member composed primarily of mafic to felsic rocks of tholeiitic to transitional affinity and an upper member composed primarily of intermediate to felsic rocks of transitional to calc-alkaline affinity. The area is characterized by decametre-scale, subvertical, anastomosing E-W deformation zones, and lower amphibolite facies metamorphism.

The deposit consists of three separate mineralized corridors, from north to south: 1) the Zone 2 Extension; 2) the North Corridor; and 3) the Westwood Corridor. The Zone 2 Extension is composed of centimetre- to decimetre-scale quartz veins rich in pyrite $\pm$ chalcopyrite-sphalerite, similar in several ways to the veins of the Doyon mine. The North Corridor is characterized by centimetre- to decimetre-scale quartz veins rich in pyrite-chalcopyrite-sphalerite, in addition to bands of semi-massive to massive sulphides representing 1) an aborted VMS system; 2) a stockwork zone associated with Westwood Corridor mineralization; or 3) a hybrid style of mineralization. The envelope around these two corridors is slightly discordant to stratigraphy. Finally, the Westwood Corridor comprises disseminations and concordant lenses of semi-massive to massive sulphides, similar to mineralization at the LaRonde Penna deposit.

This summer, detailed mapping on the discovery outcrop of the Warrenmac Lens (Westwood Corridor) illustrated several important relationships, notably: 1) felsic rocks hosting the lens are cut by low-permeability sills of basaltic andesite; 2) synvolcanic alteration is discordant and strongly transposed along the stratigraphy; and 3) Westwood Corridor mineralization is locally accompanied by felsic block tuff, rich in gold-bearing sulphide fragments, and thus synvolcanic in nature; and 4) a series of distinct slip planes complicate the spatial distribution of the mineralized zones and the host units.

A study of the geological and structural controls on these different types of mineralization will test the hypothesis of a metallogenic continuum among synvolcanic intrusion-related gold-vein mineralization and gold-rich VMS in the Archean. This type of metallogenic continuum is well documented in other younger geological environments (for example, telescoped epithermal-porphyry systems).

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Characterization of volcanic units containing sulphide fragments in the Rouyn-Pelletier Formation, Rouyn-Noranda, Québec

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The Blake River Group is subdivided into different formations, including the Horne Formation, which hosts the largest known gold-rich volcanogenic massive sulphide deposit (the Horne deposit), and the Rouyn-Pelletier Formation to the south of the Horne Formation. The Horne Formation is delimited to the north by the Horne Creek Fault and to the south by the Andesite Fault. The Horne ore deposit is hosted by a volcanic succession, several dozen metres thick, of tholeiitic to transitional felsic rocks composed mainly of coherent rhyolite and volcanoclastic deposits. This volcanic succession is characterized by mineralized zones of variable thicknesses occurring at different levels within the volcanic pile, including several brecciated felsic layers containing considerable amounts of massive sulphide blocks (for example, in the Horne West area). Felsic volcanic units and volcanoclastic units containing sulphide fragments are also present in the upper part of the Rouyn-Pelletier Formation, several dozen metres south of the Andesite Fault. These felsic volcanoclastic units have not been thoroughly studied until now, despite obvious analogies with some key stratigraphic units of the Horne Formation. The felsic units in the upper part of the Rouyn-Pelletier Formation were studied and described during the summer of 2012. They are characterized by the presence of lapilli tuff and lapilli-block tuff containing up to 30% massive sulphide fragments. Also present are massive, laminated and brecciated (lobe and flow breccia) rhyolites locally containing sulphide fragments (5%). The felsic units are intercalated with units of massive and pillowed basalt or basaltic andesite, locally appearing brecciated (flow breccias). Mafic fragments are also found in a syenite injected into felsic volcanoclastic units containing sulphide fragments. Detailed mapping as well as petrographic and litho-geochemical studies were carried out on seven outcrops during the summer of 2012 to test the hypothesis of a possible stratigraphic and geochronological correlation with the volcanic succession hosting the Horne deposit.

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Geochemical study of trace element and PGE contents of chromites in komatiites from the Alexo region (Abitibi, Ontario): preliminary results

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The increasing demand for base metals, such as Ni, and for precious metals, such as the platinum group elements (PGE), has rendered the development of lithogeochemical exploration tools based indicator mineral composition a strategic issue in the search for magmatic Ni-Cu-PGE deposits.

Komatiites, a type of ultramafic volcanic rock, are generally found in Archean greenstone belts. They often host large magmatic Ni-Cu-PGE deposits. Chromite, a common accessory mineral in komatiites, appears to be a good choice for an indicator mineral. In the absence of sulphides, chromite is capable of concentrating Ru as well as, to a lesser extent, Os and Ir and sometimes Rh. All these elements are extremely compatibles with sulphides (chalcophile elements). According to recent studies 100% of the rock's Ru budget is controlled by chromites in komatiites without sulphide mineralization. In fact, new chromite analyses from many different komatiites confirm that in non-mineralized komatiite systems, Ru concentration in chromites is high, whereas in mineralized komatiite systems, Ru concentration is near or below the detection limit.

This Master's project proposes to carry out a detailed geochemical study of chromites in komatiites from the Alexo region (Abitibi, Ontario). Selected samples will be analyzed by laser ablation inductively coupled plasma mass spectrometry to determine the trace element and PGE contents of chromites from komatiites that do not display evidence of mineralization. The ultimate goal is to use chromite as a mineral indicator for mineralized komatiite flows and to develop an exploration tool that can be used in the search for magmatic Ni-Cu-PGE deposits.

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Mineral Chemistry and Thermometry of Mafic Amphibolite-Facies Rocks in Nuvvuagittuq Greenstone Belt, Canada

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The dominant lithologies of the Nuvvuagittuq Greenstone belt (Northeastern Superior Province, Canada) are composed of mafic amphibolite-facies rocks (referred as the Ujaraaluk unit). With a minimum age of 3.8 Ga and possibly as old as 4.3 Ga, these rocks are among the oldest in the world. The Nuvvuagittuq Greenstone belt occurs in the western Minto Block, which was last pervasively metamorphosed at ca. 2.7 Ga.

Rocks from the Ujaraaluk unit are generally Ca-poor and subdivided into a high-Ti and a low-Ti group based on their bulk chemical composition. The low-Ti rocks are interpreted to stratigraphically overlie the high-Ti rocks. Here we present a detailed mineral chemistry and thermometry study of the Nuvvuagittuq mafic rocks to investigate if their paragenesis is controlled by a metamorphic gradient through the belt or whether it is controlled by geochemical variations.

Petrography and mineral chemistry reveal two different rock types: garnet + biotite + plagioclase + quartz schist without amphibole (garnet schist), occurring primarily in the central part of the area, and amphibole schist composed of biotite + amphibole + plagioclase + quartz ± garnet. Amphibole may be cummingtonite or anthophyllite or Mg- or Fe-hornblende occurring alone or in combination. Although the mineral assemblages are different, no systematic geographical distribution is found in the field.

Garnets, primarily in the central part of the Nuvvuagittuq Greenstone Belt, are mostly unzoned with respect to major cations; most have thin rims reflecting cation exchange on cooling. Garnet-bearing samples have higher whole-rock FeO^* and Al_2O_3 than garnet-poor samples. Biotite-garnet geothermometry was applied to both rock types from 18 localities, and gives temperatures clustering around 660°C. whole-rock chemistry, garnet mineral chemistry and thermometry across the region suggest that the presence of garnet is a result of the whole-rock chemistry rather than metamorphic grade.

We suggest that the event responsible for metamorphism of the Minto Block at 2.7 Ga was also the main metamorphic event that affected the Nuvvuagittuq Greenstone Belt. Neoarchean Sm-Nd ages obtained in the Nuvvuagittuq garnets also support this conclusion. Any earlier metamorphism, likely given the protracted history of these rocks, has apparently been obliterated.

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The Nb-Ta-REE mineralized system of the deposit associated with the Crevier alkaline intrusion (Grenville Province, Québec): new mapping, mineralogical, petrographic and geochemical data

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The Crevier Alkaline Igneous Complex is located north of Lac Saint-Jean in the Grenville Province (Québec). This complex, oriented N320°, follows an axis of crustal weakness known as the Waswanipi-Saguenay corridor. This corridor is related to the Saguenay Graben, in the centre of which lies the Nb-Ta-mineralized intrusion of the Niobec mine (at Saint-Honoré, near the town of Saguenay). The mineralization of the Niobec mine is associated with a carbonatite, whereas the Crevier deposit is associated with a nepheline syenite.

The Crevier Alkaline Igneous Complex is broadly subdivided into three units: (i) a main unit corresponding to a massive nepheline syenite with variable texture, (ii) a banded syenite formed by the injection of dykes of different facies (nepheline syenite, biotite syenite, carbonatized biotite syenite, and carbonatite) and (iii) pegmatitic nepheline syenite containing mineralized lenses. The relative chronology worked out during mapping reveals that the second unit was emplaced within the first, and that dyke swarms cut the first two units.

These dykes are found in the centre of the complex and are oriented parallel to the main N320° axis. The extensions to the north and south are not known. They constitute the principal target for the study of Nb and Ta metallogenic potential. Mineralization consists of pyrochlore. Field work revealed two types of mineralization: disseminated magmatic mineralization represented by small grains of pyrochlore (≤ 1 mm), and late hydrothermal mineralization that cuts the dykes. This latter type is associated with networks of veins and veinlets rich in sodalite and sulphides with larger grains of pyrochlore (≥ 1 mm).

The first results from the geochemical study on rocks from the complex (major and trace elements) reveal that Nb and Ta behave differently during hydrothermal circulation. Tantalum appears to be more mobile than Nb, which should result in differing compositions for primary pyrochlore and later-stage pyrochlore associated with veins and veinlets.

This Master's project aims to understand the Nb-Ta-REE mineralized system by unravelling the respective effects of the mineralizing process from magmatic or hydrothermal events that affected the area. Complementary studies on the carbonatites and the emplacement mechanism for the pegmatitic syenite dyke swarm will also be carried out.

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Rivière Camie hydrothermal alteration and uranium mineralization (Otish Basin, Québec)

Marion Lesbros and Georges Beaudoin (ULaval)

The paragenetic sequence at Rivière Camie was established by a petrographic study of 15 drill holes, one of which, outside the mineralized zone, was useful for distinguishing diagenetic processes from processes associated with uranium mineralization. The Archean basement reveals an early vein-type carbonate $\pm$ brick red hematite $\pm$ chlorite alteration followed by vein-type quartz $\pm$ pyrite alteration. The Proterozoic sedimentary rocks of the basin underwent intense early albitization + pink hematization followed by intense sericite/illite $\pm$ brick red hematite $\pm$ chlorite alteration, then vein-type brick red hematite $\pm$ chlorite alteration cut by pervasive vein-type limonite alteration.

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Metallogeny of the Turgeon deposit (Belledune, New Brunswick)

Erik Lalonde and Georges Beaudoin (ULaval)

The Turgeon deposit, located in the Bathurst Mining Camp, is a volcanogenic massive sulphide (VMS) deposit of Ordovician age that shares several characteristics with mafic-type VMS deposits. Mineralization occurs in the form of replacement textures (pyrite) and veins (chalcopyrite). The host rocks (andesitic basalts + gabbros) were subject to intense spilitization. Sulphide lenses, consisting of pyrite, pyrrhotite, sphalerite and chalcopyrite, occur between hyaloclastites (above) and silicified zones (below), whereas the underlying stockwork zones are chloritized. The mineralized zones are deformed by late shear faults.

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Reassessment of the mineral potential of the former St-Robert Bellarmin mine, Beauce, Québec

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The former St-Robert Bellarmin mine, situated 40 kilometres south of Saint-Georges in the Beauce region of Québec, was mined briefly in 1958 for gold, silver, lead and tungsten, and was the subject of new work in the 1980s. The rise in metal prices and the emergence of new geophysical methods not available to earlier owners prompted the current claim holder, J.A.G. Mines Ltd, to reassess the property's geology and mineral potential.

The St-Robert Bellarmin deposit, one of the rare polymetallic deposits in the Appalachians, comprises several W, Ag, Pb and Bi showings, and possibly Au. Mineralization is in the form of decimetre-scale quartz veins containing pyrite, galena, scheelite, cosalite, bismuthinite and sphalerite, associated with granodioritic dykes injected in Devonian sedimentary rocks of the Frontenac Formation, which consists of sandstones, argillites, argillaceous schists, and slate.

All available geophysical and geochemical data was compiled using GIS and 3D modelling software (ARCGIS, Surfer, Strater, Oasis Montaj and Target) in order to determine the most promising targets. The geophysical data confirmed the presence of a porphyritic intrusion in the northeast part of the property, representing the source of the quartz veins and dykes. The soil geochemistry data revealed several areas of interest, including a 500-metre-long zone to the west of the Lacombe tunnel, enriched in Pb, Ag, Bi and Mo, which has never been drilled.

A new field program carried out in the spring and summer of 2011 consisted of property-scale geological mapping, sedimentary and igneous rock sampling, and channel sampling of veins and wall rocks at the South, Centre and North mineralized zones. The 2011 work also included the completion of a ground magnetometer survey, an electrical resistivity survey sampled by multi-frequency Promis-10 (FDEM) electromagnetic induction, and a gravimetry survey. The work in the winter of 2012 consisted of geoelectric tomography sections and audiomagnetotelluric (NSAMT) surveys. These data identified the location of the St-Robert intrusive body and traced the main faults and tectonic nappes of the region down to a depth of 1,500 metres.

This new information will improve our understanding of the geological and metallogenic context of the St-Robert region and will be used to identify new exploration strategies.

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The morphology of magnetite in tills as an exploration tool: example of its application to the Halfmile Lake volcanogenic massive sulphide (VMS) deposit (Bathurst, New Brunswick)

Sheida Makvandi and Georges Beaudoin (ULaval)

The study of surface textures and grain shapes of magnetite from the Halfmile Lake VMS deposit and nearby till reveal that size, morphology, and mineral association depends on: 1) the petrology of the host rock; 2) the mode of transport; and 3) the depositional conditions. The magmatic magnetite is mostly idiomorphic, whereas magnetite from alteration zones is anhedral and accompanied by sulphides, silicates, or both. Surface textures of magnetite from till can be grouped into three categories: a) the mineral association and the inclusions and exsolutions; b) abrasion marks; and c) dissolution and postglacial precipitation.

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Iron oxide mineral chemistry applied to porphyry deposit exploration

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The trace element composition of iron oxides varies significantly depending on the metallogenic environment during deposition. This characteristic signature, measured by electron microprobe and LA-ICP-MS, is useful for establishing exploration indicators. A study was carried out on iron oxides from the world's major Cu-Mo-Au porphyry deposits, representing diverse metal associations, ages, and geodynamic environments, in order to discriminate this deposit type from others.

The petrographic study of magnetite from different deposits distinguished two types of magnetite: (1) magnetite in quartz veins with or without sulphides, and (2) disseminated magnetite in host rocks. Variations in the minor and trace element compositions of magnetites were dependent on the type of mineralization (Cu, W-Mo, etc.), and were also noted within a deposit itself as slight variations in Si, K, Al, Mn, Mg, Ti, V and Cr. By comparing the chemistry of magnetite associated with porphyry deposits to primary magnetite in NI-Cu-PGE deposits, it was possible to detect an enrichment in K, Ca, Y, Pb and V, and depletion in Mn, which may be explained by the hydrothermal origin of this type of magnetite compared to the magmatic origin of magnetite in Ni-Cu-PGE deposits. Following this, the chemistry of magnetite from porphyry deposits was compared to that of magnetite associated with mineralization in polymetallic iron oxide copper-gold (IOCG) deposits. Although Sc, Zn and V enrichment was observed, the chemical signature of magnetite from porphyry deposits is otherwise similar to IOCG deposits with regard to other elements, which may be due to their hydrothermal origins.

Based on this information, discriminant diagrams were constructed to distinguish porphyry deposit magnetites from those of other deposit types using minor and trace element compositions. As well, magnetites formed independently of mineralization but associated with various types of hydrothermal alteration in porphyry deposits can be distinguished from magnetites associated with mineralization, which can serve as exploration vectors.

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Magnetite in hydrothermal alteration associated to IOCG systems in the Great Bear Magmatic Zone, Canada

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Magnetite is a minor to major constituent of veins, breccias and incipient to intense alteration in iron oxide-copper gold systems of the Great Bear magmatic zone, Northwest Territories. Prevalence of magnetite in most of the known IOCG systems makes it a key mineral to understand and monitor their evolution and development. Multiple magnetite paragenesis associated with numerous textures are observed in these magmatic/hydrothermal systems. The macroscopic and microscopic observation of magnetite-bearing paragenesis is used to understand the processes that have generated the spectrum of textures observed. Mineral assemblages and associated textures can be used as exploration vectors to mineralized zones so distinctions between different paragenesis are essential in the comprehension of IOCG systems. To show the numerous aspects that can exhibit magnetite-associated alteration, a protocol for regional to megascopic description of replacements, veins and breccias has been developed to facilitate the description of these rocks in the field and subsequently on stained and unstained rock slabs and thin sections.

Prevailing paragenesis consists of 1) magnetite (Fe alteration), 2) amphibole-magnetite $\pm$ apatite $\pm$ albite (high temperature Ca-Fe $\pm$ Na alteration), 3) K-feldspar-magnetite $\pm$ biotite or biotite-magnetite (high temperature K-Fe alteration), with common overprint by hematite. Magnetite replacement is preferentially formed around phenocrysts, within vesicles, in groundmass, or replaces fragments in breccias. These habits suggest that magnetite replacement forms where fluids circulate through porous and permeable rocks and/or minerals. In bedded or layered rocks, magnetite alteration can form selective stratabound replacements of specific horizons. Magnetite also crystallize as breccia cement or fill veins. High temperature K-Fe alteration crystallizes magnetite with K-feldspar in felsic and intermediate igneous rocks, and biotite in siliciclastic sedimentary rocks and mafic rocks. In potassic-altered porphyritic volcanic rocks, K-feldspar first replaces the groundmass and then the phenocrysts with increasing alteration intensity whereas biotite replaces selectively pre-existing amphiboles. Replacements and veins of transitional high temperature Ca-K-Fe and subsequent high temperature K-Fe alteration are commonly followed by the mineralization stage, in which a wide variety of metal can be concentrated (e.g. Cu, Au, Ag, Bi, Co, etc.). Each type of paragenesis and textures exert a control on the aspect that will take subsequent alteration. As an example, amphibole-magnetite veins preferentially cross-cut albitized zone at the expense of the unaltered volcanic rocks. Ultimately, the main objective of the project is to produce an atlas of alteration associated to IOCG that will provide exploration tools and a framework for geologists during the exploration of under-explored terranes.

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Structural and microstructural characterization of the St-Joseph Fault and the Baie Verte-Brompton Line in the Appalachians of southern Québec

Morgann Perrot and Alain Tremblay (UQAM)

In the Québec Appalachians, the Humber and Dunnage zones respectively represent the remains of the continental margin of Laurentia and the adjacent oceanic domain obducted during the Ordovician Taconian orogeny. In southern Québec, these two zones are overlain by the Gaspé Belt, a Silurian-Devonian sequence that was deformed and metamorphosed during the Devonian Acadian orogeny. In the Humber Zone, Taconian penetrative deformation is constrained within the Notre-Dame Anticlinorium (NDA) and is mainly attributed to ophiolite obduction and accretion onto Laurentia. To the east, the NDA is bounded by the St-Joseph Fault, a steeply SE-dipping structure, synthetic to the Baie Verte-Brompton Line (BVBL), which represents a major Silurian normal fault defining a polyphased "suture" zone between Laurentia and early Paleozoic oceanic terrains. In 2011- 2012, a structural study and a sampling program were carried out along the two fault zones in two areas in the Québec Appalachians, including the two following mines: (1) the Jeffrey mine in the Asbestos area, where the BVBL is exposed along the north wall of the open pit, and (2) the Range IX mine in the Thetford Mines area, which is transected by the St-Joseph Fault. The two sites expose fault zones characterized by sheared and altered serpentinite along the contact between various metamorphic rocks (amphibolite, greenschist, phyllite, slate, quartzite) in the hanging wall and sedimentary rocks (mudstone, sandstone) and mafic and ultramafic rocks (peridotite, basalt) in the foot-wall. The BVBL and the Saint-Joseph Fault are both oriented NE and dip at about 60-70° SE. In both locations, the presence of shear bands and stair-stepping is visible along the main fault planes, clearly indicating that the main deformation increment corresponds to a normal fault movement. The metamorphic fabric in hanging wall rocks, trending N to NE and variably dipping at 40° to 60° E, is clearly reworked by ductile-brittle subsidiaries of the BVBL, indicating the late timing of the latter relative to regional metamorphism (and deformation) of rock units in the hanging wall. The orientation of striations along fault planes is variable, indicating several distinct deformation increments in certain locations, and continuous and progressive deformation in other areas. A microstructural study suggests the area of influence of each fault is relatively limited.

The surficial geochemical cycle of metals during mining: example of lacustrine sediments in Schefferville, Québec

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The surficial geochemical cycle of metals is disturbed during mining. Mining operations, soil removal, anthropogenic waste, and changing trophic conditions in aquatic systems all constitute disturbances to the surficial geochemical cycle. The preliminary study of Laperrière et al. (2009) describes the relationship between mining in the Schefferville region and metal levels in the sediments of Lac Dauriat, near the town. To delve deeper into this subject, our study intends to address the following issues:

1. What are the sources of the metals in the lacustrine sediments?
2. In what chemical forms do the metals occur?
3. What happens during the pre-mine/mine and mine/post-mine transitions?
4. Why was the steady-state pre-industrial scenario not attained until 30 years after mining ceased?
5. Is it possible to accelerate the return to natural equilibrium?

Two cores of lacustrine sediments were collected at different distances from the mining installations and analyzed (Lac Dauriat and Lac Oksana, 2 km southwest of the town).

Our analysis of the sediment cores reveals that several metals attained elevated concentrations during mining operations (1939-1977), with values often far above regional background levels. Moreover, the two lakes did not experience the exact same anthropogenic disturbances, even though they are only several kilometres apart.

It is possible to distinguish, using lead isotope data (Figure 1), at least three sediment sources for each lake:

1. Local geogenic Pb during the pre-mine period (with different compositions for the two lakes);
2. A contribution of local Pb at the beginning of mining activities, corresponding to the onset of mining, and a contribution of local Pb generated at the end of mining operations;
3. A contribution of Pb in long-range atmospheric fallout (industrial activities in Canada) during the post-mine period.

By comparing the geochemical and isotopic analyses of epiphytic lichen (atmospheric signal), mine ore, and mine waste (local geogenic signal) to the values obtained from the lacustrine sediments, we were able to determine the sediment sources for the two study lakes. Selective leaching (speciation) experiments will be used to determine the chemical forms for some of the metals (Pb and Zn) and the phases to which they are bound (ex.: organic phase). The project will also provide a better understanding of the anthropogenic effects related to mining operations in fragile arctic environments.

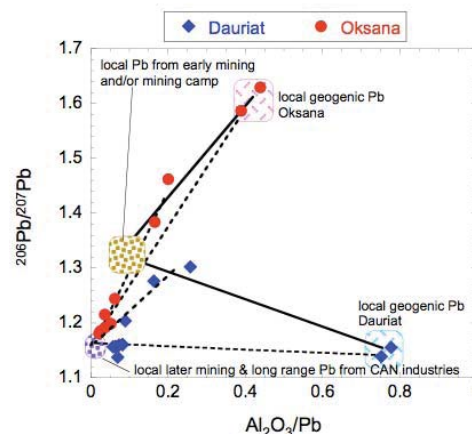


Figure 1 - Lead isotope analysis of the lacustrine sediments of Oksana and Dauriat lakes.

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Hydrogeochemistry of aquifers of the city of Québec metropolitan community, Québec, Canada

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As part of the groundwater knowledge acquisition program (Programme d'acquisition de connaissances sur les eaux souterraines; PACES) of the *Ministère du Développement durable, de l'Environnement, de la Faune et des Parcs* (MDDEFP), a geochemical study was carried out on the groundwater of the Québec metropolitan community ("CMQ") for the cities of Québec, Lévis, L'Ancienne-Lorette and Saint-Augustin-de-Desmaures, and the MRCs of Côte-de-Beaupré, Jacques-Cartier and Île-d'Orléans, representing a surface area of 3,050 km². In this region, 21% of the 750,000 inhabitants rely on private or municipal wells drilled in granular and fractured aquifers of the Grenville, the St-Lawrence Lowlands, and the Appalachians. The objective of the study is to provide a hydrogeochemical overview of the area, define the quality of the groundwater in terms of drinkability and esthetic criteria, and establish the geochemical processes controlling water quality. In order to do this, 141 samples were collected from private and municipal wells. The analyzed parameters for these samples were the physico-chemical conditions (pH, temperature, dissolved oxygen, salinity, conductivity, redox potential and total dissolved solids), anions, nutrients, soluble metals, and sulphides. Measuring the electroneutrality of the samples (% of cations-anions) provided a means for validating the quality of the analytical results. Of the tested samples, 109 with electroneutrality less than 10% were retained for multivariate statistical analysis and identification of geochemical facies, which were defined using major ions. The most common facies (45%) is Ca-HCO₃, which is associated with recharge zones and found almost exclusively on the north shore of the St-Lawrence River. The dominant facies at Île-d'Orléans and Lévis are Na-HCO₃ and Na-Cl, which represent a higher level of geochemical evolution. Principal component analysis and hierarchical groupings will help determine the groundwater origins and the geochemical processes responsible for the types of water found in the study area. In order to assess water quality, all 141 samples were compared against drinkability and aesthetic criteria. These parameters revealed that acceptable aesthetic levels were exceeded for iron (11%), manganese (15%), chlorides (5%), sodium (7%), sulphides (6%), pH (49%), hardness (5%) and total dissolved matter (19%), whereas in terms of drinkability, acceptable levels were exceeded for fluorine (11%) and barium (0.01%).

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Hydrogeological study of fractured rocks in the Outaouais: what factors influence the yield of the drinking water wells?

Arnaud Sterckx, Jean-Michel Lemieux, John Molson, Guillaume Comeau (ULaval)

In the Outaouais region, groundwater provides drinking water for more than 90% of the population living outside urban centres. For the great majority of these people, the water is supplied by domestic wells that withdraw freshwater from crystalline rocks of the Grenville Province and sedimentary rocks of the Hudson and St. Lawrence platforms, which naturally have low porosity and low permeability. Since the population of the region is expected to grow considerably in the coming years (+23% between 2006 and 2030), these aquifers will be relied upon even more heavily and new wells will need to be drilled. With this in mind, our study aims to determine which factors influence the capacity of domestic wells drilled in bedrock. Knowledge of such factors will constitute an important working tool for future groundwater prospecting in rock formations.

The data used in this study come from Québec's hydrogeological information system (Système d'information hydrogéologique; SIH) and pumping tests carried out by Université Laval in 2011 and 2012. The SIH database was processed and purged in order to retain only the most reliable data. To test the reliability of the remaining data, the SIH's hydrogeological parameters (i.e., specific capacity) were compared to the pumping test results.

Among the more than 13,500 wells inventoried in the SIH, only a thousand were retained. The permeability tests established, among other things, an empirical relationship between a well's specific capacity and the transmissivity of the source rock.

Following this, several factors were studied, such as lithology, well depth, rock confinement and distance to a lineament, in order to determine whether such factors influence well capacity.

A correlation was noted between a well's specific storage and the type of rock drilled: crystalline rocks are less productive than sedimentary rocks. It was also noted that specific capacity tends to decrease with well depth. On the other hand, there is no obvious relationship between well yield and the presence of unconsolidated deposits or lineaments.

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Investigation of ice-rich permafrost in northern Québec using 2D and 3D induced polarization tomography

Majid El Baroudi and Richard Fortier (ULaval)

The non-destructive study of ice-rich permafrost, vulnerable to the impacts of climate change along an oil pipeline, road, or landing strip in cold regions, requires suitable and effective methods for characterizing the conditions of such an environment. Among the available surface geophysical methods, induced polarization tomography (IPT) is probably the best investigative technique in this situation given the strong contrast in electrical resistivity between frozen and unfrozen soils.

IPT was used to determine the extent and conditions of a mound of permafrost near the Inuit community of Umiuq in northern Québec. Dipole-dipole and pole-dipole configurations were used to carry out the IPT in 2D and 3D, respectively. IPT inversion was performed using RES2DINV and RES3DINV software to produce 2D and 3D spatial distribution models of subsurface electrical resistivity and chargeability. These models clearly reveal an ice-rich core in the permafrost mound characterized by high resistivity values, whereas unfrozen zones are conductive.

In addition to IPT, five cone penetration (CPT) tests were also carried out on the permafrost mound. Using the logs of tip resistance, friction coefficient, temperature, and electrical resistivity obtained during the tests, it was possible to define a geocryological model for the permafrost mound. Electrical resistivity values were then attributed to different layers in the geocryological model to define a synthetic model of electrical resistivity. The electrical resistivity model obtained from the 2D IPT inversion is comparable to the one obtained from the cone penetration tests. A 2D-IPT-constrained inversion using the synthetic electrical resistivity model will be performed to generate a more realistic electrical resistivity model for the permafrost mound.

IPT is a useful surface geophysical model for characterizing soils and for determining the presence/absence of permafrost, the cryostratigraphy of the permafrost, and the spatial distribution of conditions within the permafrost. This method can be used to delineate ice-rich areas when carrying out engineering projects in cold regions.

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Geological storage of CO₂ in the Saint-Lawrence Lowlands of Québec: potential impacts at the sedimentary basin scale

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The geological storage of carbon dioxide (CO₂) has the potential to significantly reduce anthropogenic greenhouse gas (GHG) emissions in the atmosphere. Among the many options, geological storage in saline aquifers is currently the most promising.

The sedimentary Saint-Lawrence Lowlands Basin (SLLB) has great potential for the geological storage of CO₂. The permeability, porosity and depth of the sandstones in the Covey Hill Formation would allow CO₂ to be stored in a supercritical state at a density near that of a liquid. The presence of sufficiently thick Utica shale cover rocks with very low permeability would ensure the CO₂ remains confined. In addition, the water in the Covey Hill Formation sandstones is brine and thus does not represent a source of potable water. The presence of major emitters in the central SLLB adds to its interest as a geological storage site.

Even though all the conditions appear to be in place for successful geological storage in the saline aquifers of the SLLB, the concept must first be demonstrated and the environmental consequences assessed. Among the latter, two types of potential impacts at the sedimentary basin scale must be addressed:

- Brine migration toward freshwater aquifers;
- A pressure increase in the hydrogeological system, leading to the upflow of surrounding aquifers.

The objective of this project is to assess the potential impacts of the geological storage of CO₂ in the SLLB at the scale of the sedimentary basin.

To do this, we will simulate CO₂ injections using a numerical model of fluid flow at the scale of the SLLB to quantify the potential impacts of CO₂ storage. The model will simulate groundwater flow, the transport of solutes (chlorides), heat transfer, and the effects of density at the scale of the sedimentary basin.

The development of a numerical model requires a hydrostratigraphic model for the SLLB. Since no such model currently exists, it will be developed using a compilation of available hydrogeological data. These data are mostly derived from drill-stem tests carried out by oil and gas exploration companies. The methods for interpreting such tests have evolved considerably since they were first carried out, and a reinterpretation is therefore underway to ensure reliable and standardized data.

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Rare earth element abundance and mobility in the sediments of Canadian Shield target lakes

Jade Bergeron, Charles Gobei, André Tessier (INRS)

The rare earths, particularly the lanthanides (excluding Pm), are strategic metals that continue to rise in value due to their essential roles in the high tech industry. Despite this, very few countries produce rare earths, and although exploration for these elements continues in Québec, there are still no rare earth mines in the province. Consequently, the issue of environmental contamination by rare earth elements has never been evaluated, even for aquatic environments.

In order to provide preliminary data on rare earth element levels and mobility in Québec lakes, vertical profiles of the lanthanides (La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu and Y) and several other geochemical variables (pH, sulphides, sulphates, organic carbon, anions and major metals, Fe, Mn) were determined using environmental records in the form of isotopically dated (^{210}Pb ; ^{137}Cs) cores of lacustrine sediments. The same profiles were also established using the results of interstitial water samples collected from two lakes in the Canadian Shield: one situated 40 km from the city of Québec, and the other 25 km from the city of Rouyn-Noranda.

Our poster provides an overview of the results to date, presenting the most likely chemical forms of lanthanides to occur in interstitial waters. These were estimated by thermodynamic calculations using WHAM software.

Using a transport-reaction model applied to the element profiles for interstitial waters, we have determined zones based on sediment depth in which reactions with lanthanides will occur, and even the speed of these reactions. This information will open the door to discussions on the potential for lanthanide contamination of lacustrine sediments.

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Mineral potential of the southern Gouin Reservoir area

Claude Hébert (Agglomération de La Tuque and CRÉ of the Mauricie)

In late 2011, the town of La Tuque decided to include a mining component in its efforts to diversify its economy. La Tuque is part of the Mauricie administrative region and manages a vast land area known as the La Tuque Agglomération, which includes the Gouin Reservoir Basin. In association with the Mauricie CRE (Conférence régionale des élus), and with the material and logistical support of the MRN, La Tuque has assigned us the mandate to carry out reconnaissance geological work and assess the mineral potential of the southern Gouin Reservoir area. Six weeks of field work were dedicated to the project, which covers all or parts of 15 map sheets at 1:50,000 scale (31O14 to 16; 31P13 and 14; 32B1 to 8, and 32A3 and 4). No work was carried out on the reservoir or surrounding lakes, or in the areas already claimed.

We initially identified 45 targets to visit based on showings mentioned in historical work, geological maps at 1:250,000 scale established in 1960 and 1970, and magnetic field maps. Other than investigating known showings, our other objective was to try and explain each of the identified geophysical targets. As part of the reconnaissance project, which is quite different from a mineral exploration project, only one pass was made over each of the targets and one sample taken at random for analysis.

Our main observations are as follows:

- The volume of favourable metasedimentary rocks for gold, silver, copper and zinc mineralization is clearly greater than what appears on existing geological maps. These rocks are apparently similar to those of the Montauban area (gold, zinc). Anomalous values are present;
- Some favourable contexts for nickel, copper and cobalt are also present (mafic and ultramafic rocks);
- We observed thick layers of mangerite strongly enriched in iron (with or without phosphate);
- Also present are differentiated sequences of AMCG-type suites (e.g., anorthosite, leuconorite, gabbro-norite);
- One lithology in particular may be of interest to the architectural stone industry due to its characteristics that are different than those typically found in the Grenville.

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Characterization of the deformation between the Parautochthon and the Allochthon southwest of the Manicouagan Reservoir, central Grenville, Québec: preliminary results

Sophie Jannin, Félix Gervais (École Polytechnique), Abdelali Moukhsil (MRN)

The Grenville Province is divided into two large entities: the Parautochthon, consisting of North American craton and its metasedimentary cover rocks, and the Allochthon, consisting of exotic rocks thrust over the craton. In the western Grenville Province, these two entities are separated by the Allochthon Boundary Thrust (ABT). This zone underwent reverse movement between 1060 and 1020 Ma, consequently burying the Parautochthon to the base of the crust, followed by normal movement starting at 1020 Ma which led to its rapid exhumation. In the central Grenville, southwest of the Manicouagan Reservoir, the Relay shear zone may correspond the ABT. It separates rocks that were metamorphosed to the kyanite field between 995 and 985 Ma from rocks metamorphosed to the sillimanite field between 1080 and 1040 Ma. However, recent mapping work by the MRN demonstrates that: 1) this shear zone is located in the core of the Parautochthon; 2) the Parautochthon is composed essentially of tonalitic gneiss belonging to the Archean Ulamen Complex. Also found in this region is the Proterozoic Gagnon Group, formed primarily of paragneiss and iron formations. The Allochthon is composed of mangerite, gabbro and gabbro-norite belonging to the Canyon Complex (1200 Ma), paragneiss of the Plus-Value Complex (1765 to 1487 Ma), and the Tétépisca Anorthosite Suite in the southwest.

This PhD project aims to determine whether western Grenville events also took place in the central Grenville, and to better define the nature of such events. The tectonometamorphic evolution and model for the region southwest of the Manicouagan Reservoir will be developed using: 1) detailed mapping; 2) in-depth structural analysis; and 3) combined metamorphic and geochronological studies to define pressure-temperature-time-deformation paths.

Our preliminary work indicates that the main deformation in the Parautochthon was sinistral-reverse movement in a N-S to NE-SW direction, with a tectonic Grenvillian lineation plunging 10 to 50° to the south. Two other later episodes of deformation are also represented. The first, which is only observed in the south, transposed the Grenvillian lineation into a shallow plunge to the SW. This deformation was dextral-normal and oriented NE-SW to ENE-WSW. The second of these later events was sinistral-normal deformation trending N050° which only locally affected foliation. These later episodes may correspond to the normal deformation that resulted in the exhumation of the Parautochthon.

Finally, deformation is more intense in the Relay shear zone than at the boundary between the Parautochthon and the Allochthon.

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Geology of the northern Outardes 4 Reservoir area, Côte-Nord (22K05, 22K06, 22K11, 22K12 and 22K13)

Abdelali Moukhsil, Fabien Solgadi (MRN), Aphrodite Indares (Memorial University - Newfoundland), Saïd Belkacim (MRN)

The mapped region constitutes Phase II of a regional mapping project that aims to acquire new geological and metallogenic knowledge in the Côte-Nord region (NTS map sheet 22K). Situated in the northwest part of the Outardes 4 Reservoir, the study area belongs to the central Grenville Province. In addition to geological mapping at a scale of 1:125,000, a new aeromagnetic survey was also carried out, covering all of map sheet 22K, among others. This survey, combined with the mapping work, was used to delineate and identify several lithological units.

The basement in this region generally comprises porphyritic to porphyroclastic intrusive rocks of felsic to intermediate composition belonging to the Hulot Complex (1434-1373 Ma). The northwest part of the region is occupied by the Tétépisca Anorthosite Suite (1052 Ma), consisting primarily of porphyroclastic to megaporphyritic anorthosite as well as leuconorite and minor amounts of iron and titanium oxides. Lesser amounts of anorthosites and leuconorites with large volumes of mangerite and charnockite and some granitic facies (AMCG suite) are also known in the region. The Plus-Value Complex and probably the north part of the Canyon Complex, which were mapped further east during the summer of 2011, continue into the study area. The sedimentary Plus-Value Complex (<1765 Ma, >1487.6 Ma) consists mainly of biotite-garnet-sillimanite-graphite paragneiss containing horizons of quartzite, calc-silicate rocks, and marble. Migmatized paragneisses and migmatites are also present in the Plus-Value Complex. Leucocratic granites with lilac-coloured garnets were mapped along the edges and within the paragneiss units and are interpreted as anatectic granites (melting of metasediments). The north part of the Canyon Complex consists mainly of gneissic mangerite of Elsonian age (1222 Ma) containing metre- to decametre-scale slices of mafic and ultramafic rocks of Labradorian age (~1694 Ma). Other intrusive rocks, such as granite and monzonite, are also present in association with charnockites.

The regional structural grain is dominantly NE-SW, but is disrupted by the emplacement of intrusions. Regional faults producing mylonitization have been traced over distances of several kilometres. The dominant metamorphism is medium-pressure granulite facies.

The mapped region reveals a number of targets for rare earth minerals, graphite, iron oxides and titanium oxides. The mafic to ultramafic units encountered in many places throughout the region may also have significant potential for nickel and copper.

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Presentation of geophysical data published in 2012

Rachid Intissar, Isabelle D'Amours (MRN), Régis Dumont, Alan Jones (GSC)

The 2011-2012 year proved to be an excellent year for Québec in terms of acquiring public geophysical data. Géologie Québec completed approximately 415,766 linear kilometres of surveys since last year (all published), and Natural Resources Canada carried out two surveys.

The results of these surveys were published by Géologie Québec in the following reports:

- **DP 2011-06:** Magnetic and spectrometric survey covering 20 map sheets at 1:50,000 scale in the Lac Le Moyne area, Churchill Province, carried out by the company Geo Data Solution
- **DP 2011-07:** Magnetic and spectrometric survey covering 18 map sheets at 1:50,000 scale in the Rivière Koksoak area, Churchill Province, carried out by the company Eon Geoscience
- **DP 2012-01:** Aeromagnetic survey covering 33 map sheets at 1:50,000 scale in the west part of the Opatika and the south part of the Nemiscau, Baie-James, carried out by the company Geo Data Solution
- **DP 2012-02:** Aeromagnetic survey covering 17 map sheets at 1:50,000 scale in the Lac Sainte-Anne area, Grenville Province, carried out by the company Geo Data Solution
- **DP 2012-03:** Aeromagnetic survey covering 25 map sheets at 1:50,000 scale in the Manic-Outardes area, Grenville Province, carried out by the company Eon Geoscience
- **DP 2012-04:** Heliborne magnetic survey covering one and a half map sheets at 1:50,000 scale in the Malartic area, Abitibi Subprovince, carried out by the company Geo Data Solution

As part of the Geo-mapping for Energy and Minerals (GEM) program, Natural Resources Canada completed an aeromagnetic survey in the Mistastin Batholith area, at the border between Québec and Newfoundland-Labrador. The data from this survey, which covers about 15 map sheets at 1:50,000 scale in Québec, are published in **DP 2012-05** (MRN). Simultaneously, as part of the Targeted Geoscience Initiative-4 (IGC4) program, Natural Resources Canada carried out an airborne gravity-gradient and magnetic survey in the Lac Strange area, at the border between Québec and Newfoundland-Labrador. The survey covers about half a map sheet (24A 08-102) at 1:20,000 scale and was published in **DP-2012-06** (MRN).

The data from the two surveys carried out by Natural Resources Canada are also available from the Geological Survey of Newfoundland and Labrador and the Geoscience Data Repository (GDR) of Natural Resources Canada.

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Graphite potential of Québec

N'golo Togola (MRN)

Québec has good potential for graphite mineralization.

A number of graphite deposits have been identified in the Grenville Province, notably in the Outaouais and Laurentides regions, as well as in the Fermont area and southwest of the Manicouagan Reservoir. These occurrences of graphite mineralization are associated with metasedimentary units (paragneiss, quartzite, calcitic marble, dolomitic marble).

The graphite deposits of Lac des Îles, south of Mont-Laurier, and Lac Knife, north of Fermont, constitute the two largest graphite deposits in Québec.

The Lac des Îles deposit (Stramin mine), operating since 1989, is 20 km south of Mont-Laurier. Graphite mineralization is associated with bands of dolomitic marble, calcitic marble, quartzite, and calc-silicate rocks that form part of the Central Metasedimentary Belt in the southwest Grenville Province. The deposit is estimated to contain a mineral resource of 25 million tonnes, including inferred resources of 5.2 million tonnes at 7.42% carbon in graphite.

The Lac Knife deposit is 27 km south-southwest of Fermont. The host rocks of the deposit belong to the Lower Proterozoic Gagnon Group. The graphitic zones are hosted by migmatized biotitic quartzo-feldspathic gneiss and consist of disseminated fine graphite flakes. The gneiss, locally sheared, silicified and brecciated, contains an average of 5 to 10% graphite and sulphides. Layers with more than 20% graphite are brecciated. Measured and indicated resources of the deposit are evaluated at 4.97 million tonnes at 15.7% of carbon in graphite and the inferred resources, 3 million tonnes at 15.6%. The mineralized zone extends about 650 m long and 120 m wide.

The area southwest of the Manicouagan Reservoir also offers good potential for graphite mineralization. Many deposits of graphite have been discovered in the early 2000s. Among the most notable are those of Lac Guéret (GC and GR zones), Lac Guinécourt, Capitaine Cosmos, Graphi-Est, Graphi-Centre, Graphi-Ouest and Manic. In this area, the graphite mineralization is associated with quartz-graphite schist horizons or chloritized amphibole schists within units of biotite-garnet paragneiss, quartzite, or quartzo-feldspathic gneiss.

Measured and indicated resources of the Lac Guéret deposit (Zone GC) are estimated at 7.6 million tonnes at 20.4 % of carbon in graphite and the inferred resources, 2.7 million tonnes at 17.3 % of carbon in graphite.

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Mapping of surficial deposits in the Charlevoix and Haute-Côte-Nord regions (Québec, Canada): preliminary work

Julien Walter (UQAC), Mohamed El Amrani (MRN), Etienne Brouard (ULaval), Marie-Odile Chartier (UQAC), Patrick Lajeunesse (ULaval), Pierre Cousineau (UQAC)

Surficial deposit geology is a key component to understanding a region's hydrogeological environment. As part of the groundwater knowledge acquisition program (Programme d'acquisition des connaissances sur les eaux souterraines; PACES) of the *Ministère du Développement durable, de l'Environnement, de la Faune et des Parcs* (MDDEFP), UQAC is carrying out a Quaternary deposit mapping project, in partnership with the MRN, on the municipalized lands of the MRCs of Charlevoix, Charlevoix-Est and Haute-Côte-Nord. The mapping survey covers all or parts of a dozen NTS maps sheets at 1:50,000 scale (21M07, 21M08, 21M09, 21M10, 21M16, 21N13, 22C04, 22C05, 22C06, 22C11, 22C14 and 022C15) for a total surface area of 4,600 km². The work involves four phases spread over two years: 1) the preliminary phase (summer 2012); 2) the creation of preliminary maps (delivery in March 2013); 3) systematic field surveys (summer 2013); and 4) the production of final maps and a synthesis report (delivery in March 2014).

The objectives of the first phase were to define, in a preliminary manner, the stratigraphic framework and to consolidate the collaboration between UQAC, MRN and Université Laval, and to gather and inventory any existing information relevant to carrying out the project (aerial photos, maps, scientific articles...). This phase required 21 field days during which 223 sites were described using géofiches (descriptive files). The latter were then digitized and entered into a database. The sites included sand and gravel pits, quarries, road cuts, and riverside exposures, as well as sampling using a hand-held auger. Shells as well as wood, charcoal and paleosol samples were collected for dating purposes.

The assemblage of sedimentary facies in the Charlevoix region appears to be very complex. In addition to deposits laid down during the Wisconsinan deglaciation (the Saint-Narcisse morainic complex, deltaic sediments, and deep water sediments of the Goldthwait Sea), there are also thick older deposits consisting of glaciolacustrine rhythmites and stratified sands, which were observed up to 20 metres thick in some areas (Île aux Coudres cross-section). The steep topography and strong seismicity of the region make it prone to large landslides that superficially rework the land. In contrast, the Haute-Côte-Nord region is characterized by a seemingly less complex stratigraphic framework with a sharp demarcation between the highlands, generally dominated by glacial and fluvioglacial deposits, and the lowlands, dominated by clay-rich marine facies overlain by thick sandy deposits of deltaic origin on top of which large peat bogs often formed.

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Inventory of aggregate resources in the Kuujuaq region

André Brazeau (MRN) and Philippe Bélanger-Trudel (ULaval)

During the summer of 2012, an inventory was taken of the aggregate resources in the Kuujuaq region. This northern village is situated along the shore of the Koksoak River, about 50 km upstream from Ungava Bay, at a latitude of 58° 06' north and a longitude of 68° 24' west. It is located within the zone of discontinuous permafrost. The inventoried land covers approximately 330 km², extending from 10 km south of the village to almost 25 km north of the community.

The population of Kuujuaq (about 2,300 inhabitants), and of northern villages in general, is growing rapidly. Lodging and municipal infrastructure needs are very high. The presence of permafrost combined with the effects of global warming makes their construction more difficult than usual, leading to an enormous demand for aggregates to construct road and building foundations.

The inventory provides the locations, characteristics and estimated quantities of aggregate resources. Field work consisted mainly of digging test pits by shovel and visiting natural cross-sections and sand pits. Fifteen samples of sand or gravel were collected and sent to a laboratory to determine their physico-mechanical properties.

The main sources of aggregate material consist of littoral or deltaic marine sediments. The deposits (tills) and glacial landforms (drumlins) were almost all reworked by the waters of the Iberville Sea, which formed following deglaciation about 7,000 years ago. Most of the study area is below the ancient sea level, currently situated at an elevation of 180 metres. Many terraces are present, covered by boulders. These deposits repose on bedrock composed of Proterozoic granitic rocks belonging to the Churchill Province.

The deposits mainly consist of sand of variable grain size. Sources of natural gravel are rarer. The average thickness of the deposits is 4 to 5 metres.

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Inventory of aggregate resources in the Lac Mégantic region

André Brazeau and Mohamed El Amrani (MRN)

During the summer of 2012, an inventory was taken of the aggregate resources in the Lac Mégantic region. With a total surface area of 1,400 km², the study area covers parts of map sheets 21E07, 21E09 and 21E10 at 1:50,000 scale, and extends south and west to the border with the United States. The results of this work will provide the locations, characteristics and estimated quantities of aggregate resources.

Field work consisted mainly of digging test pits by shovel and visiting sand pits, gravel pits, and road cuts. In all, 163 sites were investigated and 28 samples of sand or gravel collected and sent to a laboratory to determine their physico-mechanical properties.

The basement rock belongs to the Appalachian Province. It comprises a wide range of sedimentary, volcanic and intrusive rocks. The level of deformation is variable, depending on the location, but is typically represented by well developed schistosity.

The deposits most likely to provide aggregate material are mainly of glacial origin. These generally formed during the last deglaciation about 12,500 years ago. Ice-contact and glacial outwash deposits constitute the best sources for sand and gravel supplies. These deposits are often confined to valleys. Many of them were intensely excavated in the past and are now virtually exhausted. Also present are glaciolacustrine and fluvial deposits.

The quality of the aggregate resources in the region is highly variable. These materials, plucked from the bedrock by the action of passing glaciers, reflect the wide variety of the underlying rocks.

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Mapping of surface sediments in the Outaouais: overview and outlook

Olivier Lamarche, Mélina Dubois-Verret, Marc-André Hurtubise, Sylvain Milette, Pierre-Marc Godbout, Nancy Horth, Éric Leduc, Martin Roy, Robert-André Daigneault, Michel Lamothe (UQAM)

Surface sediments in the city territory of Outaouais were mapped as part of a groundwater knowledge acquisition program (Projet d'acquisition de connaissances sur les eaux souterraines; PACES), an initiative of the *Ministère du Développement durable, de l'Environnement, de la Faune et des Parcs*. The program aims to provide an assessment of groundwater resources with a view to ensuring the availability of suitable drinking water and protecting this resource. The mandate for this project was assigned by the *Ministère des Ressources naturelles*, and its main goal is to update the existing knowledge on surficial geological formations and geomorphologic features in the study area. An area covering the equivalent of 24 NTS map sheets was mapped at a scale of 1:50,000. The mapping work was assisted using aerial photos at 1:40,000 scale.

A preliminary photo-interpretation allowed us to identify the main surficial formations, to target zones where the nature of the formations is unknown, and to locate gravel pits, sand pits and natural crosscuts that could provide information on the genesis of the deposits and the regional stratigraphy. This initial interpretation was then verified by field work that also allowed us to ascertain the nature of undetermined zones, and better define the spatial distribution of the units. The field surveys also characterized the surface deposits (colour, thickness, grain size, etc.) and documented glacial ice flow directions. The final maps were then produced digitally in ArcGIS using a standardized legend common to other PACES projects. To date, 11 maps have been completed for the eastern part of the study area, and 13 other maps should be produced from now until spring 2013.

This work better defines the distribution of the various Quaternary units present throughout the region. The preliminary data indicate that the sedimentary cover is largely dominated by till (>65%) in the higher topographic regions, whereas sand and gravel deposits (~5%) are mainly concentrated in fluvial valleys. Fine sediments, such as silts and clays, occur as a thin and relatively continuous cover along the Rivière des Outaouais. This work also improved our knowledge about the glacial history of the region, particularly concerning the locations of moraine deposits associated with major climatic deterioration.

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Implications of the reanalysis of lake sediments in the Northeastern Superior Province for the development of new exploration models

Charles Maurice (MRN)

Nearly 18,000 lake sediment samples covering a surface area of more than 260,000 km² in the Northeastern Superior Province (NESP) were reanalyzed. These samples were initially collected in 1997, at a spacing of one sample per 13 km², within the scope of a regional survey encompassing more than 26,000 samples (survey 1997520¹). About 2,000 of these, mostly samples located west of Ungava Bay, were reanalyzed in 2004 to determine their precious metal content². In 2009, 4,000 samples collected further east, in an area underlain by the Churchill Province, were reanalyzed for a large suite of elements³. The new data available today consist of analyses carried out at the same laboratory as in 2009, using the same analytical protocols³.

The database has now been upgraded with analytical results for which more than 95% of previous results were below or equal to detection limits (*e.g.*, Be and Se). Certain elements had not been analyzed previously (*e.g.*, Hg, In, Nb, Sn, Ta, Te, Tl), whereas others were simply unusable. This is the case for Bi notably, which shows a correlation coefficient of 0.09 between ICP-MS and ICP-AES results, a scatter inferred to result from interference with Cr in ICP-AES analyses.

In the Goudalie Domain and the La Grande Subprovince, the new data reveal metal associations typical of porphyry systems associated with felsic intrusives derived from a sedimentary protolith. Thus, we see, from north to south, several domains where lake sediments are successively enriched in Bi-In (Sn), Bi-W (Sn-In), Mo, Sn-W-Mo, then W-Sn. Collectively, these domains are aligned along a NNW-trending axis some 350 kilometres long, similar in size to the 300-kilometre W-Sn Jurassic Nanling Province in China. Further north, in the Utsalik Domain (Nantais Complex), the combination of high Bi and Te concentrations in lakes proximal to known gold showings may suggest the presence of mineralized systems involving bismuth tellurides. The new lake sediment data may be used to further define existing exploration models, but may also contribute to outlining geological settings previously unrecognized in the NESP.

1. 35 elements by ICP-AES, partial digestion in nitric acid (0.5 g) and 9 elements by neutron activation (10 g)
2. Au, Pd, Pt by fire assay with ICP-MS (5 to 15 g)
3. 53 elements by ICP-MS, partial digestion in aqua regia (0.5 g)

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Gold potential in the North Domain of the Ungava Trough

Daniel Lamothe and Olivier Rabeau (MRN)

The gold potential in the North Domain of the Ungava Trough was demonstrated during regional mapping work carried out by the MRN during the 1980s. An orogenic (mesothermal) gold favourability study covering this area has been carried out using spatial analysis techniques. This work has defined several high favourability zones that will be made public via GESTIM at the opening of Québec Mines 2012, which will highlight the gold potential of this underexplored area of the Ungava Trough.

About 20 geological parameters associated with gold deposits were used. The probability of a spatial association was calculated for each parameter using the "weight of evidence" method; the weights thus obtained were converted into fuzzy values and then combined using a fuzzy logic approach. To avoid over-weighting the results, the combination of parameters using fuzzy operators was optimized to obtain a neutral background value (0.5). Favourable zones were designated by choosing a significant and predictive threshold from among the range of fuzzy values represented on the resulting map.

Modelling of the data was done using the ModelBuilder tool in ArcGIS 10. The process for calculating mineral potential has been fully programmed and can be automatically executed in several minutes. The possibility of quickly testing new parameters or different calibration sets represents a significant improvement to the mineral potential assessment process. Most of the operations use unmodified tables of data from the SIGEOM geodatabase as the source data. This approach will make it easy to generate a new mineral potential map following any SIGEOM updates that affect the source data for the model.

ACRONYMS

- ACPE: Association canadienne des prospecteurs et entrepreneurs
- AEM: Agnico-Eagle Mines
- AEMQ: Association de l'exploration minière du Québec
- AMQ: Association minière du Québec
- BAPE: Bureau d'audiences publiques sur l'environnement (Gouvernement du Québec)
- CCSN: The Canadian Nuclear Safety Commission
- CERM-UQAC: Centre d'étude sur les ressources minérales de l'Université du Québec à Chicoutimi
- CGC: Commission géologique du Canada
- CGC-CC: Commission géologique du Canada - Centre du Canada
- CGC-O: Commission géologique du Canada - Ottawa
- CGC-Q: Commission géologique du Canada - Québec
- CGO: Commission géologique de l'Ontario
- CMIC: Conseil canadien de l'industrie minière
- CNRS: Centre national de la recherche scientifique
- CNSC: Canadian Nuclear Safety Commission
- CONSOREM: Consortium de recherche en exploration minérale
- CRC-MM-UQAC: Chaire de recherche du Canada en métallogénie magmatique, Université du Québec à Chicoutimi
- CRE: Conférence régionale des élus
- CRÉBJ: Conférence régionale des élus de la Baie-James
- CRPG: Centre de recherches pétrographiques et géochimiques, France
- CRRNTBJ: Commission régionale sur les ressources naturelles et le territoire de la Baie-James
- CRSNG (RDC): Conseil de recherches en sciences naturelles et en génie du Canada (subventions de recherche et développement coopérative)
- CSST: Commission de la santé et de la sécurité du travail
- CU: Carleton University
- DIVEX: Diversification de l'exploration minérale du Québec (Réseau de recherches géoscientifiques)
- ENSG/CRPG: – Nancy Université, École nationale supérieure de Géologie / Centre de recherche de pétrographie et géochimique
- FQRNT: Fonds québécois de recherche sur la nature et les technologies
- GC-DLG: Géomatique Canada - Division des levés géodésiques
- GC-GSD: Geomatic Canada - Geodesic Survey Division
- GEOTOP UQAM-McGILL: Centre de recherche en géochimie et en géodynamique de l'Université du Québec à Montréal et de l'Université McGill
- GSC: Geological Survey of Canada
- GSC-O: Geological Survey of Canada - Ottawa
- GSC-Q: Geological Survey of Canada - Québec
- INRS: Institut national de la recherche scientifique
- INRS-ETE : Institut national de la recherche scientifique – Centre Eau, Terre et Environnement
- INSU: Institut national des Sciences de l'Univers
- McGill: Université McGill
- MDDEFP: Ministère du Développement durable, de l'Environnement, de la Faune et des Parcs
- MISA: Mines, innovations, solutions et applications
- MRN: Ministère des Ressources naturelles
- MPMPs: Mineral potential maps production system (MRN)
- MTP: Miller Thomson Pouliot
- NTS: National Topographic Series
- OGS: Ontario Geological Survey
- OSUC: Observatoire des Sciences de l'Univers en région Centre, Université d'Orléans, France
- PDAC: Prospectors and Developers Association of Canada
- Poly: École Polytechnique de Montréal. Département des génies civil, géologique et des mines, Montréal
- RNCREQ: Regroupement national des conseils régionaux de l'environnement du Québec
- RSC: Ressources Strateco
- SPCPM: Système de production des cartes de potentiel minéral (MRN)
- TGI-3: Targeted Geoscience Initiative (2005-2010) – GSC
- UBC: University of British Columbia
- U d'O: Université d'Ottawa
- U of A: University of Alberta
- U of O: University of Ottawa
- UL: Université Laurentienne
- ULAVAL: Université Laval
- UNB: University of New Brunswick
- UQAC: Université du Québec à Chicoutimi
- UQAM (SCTA): Université du Québec à Montréal (Département des Sciences de la Terre et de l'Atmosphère)
- UQAT: Université du Québec en Abitibi-Témiscamingue
- URSTM-UQAT: Unité de recherche et de service en technologie minérale de l'Université du Québec en Abitibi-Témiscamingue



Ressources naturelles
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