



QUÉBEC MINES 2013

CROSSROADS OF GEOSCIENCE
AND MINERAL RESOURCES

SCIENCE – INNOVATION – SOCIETY

ABSTRACTS OF ORAL
PRESENTATIONS AND POSTERS

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Québec 

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INVITATION FROM THE HONORARY PRESIDENT OF QUÉBEC MINES 2013

Many Québécois view the mining industry as part of a global market whereby the level of activity is affected by fluctuations in international prices for metals and minerals, by changing demands driven by the needs of emerging countries, and by competitiveness in terms of grade, operating costs and transport. Others see it as a local activity with significant concerns in terms of stable, well-paid jobs, quality of life, as well as potential consequences, whether real or expected, on the immediate environment.

While these two viewpoints do depict important aspects of the industry, they also paint an incomplete and unbalanced portrait by failing to recognize important elements. It is imperative that we rectify this situation, and this is where Québec Mines plays an essential and critical role.

The modern mining industry relies on a large body of scientific and technological knowledge. Québec possesses state-of-the-art geoscientific infrastructure, and over the years has produced highly qualified men and women in a variety of fields in the mining sector.

The mining industry is an economic driver for Québec: it represents 30.5% of the province's total foreign exports and is a major source of well-paid jobs, particularly in outlying regions, those without well-diversified economies.

The mining industry has and will continue to face long-term issues. Investments in the mining sector are characterized by substantial initial outlays that must be made long before any revenue can be generated, and also by elevated technical, economic and financial risks. The time between the discovery of a mineral deposit and the start of production ranges from 8 to 15 years. In these circumstances, it is not surprising that optimal and sustained contributions to the economic growth of a region depend on stable and appropriate policies, as well as sensitivity on the part of the industry, to maintain a balanced relationship with the host environment. Québec Mines 2013 is an effective way to raise awareness about the nature, importance and contribution of the mining industry to Québec society. This gathering is also an ideal time to learn more about the latest scientific, technological, political and industrial developments that are shaping the future of the mining sector. It is also a great opportunity to interact with members of the industry, and those developing and administering the policies that govern Québec's mining sector. As our continued success depends on your participation, we hope to see you there.

I look forward to meeting you.

Pierre Lortie

Senior Business Advisor
Dentons Canada S.E.N.C.R.L.



MESSAGE FROM THE MINISTER OF NATURAL RESOURCES

SHAPING THE FUTURE OF THE QUÉBEC MINING INDUSTRY

I am pleased to extend this invitation to all players in the broad field of geosciences and mining development to attend Québec Mines 2013.

This year, the convention highlights the importance of research, new practices and social responsibility in mining development. Science, innovation, society: these three words set the foundation for our government's approach to fostering the responsible development of Québec's mineral resources.

Québec Mines 2013 will offer multiple opportunities to acquire new knowledge and discuss these issues. By attending the conference, you will be contributing to shaping the mining industry of tomorrow in harmony with the environment and communities for the benefit of all Quebecers!

I wish you an excellent convention!

A handwritten signature in black ink, appearing to read 'M. Ouellet'.

Martine Ouellet

Minister of Natural Resources of Québec

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SESSION 1

Strategic futurecasting: What can scenarios of the future teach us today?

JEFF LOEHR AND GEORGE HEMINGWAY
(VCI-VIRTUAL CONSULTING INTERNATIONAL)

We will paint pictures of possible mining futures in terms of operations and organization and explore what guidance their common threads and principles provide to Innovation leaders today. The visions of the future blend trends, mining company visions, potential disruptions in technology, societal changes and our experience in developing the mines of the future. Insights emerge that every mining company should be aware of and which will be useful for thinking about developing and implementing technology in today's mines. We draw on our experiences of developing innovation programs for Rio Tinto, AngloGold Ashanti, Vale and other leading mining companies to ground this presentation in the here and the now.

SESSION 1

The mine of the future: Intelligent ore management

MARTIN PROVENCHER (IBM CANADA)

Mining companies face increasingly difficult challenges when it comes to the extraction and delivery of the right product to the right client at the right moment, all the while remaining profitable. Market fragmentation and variations in the quality of mine materials, combined with competition and volatility in the market prices for raw materials, are factors that apply greater pressure on mining costs. Mining operations are also faced with a series of problems in logistics optimization, related to moving the material from the mine to the client. The mining industry uses assets that represent considerable capital investments, which must be managed in the most optimal way possible throughout the ore supply chain. In the meantime, technology is rapidly advancing and increasingly available. People now use smart phones during their daily activities, and houses are equipped with sensors and automated systems for lighting, heating and air conditioning. These technologies can now be used by the mining industry to optimize operations and reduce costs, all the while improving the long-term viability of mining activities.

This presentation will address the future of ore management logistics. It will cover, from a practical viewpoint, the way in which the intelligent use of data, combined with new technologies, can lead to an integrated management approach for operations and planning.

SESSION 1

The evolution of canadian mining: Open innovation for survival and growth

ALAN GALLEY AND CARL WEATHERELL (CANADA MINING INNOVATION COUNCIL)

With today's complex global economic environment many Canadian-based mining companies have to make serious financial decisions in order to maintain shareholder confidence in a soft commodities market. The result is commonly less spending on a company's innovation agenda, with the result being an increased gap between operational complexities and capabilities. One solution to closing this gap is to consider a national-scale industry consortium approach to ensuring a company can remain on the leading edges of technology and knowledge curves.

The not-for-profit Canada Mining Innovation Council was developed as a strategic approach to facilitate open innovation through the development of industry consortia linked with a national-scale, networked community of colleges, universities and service providers. CMIC is focused on taking mineral industry defined challenges and devising solutions through a combination of new R&D avenues and incorporation of existing technologies outside of the conventional mineral industry sphere. The CMIC mandate also includes breaking down barriers between the different segments of the mining continuum so that innovative breakthroughs in one segment strategically impact the others, thereby improving overall company efficiencies and cost effectiveness.

SESSION 1

Groupe MISA: Support mechanisms for innovation, achievements to date, and outlook for the future

ALAIN BEAUSÉJOUR (GROUPE MISA)

When it comes to innovation, the mining crowd is already sold on the idea. The real question isn't whether we should innovate, but how? For five years, Groupe MISA has been promoting mining innovation by drawing on best practices in innovation management. The MISA approach is squarely centered on business logic. Its road map already includes several noteworthy accomplishments. But we must do more! The pace must be accelerated if Québec's mining sector is to make its mark as a world-class centre of excellence.

Is the "MISA method" the answer to the questions of "how"? How can networking stimulate the culture of innovation? How does incorporating the value chain raise performance standards and spearhead innovative practices? How do we weigh the "risk" of innovation against operational risks? How can we combine innovation management with the many business components required to launch Québec's mining sector companies toward international markets?

SESSION 1

Laser-induced breakdown spectroscopy (LIBS): A new tool for the mining industry

MOHAMAD SABSAHI, PAUL BOUCHARD, FRANÇOIS DOUCET, LÜTFÜ ÖZCAN, ANDRÉ MOREAU, AISSA HARHIRA AND ALAIN BLOUIN (NRC)

The minerals industry is facing significant challenges – declining ore grades, increasingly complex ores with higher levels of impurities, and pressure to improve environmental performance leading to increased production costs. To meet these challenges, technologies are sought for online measurements that provide key analysis information at all steps, from mine to metal. In all the steps in the value chain, it is critical that operating parameters be adjusted and controlled so that the chemistry of the melt, the solution or the slurry is within predetermined limits. Presently, the complete turnaround time for sampling, sample transfer, analysis and communication of the results to the operators is often in the order of hours, or more. Virtually eliminating this delay by on-line Laser-Induced Breakdown Spectroscopy (LIBS) analysis will significantly increase productivity.

The LIBS technique offers the possibility of real-time analysis of multi-elements in mineral ore samples, thus allowing a fast on-line chemical analysis of these samples. The LIBS technique uses a high-power pulsed laser whose beam is focused to produce a plasma on the sample to be analyzed. The light emitted by the plasma is analyzed with an optical spectrometer, and provides information on the chemical composition of the sample. An important advantage of the technique over classical methods stems from the possibility of *in-situ* analysis of virtually all types of materials (solids, liquids, molten materials and gases) with standoff capabilities, without the need for any sample preparation.

In our laboratory, LIBS has been used in various scientific and industrial applications, such as the analysis of metal alloys, liquids, and minerals. Its efficiency and robustness have been proven in many applications. LIBS can analyze a wide range of materials on site quickly, and detect quantities in the range of parts per million. In this presentation, we will present our results for the real-time analysis of molten metals and effluents in metal processing, the on-line analysis of metal ore slurries and mineral ore samples, etc. In particular, we will be focusing on the application of LIBS for analyzing gold ore samples.

SESSION 1

The Télébec research laboratory in underground communications: A leader in telecommunications solutions for Québec mining companies

MOHAMED AÏLAS (UQAT)

Created in 1999, the Télébec Underground Communications Research Laboratory (TUCRL), at the Université du Québec en Abitibi-Témiscamingue (UQAT), addresses the issue of wireless communication in underground mines, specifically looking at the propagation of electromagnetic waves in underground environments. Over the last three years, the laboratory also focused its research on wireless communications in sparsely populated areas in order to respond to the communication needs of the inhabitants in such areas.

The TUCRL has a highly qualified team composed of professors, postdoctoral students and graduate students, and a support group of engineers and a technician. The laboratory collaborates with several different internationally renowned universities, and is supported by Télébec (a division of Bell Aliant), the mining industry, and several government funding programs.

The laboratory's research work has established propagation models for complex environments, leading to a better understanding of wireless communication behaviour. This work and the innovative spin-offs facilitate more efficient communication in confined environments and in zones with low user densities.

In order to reach its research objectives, the laboratory has undertaken several projects over the years (multimedia wireless access for underground metal mines; very large bandwidth wireless access for confined areas; wireless communication in the 60 GHz bandwidth, etc.). These projects generated numerous spin-offs for the mining industry:

- ▶ Hybrid WIFI (a/b/g/n)/DOCSIS communication system over a coaxial cable;
- ▶ Long-distance wireless high-speed link;
- ▶ Wireless MESH network/wireless sensor network;
- ▶ Wireless IP communication system;
- ▶ Multiservice solution over a radiating cable;
- ▶ Information collection system for preventative maintenance;
- ▶ Low-speed remote operations;
- ▶ Wireless Kiosk mode, etc.

This presentation will review the laboratory's innovative solutions that are relevant to the mining industry and present its directions for development in the years to come.

SESSION 1

How can optical-photonic technologies of today and tomorrow contribute to increasing your productivity?

PIERRE GRENIER (QUÉBEC INTERNATIONAL)

Despite the low profile, optical-photonic technologies are present in all aspects of the mining industry. Whether it is in exploration, mining or rehabilitation, much of the essential data for decision making comes from optical-photonic systems such as LIDAR measurements, hyperspectral imaging, chemical analyses and 3D imaging.

Are you aware that the know-how of optical-photonic businesses is now recognized worldwide? Did you know that solutions are available to meet your particular needs? Are you aware that ABB Analytical Measurements has a business unit for measurement products – a team of optical-photonic experts that specialize in the mining sector and are based in the city of Québec? Did you know there are solutions that can be set up to improve the efficiency of your processes? And that there are applications to improve the security of your processes? Do you know how the businesses and research centres of this sector work together so they can provide you with customized solutions? Would you like to learn who these equipment providers are and how you can set up a project with them? These are the questions we will address in the next 20 minutes.

SESSION 2

Geology of the Malartic area

PIERRE PILOTE, PIERRE LACOSTE, JAMES MOORHEAD (MRN), RÉAL DAIGNEAULT (UQAC), VICKI MCNICOLL (GSC) AND JEAN DAVID (MRN)

The Malartic area is located in the southern Abitibi Subprovince. This three-year project (2012-2014) covered, in 2012, the northeast quadrant of NTS sheet 32D01 and during the summer of 2013, the southeast quadrant of NTS sheet 32D08 (La Motte area) at a scale of 1/20,000. This area corresponds to the extension of volcanic units observed in the Val-d'Or area.

The Malartic area is underlain by alternating volcanic units (Malartic, Louvicourt, Blake River, and Piché groups) and sedimentary units (Cadillac, Kewagama, and Pontiac groups) of Archean age and of variable thickness and extent. The Malartic (MG) and Louvicourt (LG) groups encompass the La Motte-Vassan (LVF, 2714 ± 2 Ma), Dubuisson (2708 ± 2 Ma), Jacola (2706 ± 2 Ma), Val-d'Or (2704 ± 2 Ma), and Héva (2702 ± 2 Ma) formations. The age of the LVF suggests it may be contemporaneous with the upper part of the Kidd-Munro Assemblage in Ontario. The MG and the LG consist of ultramafic flows and sills, basaltic-andesitic-rhyolitic flows, and various volcanoclastic rocks. S0 stratigraphic surfaces generally trend WNW to N-S, with variable dips. Stratigraphic tops are to the southwest or west in the southern part of the area, and to the north or east in the northern half of the area. These reversals may be explained in part by the presence of the La Motte-Vassan Anticline, an F1 structure resulting from the emplacement of the synvolcanic La Pause Pluton (2710 ± 1 Ma) in the Preissac area. An S1 schistosity, subparallel to S0 stratigraphic surfaces, is commonly observed. This fabric is overprinted by an S2 cleavage trending E-W and steeply dipping to the north. The metamorphic grade ranges from the greenschist facies in the southern part of the area to the amphibolite facies in the northern part. An important structural feature in the southern part of the area is the presence of a major Z fold (F2), with an axial planar cleavage (S2) oriented E-W to ENE that cross-cuts the earlier S1 schistosity. The trace of this fold does not appear to continue eastward however, it just fades into the trajectory of the Norbenite Fault. These E-W folds and movements parallel to lithological assemblages generated dilation zones favourable for the emplacement of late gold-bearing intrusions such as the Camflo stock for example. The late to post-tectonic Preissac (2680-2660 Ma), La Motte (2642 Ma), and La Corne (2680-2642 Ma) plutons, as well as several other discrete satellite intrusions, cross-cut and deeply disturb the original volcanic and structural architecture that developed prior to their emplacement.

The Malartic area is bordered to the south by the Cadillac Tectonic Zone. It is also affected by numerous shear zones, deformation zones, and longitudinal faults, the most important ones being the La Pause, Parfouru, Norbenite, Marbenite, Manneville South, and Rivière Héva faults. These faults are defined by a mylonitic foliation, subparallel to schistosity S1 and locally S2, that follows for the most part the regional tectonic fabric. These faults, although important on a regional scale, are not insurmountable obstacles for the reconstruction of volcanic sequences. Significant gold deposits and showings with various ages of emplacement (Canadian Malartic, Barnat-Sladen, East Malartic, Malartic Goldfields, Camflo, Malartic Hygrade, Orion #8) are commonly spatially associated with specific sets of pre-tectonic (tonalitic) or syn- to post-tectonic (tonalitic-monzonitic) stocks and dykes bordering these faults or enclosed within the fault zones.

The results of this work will help improve our understanding and lead to a better definition of the mineral potential of this area. They will also help guide the search for various types of gold deposits in comparable settings elsewhere in the Superior Province.

SESSION 2

The Canadian Malartic mine, Abitibi, Québec: Geological characteristics and relative timing of low-grade bulk-tonnage gold mineralization

STÉPHANE DE SOUZA, BENOÎT DUBÉ,
VICKI McNICOLL, PATRICK MERCIER-LANGEVIN,
CÉLINE DUPUIS (GSC), ROBERT CREASER (UNIVERSITY
OF ALBERTA), PIERRE DE CHAVIGNY AND DONALD
GERVAIS (OSISKO MINING CORPORATION)

The Canadian Malartic mine exploits a low-grade bulk-tonnage gold deposit (P&P reserves of 10.9 Moz; 345 Mt @ 0.98 g/t Au) in which mineralization is hosted mainly by metasedimentary rocks of the Pontiac Group and deformed porphyritic monzodioritic to granodioritic intrusions located south of the Larder Lake–Cadillac Fault Zone. The Pontiac Group consists of turbiditic greywacke affected by a dominant WNW to NW cleavage dipping to the NE (70–90°). The Sladen Fault, which generally marks the southern contact at surface of a mineralized porphyritic intrusion, is oriented E-W and dips to the south (45–85°). Two orientations have been documented for the mineralized envelopes, E-W and NW-SE, with opposing dips to the south and north, respectively. Mineralized rocks typically contain calcite and traces to 3% disseminated pyrite. Visible gold is rare. In addition to gold, the metal signature of the mineralization consists of traces of Bi-Te-W and locally Mo. The majority of the mineralization is found in metasedimentary rocks as replacement zones and stockworks of quartz-feldspar-biotite-sericite-pyrite. Laminated and/or brecciated mineralized veins of quartz ± pyrite are also present. In the intrusions, mineralization consists of replacement zones of quartz-feldspar-pyrite-carbonate with a carbonatized (calcite) and hematized envelope. This envelope contains millimetre- to centimetre-scale veins of quartz-calcite ± pyrite locally forming stockworks. Also present in the intrusions are pegmatitic veins of quartz-feldspar-carbonate-tourmaline-biotite-galena-scheelite with reddish K-feldspar and hematite alteration in the vein walls. Mineralization is preferentially developed along the Sladen Fault, fold hinges, and NW-SE brittle-ductile structures. The cross-cutting relationships and relative chronology documented in different mineralized zones suggest the latter structures formed contemporaneously with the main phase of mineralization. The geometry of the mineralized bodies, their spatial association with structural features, and the presence of laminated mineralized quartz veins indicate syn-deformational mineralization and/or remobilization of pre-existing mineralization. The preferred working hypothesis is that the Canadian Malartic gold deposit and its present geometry are the result of syn-deformational mineralization superimposed on a magmatic-hydrothermal system associated with porphyritic intrusions emplaced near the Larder Lake–Cadillac Fault.

SESSION 2

New developments in mineral-scale trace element analysis and mapping in ore deposit research and exploration: examples from gold deposits of Québec and Ontario

SIMON JACKSON, JIANFENG GAO
AND BENOÎT DUBÉ (GSC)

Laser ablation (LA)-ICP-MS has long been used for rapid, spatially-resolved trace-element analysis of minerals in petrographic sections. Recently, advances in instrumentation and data processing software have spurred development of element *mapping* of geological minerals. At the GSC, new techniques have been developed for generating quantitative, high resolution (down to <10 µm), major and trace element (down to low ppb) concentration maps. These maps frequently provide extraordinary insight into the behaviour and paragenesis of ore and associated elements during mineralizing processes. Here, we report results, emanating from the GSC's TGI-4 program, of element mapping applied to sulfide minerals from two major Canadian gold deposits.

The Archean Canadian Malartic deposit (Québec), consists of a shell of disseminated Au and pyrite mineralization hosted by altered monzodiorite and granodiorite porphyries and Pontiac metasediments. While ore is spatially associated with the intrusions, most mineralization is hosted within the metasediments and is preferentially developed in association with the Sladen fault and NW-SE-oriented fold hinges and deformation zones, leaving the origin of the deposit open to interpretation.

Two main generations of pyrite are present at Malartic: inclusion-poor and inclusion-rich. Element mapping indicates that Au is largely concentrated in the inclusion-rich pyrite, together with Ag, Sb, Te, Pb, Bi. Nickel, As and Se contents can be highest in either pyrite, making them unreliable pathfinders. Molybdenum is concentrated along the margins of both pyrite types, indicating that it is late and perhaps associated with late, fractionated melts, compatible with a 'porphyry' model, or with remobilization from an earlier magmatic-hydrothermal stage.

The Musselwhite mine (Ontario) is a structurally-controlled banded iron formation (BIF)-hosted gold deposit that occurs in a complex amphibolite grade Archean volcanics and volcanoclastic setting, including chemical sediments and local argillaceous units containing mm to cm diagenetic sulphide nodules that have partially recrystallised to pyrite and pyrrhotite. Element mapping shows that the nodules are strongly enriched in Au (up to >1000 ppb) and commonly associated elements (As, Se, Ag, Sb, Te, Tl, Pb, Bi), while the recrystallised sulphides are relatively depleted in these elements.

These results open up the possibility that the Au at Musselwhite was sourced, at least in part, from diagenetic sulphide nodules that released Au, S and other metals into a fluid during metamorphic/hydrothermal recrystallisation. Ores formed where metal-rich fluids were structurally focused and intersected reactive BIF host rocks. Thus, Au-rich diagenetic sulphide nodules in argillites could be an important new exploration indicator, as proposed elsewhere.

SESSION 2

Geological reconnaissance drilling in the area between Lac Quévillon and Lac Turgeon

PIERRE-LUC DESCHÊNES AND GUILLAUME ALLARD (MRN)

A drilling program combining the study of Quaternary deposits and systematic sampling of the underlying bedrock was undertaken to better define the geology in this area. A total of 308 rotasoni holes were drilled in the central part of the Abitibi Greenstone Belt. The study area covers approximately 6,500 km² and is located between the towns of Lebel-sur-Quévillon and Normétal. This area is covered by a thick layer of unconsolidated deposits, such that the bedrock is largely hidden.

The objectives of this geological survey are:

- ▶ To document the geology of volcano-sedimentary bands,
- ▶ To better define the geology of intrusions in the area,
- ▶ To assess the mineral potential of the area by defining favourable geological settings for the discovery of new mineral deposits.

Other than a few Proterozoic dykes (Matachewan, Biscotasing and Abitibi dykes), the rocks in the study area are Archean in age. The earliest volcanic rocks in the area belong to the Valrennes Formation and are mainly composed of basalts, andesites, and felsic tuffs. These are overlain by volcanic rocks of the Normétal Group, the Clermont-Disson Formation, the Vanier-Dalet-Poirier Formation, and the Desboues Formation, which have a similar composition. The Rivière Octave Formation constitutes a major unit of felsic to intermediate volcanoclastic rocks. These volcanic rocks are unconformably overlain by siliciclastic metasedimentary rocks of the Glandelet Formation. The drilling and mapping program was successful in defining numerous deformation zones that most likely played a role in the emplacement of various plutons in the area (Mistaouac Pluton, Nissing-Oditan Pluton, Lac de la Perdrix Pluton, Bernetz Intrusion, and Marest Pluton). All geological units are cut by several types of intrusions, namely gabbros as well as quartz- and/or feldspar-phyric felsic intrusions. The most important deformation zones identified in the area are the Laflamme-South and Laflamme-North deformation zones. Regional metamorphism reached the greenschist facies, locally reaching the middle amphibolite facies along the borders of certain plutons.

The Sleeping Giant mine, the Vior deposit, the presence of favourable alteration patterns, and the identification of synvolcanic intrusions are all indicative of the area's potential for mineral deposits associated with volcanic activity. The extension of two deformation zones in the area, the presence of extensive carbonate alteration, and the identification of lode gold occurrences also attest to the potential of this area for orogenic gold deposits.

SESSION 2

High-resolution multi-parameter analysis of drill core from the Chibougamau region – Implications for mineral exploration

PIERRE-SIMON ROSS, ALEXANDRE BOURKE (INRS), FRANÇOIS LECLERC (MRN) AND ALEXANDRE BOULERICE (INRS)

LAMROC — the INRS' mobile laboratory for the physical, mineralogical and chemical characterization of rocks — can take several types of drill core measurements (density, magnetic susceptibility, geochemistry and mineralogy) nearly simultaneously and in a non-destructive manner. The system also acquires a high-quality digital image of the core. The INRS received a mandate from the MRN for 2012 to 2014 to carry out a high-resolution multiparameter analysis of drill core from the Chibougamau region (northeast Abitibi Subprovince). The main objective is to better understand the Waconichi Formation to the north and south of the Lac Doré Complex (LDC). In 2012 and 2013, we analyzed three exploration drill holes from the vicinity of the former Lemoine mine (south of the LDC). These holes passed through the Lemoine Member and some of the LDC rocks. Three other drill holes from the Lac Taché area to the north were also analyzed. The data provide more than 11,000 measurements of density, magnetic susceptibility, and infrared and visible spectrometry, and roughly 5,600 geochemical measurements (GM 67111).

Highlights of the first year of the program include:

- ▶ In the area of the former Lemoine mine, which exploited one of the richest VMS deposits in Canada, the Waconichi Formation is divided into several felsic units. In a composite section located 3.2 km east-northeast of the former mine, the most altered rocks (chlorite-sericite) are found in the “Zr-rich Marelle Rhyolite” unit (now the “Alpha Rhyolite” unit), and not in the Lemoine Rhyolite, the summit of which hosts the deposit. The Alpha Rhyolite, interpreted as an intrusive unit, is lower in the stratigraphic sequence and may represent a VMS exploration target.
- ▶ The geology in the area south of Lac Taché was not well known before the current study. We have demonstrated that the geology can be reinterpreted as a combination of rocks belonging to the LDC and the David Member (Obatogamau Formation). The Allard Member (Waconichi Formation) is found at the summit of this sequence. The presence of strongly magnetic and iron-rich LDC zones to the south of Lac Taché indicates the area's potential for Fe-Ti-V deposits.

SESSION 2

Geological and metallogenic context of the Kuujuaq, Lac Saffray and Ungava Bay region, Southeast Churchill Province, Québec

DANIEL BANDYAYERA, ISABELLE LAFRANCE, MARTIN SIMARD AND CARL BILODEAU (MRN)

The southeast part of the Churchill Province, formerly the Rae Province, is bounded by the Archean Superior craton to the west, the Archean Nain and Makkovik cratons to the east, and the Proterozoic Grenville Province to the south. In the centre is the Core Zone, an Archean craton that was deformed and reworked during the Paleoproterozoic, which is bordered to the west and east by Paleoproterozoic rocks deformed during the New Québec (Labrador Trough) and Torngat orogenies respectively. The region is characterized by a dominant NW-SE structural grain produced by the oblique collision between the Core Zone and the Superior craton during the New Québec orogeny (1.82 to 1.77 Ga). The Rachel-Laporte Zone, to the west, is composed of metasedimentary rocks and amphibolites, and is considered the metamorphosed equivalent of the Labrador Trough. The west part of the Core Zone consists of slices of Paleoproterozoic rocks thrust over rocks of the Rachel-Laporte Zone, which in turn overthrusts by deformed Archean rocks. The Archean rocks are mainly gneissic complexes intercalated with slices of paragneiss and amphibolite. Also present, in the west part of the Core Zone are E-W-trending granodioritic to granitic intrusions of Archean age with very high magnetic susceptibility. Lithological, geochronological and structural correlations between these intrusions and those of the Superior craton, just west of the Labrador Trough, suggest that part of the Core Zone corresponds to a block that became detached from the Superior craton during the Proterozoic, at approximately 1.88 Ga. Numerous syn-tectonic to late tectonic monzodiorite, granodiorite and granite intrusions of Paleoproterozoic age cut the older rocks. The largest of these is the De Pas Batholith, which extends for more than 600 km in the heart of the Core Zone and is interpreted as a continental magmatic arc.

New mineral showings and sites of economic interest, several of which are associated with geochemical anomalies in lake sediments, were discovered in the Rachel-Laporte Zone and the Core Zone, typically as metre- to decametre-scale rusty and sulphidized zones. The metallogenic contexts of the mineralized showings in the Rachel-Laporte Zone are similar to those in volcano-sedimentary rocks of the Labrador Trough. Several sites of interest are also found near major thrust faults.

SESSION 2

Iron ore deposits in the Labrador Trough: past, present and future developments

JAMES CONLIFFE AND ANDREW KERR (GEOLOGICAL SURVEY OF NEWFOUNDLAND AND LABRADOR)

Virtually all of Canada's iron-ore production comes from western Labrador and northeastern Québec, within a geologic region known as the Labrador Trough or *la Fosse du Labrador*. High-grade iron ore was first discovered near the Québec-Labrador border in 1929, with production commencing in the Schefferville area in 1954. Over the past 60 years the region has developed into a world class iron ore district, and the quality of steel-making products from its deposits is renowned in the global market. In addition to several active mines in Labrador and Québec, recent exploration has identified more than 100 billion tonnes of NI 43-101 compliant identified resources (measured, indicated and inferred).

Iron ore deposits are hosted in a sequence of cherty iron-rich sediments which outcrop continuously for more than 1100 km. The most widespread iron ore deposits in the Labrador Trough are weakly metamorphosed sedimentary iron formations (~30% Fe), termed taconites. Although not presently exploited, these deposits represent very large resources of low-grade material, with more than 82 billion tonnes of identified resources. Current and near-future production is dominated by metamorphosed iron formations (metataconites) in the Wabush-Labrador City-Fermont area. Large reserves of such material remain at four existing mines, and advanced exploration projects now define more than 9 billion additional tonnes of iron ore. These metamorphosed deposits profit from metallurgical and processing advantages, and their location in areas of existing infrastructure grants them obvious development priority. Production of high-grade "direct shipping" iron ore (DSO; > 55% Fe) recently resumed in the historic Schefferville camp. These ores are generally considered of supergene origin, although other hydrothermal processes may be involved in their formation. High-grade nonmagnetic "hard" hematite ores also occur, but the origins and full extent of this potentially important deposit type have yet to be defined. However, new discoveries of hard hematite ores may have important implications for future exploration.

Current research is focused on classifying iron ore deposits in the Labrador Trough and developing genetic models that may have implications for future exploration, with an emphasis on understanding the role of hypogene and supergene processes in the development of high-grade deposits. Despite a long history of exploration, integrated and comparative modern scientific information on these world-class resources remains limited. There is no doubt that the Labrador Trough will remain Canada's leading iron-ore district, and renewed scientific studies should have an important role in its continued exploration, especially in more remote areas.

SESSION 2

Geology, alteration, and metamorphism of Paleoproterozoic volcanogenic massive sulphide (VMS) deposits in the Snow Lake area, Flin Flon Belt, Manitoba

**SIMON GAGNÉ (MANITOBA GEOLOGICAL SURVEY),
ALAN H. BAILES (BAILES GEOSCIENCE),
ANTHONY E. WILLIAMS-JONES AND ANDREW HYNES
(MCGILL UNIVERSITY)**

The Snow Lake area represents a prolific metallogenic province for volcanogenic massive sulphide (VMS) deposits. A Paleoproterozoic (1.89 Ga) sequence of bimodal volcanic and volcanoclastic rocks, metamorphosed during an episode of regional metamorphism at ca. 1.82 Ga, hosts 18 VMS deposits (Zn-Cu and Cu-Zn±Au), including the Chisel North mine and the Lalor deposit discovered in 2007. The Chisel North deposit contained more than 2.6 million tonnes of ore grading 9.49% Zn, 0.21% Cu, 0.58 g/tonne Au and 21.43 g/tonne Ag. Production commenced in July 2012 at the Lalor deposit, which hosts the largest ore reserves in the Snow Lake area with 18.1 million tonnes of ore in zinc-copper zones (8.97% Zn, 0.64% Cu, 0.64 g/tonne Au and 25.24 g/tonne Ag) and 5.4 million tonnes of ore in copper-gold zones (0.46% Zn, 0.47% Cu, 4.7 g/tonne Au and 30.6 g/tonne Ag).

The Snow Lake area is characterized by the presence of extensive alteration zones metamorphosed to the amphibolite facies. Altered rocks are the end result of alteration on the ocean floor during the formation of VMS deposits. The alteration halo around Lalor and Chisel North includes concordant regional alteration (silicification, albitization, epidotization), semi-concordant alteration peripheral to the ore deposits, and discordant alteration pipes immediately underlying the sulphide lenses. The semi-concordant alteration includes assemblages enriched in staurolite, garnet, amphibole, biotite, chlorite, and muscovite, with significant amounts of kyanite, cordierite and gahnite. The discordant alteration pipes host sulphides and are generally characterized by the abundance of anthophyllite-cordierite or carbonate-tremolite-chlorite/talc assemblages.

The effects of regional metamorphism on the alteration halo and mineralization of a VMS ore deposit can have profound impacts, for both regional and local exploration as well as mining and metallurgy. The geological setting, distribution, and evolution of hydrothermal systems responsible for the formation of the Chisel North and Lalor deposits will be discussed, with a particular focus on the effects of regional metamorphism on altered rocks and mineralization (reactions between sulphides, silicates, and oxides; gahnite distribution and formation). Marginal zones in the Chisel North deposit enriched in Pb-Ag-Au will also be examined, to gain a better understanding of the effects of metamorphism on gold-bearing zones also enriched in S, Pb, Ag, As and Bi.

SESSION 3

Evolution of ore deposit models in the Abitibi and implications for exploration

MICHEL JÉBRAK (UQAM)

Since 1980, numerous base metal (Ansil, Bouchard-Hébert, La Ronde, etc.) and precious metal (Casa Berardi, Lapa, Goldex, Bachelor, Malartic, etc.) ore deposits have been discovered and brought into production in the Abitibi region. With its rich mining documentation and the quality of its fieldwork, the Abitibi has contributed to global ore deposit knowledge some of its most widely known models such as those for orogenic gold deposits and massive sulphides in bimodal volcanic settings.

At the end of the 1970s and the early 1980s, there was significant controversy surrounding the distinction between sulphide bodies and gold lodes, and while mine geologists established links, geochemists outlined discontinuities. In the early 1980s, fieldwork, at the Sigma mine in particular, paved the way for the concept of orogenic gold mineralization, spreading first in Ontario then across the world. The link with paleoseismicity introduced an actualistic vision of ore-forming processes. However, the search for sources never really came to a conclusion and the concept gradually lost its acuity, replaced by a more analytical vision of processes. Our understanding of massive sulphide settings also benefited from more and more detailed volcanological fieldwork and a better understanding of alteration processes in the late 1980s. The role played by depth in fluid chemistry and volcanogenic environments made it possible to establish links between mineralogical classifications and ore deposit categories. Integrative models predominantly based on petrology and volcanology were developed in the late 1990s and successfully explained the more deformed ore deposits east of Rouyn. For over 40 years however, the typically classic role of felsic magmatism has been largely overlooked. Isolated studies in several districts in the Abitibi eventually raised awareness about the metal potential of Archean porphyry systems and led to the revival of the Malartic district.

This history shows that exploration has especially benefited from advances in ore deposit knowledge. The integration of processes (source, transport) will be required in the future, to determine the key factors leading to metal accumulations. Our innovations have been mainly endogenous, regional, although the Yilgarn craton in Australia occasionally served as a model. Finally, rising metal prices are now fostering the development of new models for deep-seated or low-grade ore deposits (Au, Ni), and even for new commodities (REE). The Abitibi is thus destined to remain a source of innovation in the field of mineral exploration.

SESSION 3

Abitibi stratigraphy and geochronology over the past 30 years and their impact on mineral exploration

JEAN GOUTIER (MRN)

Establishing the stratigraphy of Archean rocks may be difficult due to the lack of fossil time markers, commonly discontinuous units, and extensive surface areas overlain by more recent deposits. The abundance of faults cross-cutting geological units is certainly not a facilitating element. Two important methods that have been used to improve correlations between units are geochemistry and geochronology. In this presentation, we will review the various elements that marked the evolution of stratigraphic knowledge in the Abitibi, namely geological compilations, U-Pb age determinations, immobile element geochemistry, and computer tools. The example of the Blake River Group, the most base metal-rich geological unit in the Archean, is very interesting in this regard. A good understanding of Blake River stratigraphy, coupled with geophysical and geochemical methods, has led to the discovery of volcanogenic massive sulphide (VMS) deposits at greater and greater depths. New U-Pb ages helped define the succession of mineralized horizons and revealed that the largest VMS deposits formed both at the base of the group (Horne and Quemont) and at the top (Bousquet and LaRonde), guiding exploration efforts along these two stratigraphic levels. At the scale of the Abitibi as a whole (Ontario and Québec), U-Pb ages have proven useful to establish correlations between major units. They have namely been used to locate sequences comparable to the Kidd-Munro Assemblage that hosts the giant Kidd Creek Cu-Zn ore deposit in Ontario.

SESSION 3

Synthesis of knowledge acquisition in the Ontario segment of the Abitibi Subprovince: A review of 1993-2013

SONIA PRÉFONTAINE (OGS), JOHN AYER (MERC),
ANDY BAJC AND STEW HAMILTON (OGS)

Over the past 20 years, the Ontario Geological Survey has been involved in numerous studies of the Abitibi Subprovince greenstone belt. Many maps have been generated, both of the bedrock at various scales and of airborne geophysical surveys. The OGS has also carried out systematic geochronological (U-Pb dating) and geochemical studies, as well as more thematic projects such as: 1) structural studies on lode gold deposits and associated major faults; 2) work on gold mineralization and volcanogenic massive sulphides, as well as nickel and platinum group element mineralization associated with komatiites; 3) metamorphic studies; and 4) studies on the intrusions in the greenstone belt. This database has greatly improved our understanding of the Abitibi Subprovince and has led to major revisions of its stratigraphy, architecture and economic potential.

In addition, the Ontario Geological Survey has carried out many glacial sediment studies and sampling programs covering both lesser known areas as well as historic exploration and mining regions. This work has focused on: 1) humus, soil and till; 2) lacustrine sediments and surface waters; and 3) fluvial sediments and modern alluvium. Other studies on tracking kimberlite indicator minerals and indicator minerals for metamorphosed or magmatic massive sulphides, as well as indicator minerals for gold mineralization, have been carried out using samples of till and alluvial sediments. Collectively, this work has identified new explored targets. Furthermore, several mineral exploration case studies have compared the geochemical signatures of mineral deposits in terms of: 1) the type of surface material, for example till vs lacustrine sediments vs water; 2) the type of environment, for example the footprint of a mineralized target buried under thick vs thin Quaternary cover; and 3) the type of mineralization, for example the signature associated with a small lode gold deposit vs a large gold deposit associated with syenites and metasedimentary rocks. Other case studies have examined different soil extraction leaching techniques or the physical, chemical and microbiological processes associated with deeply buried deposits. These case studies aim to determine the best method for detecting mineralization using surficial deposits.

SESSION 3

Geophysics applied to mineral exploration in the Abitibi or the Quest for the Holy Grail

MICHEL ALLARD (GLENCCORE)

Given the glacial sediment cover masking extensive parts of the bedrock in the Abitibi Subprovince, geophysics is indispensable to support the work of exploration geologists. It is estimated that geophysics has in fact contributed to the discovery of approximately 75% of all hidden volcanogenic sulphide deposits, particularly in the 1950s after exploration companies perfected airborne electro-magnetic (EM) surveying techniques.

Over the past 30 years, the expansion of computing power and memory, the development of specialized and effective processing and modeling software, the use of satellite positioning systems, and the development of new extremely sensitive sensors have revolutionized geophysical techniques. The unrelenting efforts of scientists, entrepreneurs, and exploration companies were all secretly focused on inventing the ultimate geophysical tool that would discriminate between good and bad anomalies. Thus, several airborne, ground-based or downhole EM systems were perfected and many others were invented. Airborne and downhole gravity methods were finally developed. Seismic techniques used in the oil industry were tested at great cost in most mining camps.

However, despite these advances in geophysical techniques and increased knowledge on the geological and geochemical processes involved in the emplacement of ore deposits, the rate of discovery of new economic deposits has considerably diminished in the Abitibi over the past 30 years.

This is certainly not due to lack of effort, and a few ventures were indeed successful. Vast expanses of the Abitibi belt were re-examined. The results of surveys completed with new EM systems, combined with the results of high-resolution magnetic surveys, have uncovered new targets and helped focus follow-up efforts on certain discrete targets in areas deemed favourable.

Various examples of exploration campaigns, university research studies, and coverage programs by government agencies will illustrate the recent evolution of geophysical techniques and knowledge. These examples will be used to discuss the advantages and limitations of modern geophysical techniques, and will serve to reiterate the well-received notion that exploration always benefits from a global approach integrating models and data from various sources and at various scales.

SESSION 3

Exploration methods for volcanogenic massive sulphides in the Abitibi: Contribution of geochemical data processing

STÉPHANE FAURE (CONSOREM-UQAM),
SYLVAIN TRÉPANIER (VIRGINIA MINES)
AND RÉAL DAIGNEAULT (UQAC)

The Abitibi constitutes an exceptional laboratory to study fossil hydrothermal systems along synvolcanic faults. These faults and their associated mineralogical alteration zones were initially recognized in the Noranda central camp as a result of a field-based approach. These pioneer studies helped establish a spatial correlation between certain faults in the caldera and volcanogenic massive sulphide (VMS) bodies enriched in zinc-silver and copper-gold, and provided the building blocks used to develop the Noranda-type ore deposit model. Since the end of the 1970s, several geochemical approaches focussing on VMS-related alteration zones have been proposed, namely element ratios, mass balance calculations, and normative alteration mineralogy. Each of these three methods has advantages and limitations, and their effectiveness depends on the amount of data to process, the geological complexity (multiple lithologies), and the availability of analyzed elements. Depending on the method, the main difficulties lie in neutralizing the effects of differing lithologies, or in determining the least altered precursors. Normative mineral calculations using NORMAT or LITHOMODELEUR software make it possible to reconstruct the final mineralogy based on a geochemical analysis, regardless of lithology, and thus to identify the alteration process. Mass balance calculations on a single or multiple precursors, or on precursors modeled by neural networks (LITHOMODELEUR) may be used to quantitatively characterize the alteration in terms of gains and losses in elements affected by metasomatic processes.

In the Abitibi, most geochemical characterization studies of alteration zones have focused on proximal VMS environments (pipe alteration). Over the past twenty years, access to enormous databases from mining companies, and the processing capacity of computers have made it possible to reconstruct the flow paths of mineralizing fluids at the scale of a mining camp. The main results obtained by CONSOREM, based on litho-geochemistry data processing using either of the three methods, will be presented and compared for the Noranda, Val-d'Or, Matagami, and Selbaie mining camps. The geometry of reconstructed hydrothermal systems is not much different from one method to another, as illustrated in the Val-d'Or mining camp. The porosity of the volcanic sequence and the size of the hydrothermal system are factors that influence the map distribution of alteration zones. Depending on the orientation of volcanic stratigraphy in the camp, conformable alteration parallel to volcanic stratigraphy, or cross-cutting alteration along synvolcanic faults may be distinguished.

SESSION 3

Evolving thoughts on faults and deformation zones in the Abitibi Subprovince

RÉAL DAIGNEAULT (CONSOREM-UGAC)

“Major faults”, “fault zones”, and “deformation zones” are all common expressions used to describe regional discontinuities in the Abitibi such as the Cadillac Fault. Many of these major faults were identified very early on during the first geological surveys of the southern Abitibi, given their association with gold mineralization. But only recently have they been integrated into various verticalist or horizontalist geodynamic evolution models.

Various sets of planar and linear fabrics form the physical manifestations of faults in the field. In particular, an intense and commonly steeply dipping schistosity may be developed over widths ranging from several decametres to several hundred metres and over a strike length reaching up to one hundred kilometres. These fabrics may be conformable or cross-cutting relative to stratigraphy and the nature of affected protoliths may be difficult to ascertain.

If the intensity of the main foliation appears to be an indication of the degree of deformation, the coaxial or non-coaxial nature of the latter remains debatable. Dominantly reverse movements or simpler shortening are interpreted based on the observation that these deformation zones are predominantly characterized by a down-dip or steeply plunging stretching lineation.

Sinistral and/or dextral strike-slip components, commonly subsequent to shortening, have also been proposed. On the Québec side of the border, the presence of dextral shearing indicators, stretching lineations, and directional striations that developed locally and overprint down-dip lineations is interpreted as the expression of late strike-slip movement. These fault zones are commonly branching, may separate into distinct splays and exhibit different structural styles across their length, which adds another layer of difficulty when attempting to identify and name these zones.

The interpretation of deformation zones in sparsely exposed areas such as the northern Abitibi is largely confirmed by aeromagnetic surveys, where these structures may be inferred by the presence of detached domains with distinctive magnetic fabrics. Their relative significance and their role in the geodynamic evolution of the Abitibi remain open for discussion. So-called “major” structures generally correspond to boundaries between terrains of contrasting nature and structural style. The presence of adjacent “Timiskaming”-type sedimentary units, discontinuous ultramafic units, and strong carbonate alteration, appear to be significant characteristics.

SESSION 4

Geomechanical challenges in Québec mines

VERONIQUE FALMAGNE (AGNICO EAGLE MINES)

Transforming a geological anomaly into a successful mining operation requires the sustained efforts of various technical groups and specialists working together over a period sometimes reaching several years. To upgrade a mineral resource to a mining reserve, a mining plan must be developed, demonstrating that mining the resource is technically and economically feasible. Preparing a mining plan namely involves designing one or several mining methods suitable for the orebody and the economic parameters of the project, as well as a mining sequence targeting zones identified as economic. Fluctuations in metal prices affect the definition of economic zones and thus require adjustments to the mining plan. Selection of the mining method and the appropriate mining sequence constitutes one of the first steps in the development of a mining project and is typically performed when the amount of information available is commonly limited and often consists only of diamond drilling data.

Québec namely has gold and base metal mines in the Abitibi and Chibougamau mining camps, iron ore mines in the Côte-Nord region, a niobium mine in Saguenay and nickel operations in Nunavik. The development of a mining method and sequence is closely related to the inherent characteristics of an orebody, its shape, size, location, and depth, as well as the type and quality of the rock mass and associated physical constraints such as hydrogeological conditions, ground pressure, and other material, technical, and economic criteria. From a geomechanical standpoint, open pit mines are typically faced with challenges relating to rock mass quality and fracturing and to local hydrogeological conditions. In historical mining camps, the presence of prior underground excavations represents an additional challenge that requires vigilance and thorough investigation, instrumentation, and monitoring techniques. Ground pressure increases with depth. As they develop deeper and deeper, mines must face particular environments and must manage rock mass deformation and rock bursts. In northern Québec, mines operate in permafrost conditions where ground support techniques must be adapted to take into consideration temperature conditions in the rock mass. Finally, underground bulk mining is becoming increasingly used worldwide. The first Canadian mine of this kind was inaugurated in British Columbia, and one mining project in Québec is planning to use this technique in the future. These mining methods will bring their own set of challenges to mining companies operating in Québec.

SESSION 4

Ground control in permafrost conditions

PAUL GERMAIN (GLENCORE)

The Raglan mine operations are located along the northern tip of the Ungava Peninsula in Nunavik. The property extends for 70 km along an east-west axis and is located 1,800 km north of Montréal and 500 km northwest of Kuujuaq, the capital of Nunavik.

The Raglan mine facilities include three active underground mines, one mine in the closure phase and two mines under construction. The mining site also includes a concentrator, a power plant, and administrative and residential buildings. Since the beginning of its production in December 2013, Mine Raglan's production has increased gradually to 1.3 million tonne of ore annually.

The isolated and fragile nature of the site, combined with the hostile arctic environment, create unique challenges. The site is located in a subarctic region characterized by its permanently frozen subsoil (permafrost). The climate is harsh, with low temperatures and persistent winds that generate frequent episodes of drifting snow.

Although ground control in permafrost conditions has always been perceived as benefiting from a competency that is in fact largely exaggerated, other challenges emerge when we work in such environment. Current measurements indicate that the permafrost extends a depth of about 600 m at the Raglan site. Thus, transitioning from permanently frozen conditions to a warmer rock mass brings up many questions about the general behaviour of the rock mass depending on the type of mining method involved. Many aspects must be discussed to answer this question, in particular the temperature measurement in the rock mass and thermal exchange coefficient, the performance of ground support below freezing point, the useful life of ore raises. Those aspects will be presented, supported by a few examples of rockfalls that occurred with various mining methods, as well as the demonstration of the results of the first natural stress measurements north of the 60th parallel, with the most advanced measurement technique in the world, entirely developed in Québec.

SESSION 4

Development of a damage simulator to study the vulnerability of areas subject to landslide hazards

ALI SAEIDI (UGAC), OLIVIER DECK AND THIERRY VERDEL (UNIVERSITÉ DE LORRAINE, FRANCE)

The extraction of ore and other materials via underground mining may lead to ground subsidence. In urbanized areas, these events may cause significant damage to buildings. Consequently, the objective of this study is to develop a damage simulator to study the vulnerability of areas subject to landslide hazards associated with the presence of underground excavations. The simulator is designed by combining a mine subsidence forecasting method, vulnerability functions for damage assessment, and a database of buildings. The scientific contribution of this study is the development of vulnerability functions for buildings in areas subject to mine subsidence. These functions are comparable to those used for other hazards such as earthquakes and tsunamis. To do so, we created and applied a methodology based on Monte Carlo-type simulations. This methodology uses existing damage assessment methods in areas subject to mine subsidence (empirical or analytical methods). It takes into account the uncertainty associated with both the shape and mechanical parameters of buildings and soil-structure interactions for analytical methods. With this methodology, vulnerability functions were developed for reinforced and non-reinforced masonry buildings, typical of buildings in the Lorraine iron ore fields. These functions were validated by comparing the results with observed damages incurred during subsidence events that took place between 1996 and 1999 in Lorraine.

Subsequently the influence functions method was implemented in the simulator with certain developments to take into account the variable angles of influence and to calculate horizontal ground deformation. The results of this method were validated using a subsidence event that occurred in the Lorraine iron ore fields.

Finally, a probabilistic approach to damage assessment was implemented in the simulator, taking into account various possible subsidence scenarios. The simulator was applied to buildings in the town of Joeuf and yielded the following results: assessment of the mine subsidence hazard in the town, a map of damages, determination of an average and standard deviation for building damage, and probability of reaching specific levels of damage.

SESSION 4

Starting up production at Éléonore with its various geomechanical challenges

PIERRE-LUC LAJOIE, DENIS FLEURY AND LUC JONCAS
(GOLDCORP)

The Éléonore mine is located along the shores of the Opinaca Reservoir in the Baie-James region. The ore deposit extends from surface to a depth of 1,400 m. It consists of several subparallel ore lenses extending over approximately 800 m strike length. Underground development began in June 2010 with the exploration shaft, followed by excavation of the ramp in April 2011. Production is expected to begin in early 2015, at a rate of 3,500 tonnes per day. Expansion to 7,000 tonnes per day is planned for 2017, once the production shaft is commissioned. Selected mining techniques will include a mix of primary-secondary transverse stoping and longitudinal retreat depending on the thickness of individual lenses. A good understanding of the hydro-geological conditions is critical given the location of the ore deposit. Structural characterization and cementing will also be important, not only to ensure the stability of openings but also the safe development of infrastructure. Finally, as the ore deposit extends beyond 1,000 m depth, and considering the production rate, potentially high levels of stress are another issue that should not be overlooked. In this regard, current and future investigations will focus on adjustments to ground support, the acquisition of a seismic system, and resizing of openings.

SESSION 4

Methodologies for ground control challenges in underground mines

HANI MITRI (McGILL UNIVERSITY)

This presentation describes the results of recent research projects at McGill University's Mine Design Laboratory. These projects include: 1) ore dilution at the Lapa mine; 2) geotechnical risk assessment in deep drifts at the Garson mine in Sudbury; and 3) the mechanical strength of cemented rock fill subject to blasting vibrations at the Birchtree mine in Thompson. All three projects use a variety of digital modeling tools ranging from static two-dimensional models to dynamic three-dimensional models. Factors that influence ore dilution were studied at the Lapa mine, namely the effect of stope dimensions and rock mass properties. A detailed analysis of the CMS database was carried out to develop empirical models to help mine planners estimate ore dilution in future stopes. At the Garson mine, the stability of drift intersections in deeper developments was studied with FLAC3D^{MC}. The digital model was calibrated with measurements from the MPBX extensometer and load cells installed on anchor bolts. Stochastic analysis was performed at each intersection to estimate the probability of instability at the intersection and the associated geotechnical risk. Back analysis of microseismic data was carried out to identify the source and amplitude of major seismic events. A mine-scale FLAC3D^{MC} model was developed and calibrated with *in situ* stress measurements and microseismic data, prior to using it to estimate the stability of ore pillars at the end of the mining plan. New 3D dynamic modeling techniques were developed to reproduce dynamic fault slip phenomena and to determine the mechanical properties of faults by back analysis, to gain a better understanding of the relationship between the occurrence of seismic events and mining rates. At the Birchtree mine, the mechanical strength of cemented rock fill is studied using a large-scale uniaxial compression testing facility that was specifically designed for this test and built underground. Blast vibration *in situ* measurement tests were designed and implemented to gain a better understanding of the impact of blast vibrations on the stability of exposed backfill blocks. Dynamic FLAC3D^{MC} models of backfilled stopes were calibrated with the *in situ* vibration measurements and used to predict the stability of backfilled blocks.

SESSION 4

Geomechanics and ground control at the Niobec Mine

JEAN-FRANÇOIS DORION (IAMGOLD)

The Niobec underground mine is located 25 km northwest of the City of Saguenay (Chicoutimi), in the municipality of Saint-Honoré. The Niobec mine is the only North American source of pyrochlore, the main niobium mineral.

Commercial production began in 1976. The ore is mined in open stopes averaging 60 m in length by 24 m in width by 90 m in height. Horizontal pillars are left between stopes, dividing the mine into mining blocks. The production rate currently stands at 6,500 tonnes of ore per day. Based on known resources and reserves, the mine life is estimated at more than 40 years, assuming the use of block caving mining methods. The ore deposit remains open at depth.

Seismic events have occurred in recent years. Most of these events occur in the pillars or directly in the stopes. Damage observed following rock bursts consists of minor projected rocks, overbreaks, and cracks. The presence of syenite zones and major joints seems to play a significant role in the damage associated with rock bursts. No significant damage has been observed to mine support structures. Since there is no seismic system on site, the epicentre of seismic events is often difficult to ascertain.

The design of a seismic system was undertaken during the summer of 2012. The final design is a 48-channel system including 6 triaxial geophones and 30 uniaxial accelerometers installed on 8 mine levels. This system will be used to monitor current mining activities as well as the evolution of future block caving operations. The seismic system is expected to be commissioned in mid-November 2013.

SESSION 4

Challenges related to adequate underground paste backfill design

TIKOU BELEM AND MOSTAFA BENZAAZOUA (IRME-UGAT)

Given the strong demand for metals from emerging countries worldwide, mineral production has reached sustained levels. As a result, the mining industry generates significant tonnages of solid waste (waste rock and fine tails) that must be stored adequately. In line with its concern for sustainable development and environmental protection, the mining industry fully endorses its moral responsibility to reduce its environmental footprint. In this regard, over the past decades the dominant trend has evolved toward “integrated or green mining”, in other words environment-friendly mining. This is namely achieved by reusing more than 50% of fine tails, which are typically more problematic in terms of acid generation, to produce cemented paste backfill. This paste backfill acts as secondary ground support in underground excavations, and leads to improved extraction in secondary stopes. But to ensure the viability of paste backfill technology, mine backfill operations must result in profitable mining and guarantee the highest security for mine workers. The main challenge in this regard is to design a backfill material that will provide good stability to backfilled stopes. In addition to this main challenge, other issues must be addressed to design an adequate cemented paste backfill material destined to fill underground excavations. Among other things, it is necessary to determine the required resistance (based on a calculated safety factor), the physical characteristics (grain size distribution curve) and mineralogy (presence of sulphides and/or clay minerals) of the tails, the rheological parameters (slump, % solids, adequate shear strength and viscosity), establish the right formula for the backfill mix (taking into account the physical and chemical properties of the mix), make an effort to reduce backfill operating costs (possibly reducing the amount of binder), understand the hydromechanical properties (self-weight consolidation), and master the backfilling sequence (pore pressure dissipation and pressure on barricades). In this presentation, all of these challenges will be reviewed, first by presenting the current state of knowledge, the issues that have been resolved and those that can be addressed, as well as new avenues to explore.

SESSION 4

Geomechanical challenges associated with mine design at the Renard diamond project

PATRICK MERCIER AND GUY BOURQUE
(STORNOWAY DIAMONDS)

Located near the Otish Mountains in the central-north part of Québec, the Renard diamond project, Stornoway's wholly owned flagship asset (TSX: SWY), is in the process of becoming the first diamond mine in Québec. In November 2011, Stornoway published the results of a feasibility study on the Renard project, followed by an optimization study in January 2013, which highlighted the potential of the project to become significant producer of high-value rough diamonds over a long mine life. The project benefits from a large and growing resource, good mining conditions, strong community acceptance, a modest environmental footprint and, under the auspices of the province's Plan Nord program, the development of direct-to-mine road infrastructure.

To date, nine kimberlite chimneys have been identified within an area of 2 km² on the Renard property and delineated to different degrees. Of the nine chimneys, only three have been subject to feasibility studies (Renard 2, Renard 3 and Renard 4), which defined a total of 21.7 million tonnes of reserves at an average grade of 75.8 carats per 100 tonnes. The mining strategy for these reserves involves a combination of two small open pit mines followed by underground mining from which the material will be extracted using a main ramp and a fleet of 60-tonne trucks.

A number of in-depth geomechanical studies have already been carried out with the aim of validating the selection of blasthole shrinkage as the mining method. These studies ensure the long-term stability of the underground and surface mining infrastructures as well as the project's economic and operational viability. Studies of geostructural analyses and modelling using FLAC3D^{MC} software have also been carried out to determine the placement of infrastructure around the perimeter of the underground workings in relation to the influence zones of faults and mining-induced bedrock subsidence, all the while taking into account the addition of barren backfill. Given that fragmentation is a key parameter in the operational success of the Renard project, an empirical study was undertaken to determine the stable dimensions of the mine workings, with the goal of controlling ore fragmentation by drilling and blasting. Drawpoint design was also a key factor in the project's success, which is why REBOP^{MC} software for the flow simulation of fragmented rock was an essential tool during the reserve calculation and will again be crucial for planning ore extraction at the different drawpoints during the operational phase.

SESSION 5

Challenges and opportunities associated with the development of giant low-grade gold deposits

JACQUES McMULLEN (BBA)

Background

More and more gold mining projects are characterized by a low gold grade coupled with very large volumes of ore to extract and process. These ore deposits are specifically mined by open pit methods. Ore processing is generally fairly conventional. However, the mineralogical deportment of gold may be variable and must be well defined. In many cases, these types of ore deposits occur in hard, resistant host rocks, another important factor to take into consideration.

Breakeven point: negative variables and perceptions

Given the low gold grades associated with these ore deposits, it becomes necessary, to achieve profitability, to have higher daily production rates to compensate for the lower grade of the ore, based on the "production volume" effect. Consequently, the initial capital cost required to bring a deposit into production can rapidly increase; it can even become an impediment to achieving the minimum return on investment threshold and can also limit potential financing options. In addition, financial markets have become more restrictive concerning access to capital, for a multitude of reasons not all related to the estimated return on investment. Broadly speaking, and listing just a few of these factors, challenges associated with bringing projects into production according to schedule and initial capital cost estimates, deviations of operational performance after start-up, write-offs, increasing royalties and other forms of third-party compensation, are all elements that affect the net return and contribute to the perception that these projects are high risk.

Taking advantage of the situation

This is a good opportunity to take stock by looking at the causes behind these encountered deviations, which, if they are adequately assessed, may be eliminated to generate more robust projects. It is also possible to take advantage of some of these variables to generate a more economic positioning of the project at the design phase. The risk associated with fluctuating metal prices will always remain however, in a context where profit margins for projects are getting smaller and smaller, making it even more important to take advantage of these opportunities whenever possible.

Potential solutions

First, it is important to complete a detailed characterization of the ore deposit at the onset. This approach, which may also be referred to as block model geo-metallurgical modeling, is crucial. When performed adequately, this step will help minimize the negative impact of many imperfections that might otherwise occur. This modeling step must cover much more than the quantitative gold content of the mineral resource. The next step, which is directly linked with ore deposit characterization, is to promote a stronger multidisciplinary integration of operational concepts; this can help develop significant synergy during the initial development phases of the project. The operations team must also show its adaptability and be willing to question established operational procedures and in certain cases, consider modifying the way things are done.

SESSION 5

Challenges and constraints associated with measuring gold distribution in new gold-bearing ores

JEAN-FRANÇOIS WILHELMY (COREM)

There is considerable contrast between the gold ores that were processed a decade ago and those being extracted today. The gold-bearing minerals that constitute modern ores are much more diluted, of finer grain size, and more difficult to cyanide.

Quantitative mineralogy, which uses a new generation of automated microscopes (QEMSCAN and MLA), has advanced in parallel with improvements in the beneficiation of base metal, rare earth and iron/titanium ores, but has encountered specific constraints that limit its effectiveness when dealing with gold. The mineralogical study of modern-day gold ores must therefore rely on a combination of more classic methods and the best techniques that quantitative mineralogy can offer.

A quick review would show that, among modern ores, only a fraction of the gold is difficult to process. It is often financially significant and more profitable to better understand the location and nature of the gold that cannot be recovered using conventional procedures than to characterize the easily recoverable fraction. Applied mineralogy methodologies capable of measuring the distribution of residual gold in processed samples (at the industrial or semi-industrial scales, or in the laboratory) are therefore suggested.

SESSION 5

Gold ore processing at the Éléonore project

JEAN-FÉLIX LEPAGE (GOLDCORP)

During the successive phases of development, many metallurgical testing programs were carried out using ore from the Éléonore project. Metallurgical, operational, environmental, and mining criteria were then taken into consideration to select the appropriate strategies for comminution, gold recovery, and tailings management. Currently in construction, the mill has a capacity of 7,000 tonnes per day and includes primary, secondary, and tertiary crushing phases. One-step grinding is followed by sulphide flotation. Two cyanide leach and carbon-in-pulp circuits are planned to recover gold from the concentrate and the tails. In addition, gravity concentrators, an ultrafine grinding phase, a cyanide destruction circuit, and a paste backfill and tailings filter plant are also included.

SESSION 5

Operational issues related to concentrator start-up

STEVE BELLEC, DANIELLE BOUFFARD
AND MATHIEU BÉLISLE (SOUTEX)

Over the past decade, the significant increase in gold prices has greatly contributed in modifying the nature of new gold projects by making it feasible to mine low-grade gold deposits. The start-up period for new concentrators, which extends from the commissioning of circuit equipment to the ramping up of production, is a critical period during which processing operations must be carried out in a structured, controlled manner so as to progressively reach pre-established production targets consistent with design criteria. The level and variety of risks associated with this pivotal time are often aggravated in the case of low-grade projects. By implementing a systematic assessment of risks, their probability of occurrence and their impacts, it is possible to introduce a series of preventive and corrective measures to reduce the potential impacts on the achievement of production targets. In this presentation, the major risks associated with operating a new concentrator during the start-up period will be identified along with a series of measures proposed to minimize these risks.

The mining industry's contribution to Québec society: Past and present

PIERRE LORTIE (DENTONS CANADA S.E.N.R.L.)

The Club of Rome's report entitled *The Limits to Growth*, published in 1972, predicted a shortage of the main metals and minerals in the present decade, along with steady growth in prices. In reality, however, despite a significant increase in consumption, mineral reserves are considerably more extensive today than they were when the report was published, and world prices in real terms are actually falling. How has the mining industry changed during this period? What are the implications for Québec? How can public policies be made to reflect the long-term characteristics of an industry that is at the mercy of short-term fluctuations, to ensure that it makes the best possible contribution to Québec society? Why do we have so few large mining companies in Québec, and what can be done to remedy this situation?

SESSION 6

Main findings on the BNQ 21000 Approach tested by members of the Québec Mining Association

FRANCINE CRAIG (COHÉSION-RSO) AND NATHALIE TREMBLAY (QUÉBEC MINING ASSOCIATION)

Social acceptability is at the very heart of mining. As such, it is clear that integrating sustainable development into the practices of mining companies in Québec is an important issue for our industry. Now more than ever, mining projects must be carried out within the scope of a collaboration between the mining company and its stakeholders, and must clearly demonstrate their contribution to the socio-economic development of regions and to environmental protection.

In 2011, the Québec Mining Association enthusiastically accepted the Québec government's invitation to take part in the BNQ 21000 Project. Eighteen (18) mining companies agreed to test the BNQ 21000 Approach. The objective of this initiative was to improve the BNQ 21000 Approach so as to adapt it, as much as possible, to organizations in Québec in order to promote, facilitate, and accelerate the development of a social responsibility culture. This approach involves two main components, namely a new sustainable development standard for Québec, titled: *Développement durable - Guide d'application des principes dans la gestion des entreprises et des organisations*, and an implementation methodology.

Two years later, the project is nearing the end of its development phase. The first part of our presentation will focus on the BNQ 21000 Approach in general. In the second part, we will discuss the pilot project involving members of the Québec Mining Association, and will present the main findings based on the experience of participating mining companies. Thanks namely to their significant contribution to the BNQ 21000 Project, all organizations across Québec now have access to an approach that is better suited to their needs.

The BNQ 21000 Approach is now available online at: www.bnq21000.qc.ca. It provides free access to the BNQ 21000 Standard (Guide) and the BNQ 21000 Method. The latter proposes a step-by-step approach, strategic management tools, user guides, reference documents, and a governance framework, including training for employees and executives, to help organizations promote, facilitate, and accelerate the integration of sustainable development within their organization.

SESSION 6

Arnaud Mine: Application of the sustainable development evaluation grid developed by the Chair on Eco-advising

OLIVIER RIFFON, HÉLÈNE CÔTÉ, DAVID TREMBLAY (UQAC), STÉPHANIE PRÉVOST (CPESI) AND CLAUDE VILLENEUVE (UQAC)

In light of the growing global demand for commodities, major industrial projects are planned in Québec and namely in peripheral regions. These megaprojects are potential drivers of economic development, but they also entail significant social and environmental impacts, and raise issues relating to land use and territorial governance. The town of Sept-Îles is faced with this type of situation. An apatite (phosphate) mining project led by Yara International ASA and Investissement Québec lies within the city limits of Sept-Îles. The future mine is expected to process 30,000 tonnes of ore per day, to be shipped to Norway for further processing.

In Québec, municipalities have very few legislative tools at their disposal when such projects arrive on their territory. Administrations and communities must therefore innovate and adapt their strategies and their actions. The concept of sustainable development, and the tools that go with it, may be used for political and institutional innovation and may help municipalities deal with the issues related to such projects.

Within the scope of a research-intervention project, the Chair on Eco-advising, in collaboration with the *Corporation de protection de l'environnement de Sept-Îles* (Sept-Îles environmental protection corporation; CPESI), used the sustainable development evaluation grid developed by the Chair to analyze the environmental impact study for this mining project. This research-intervention project namely involved a training session on the grid for the evaluation committee, assistance during the grid-based project evaluation, preparation of an educational tool for the general population and development of web space on a website devoted to sustainable development, management of the web platform, answering questions from the public, and preparation of a report.

This evaluation approach resulted in three types of impacts. Firstly, the evaluation led to a series of proposals to improve the project listed in priority, including environmental and social considerations raised by the analysts and the community. Secondly, as a result of this research project, decision-making processes evolved in the municipality as the evaluation grid was considered to be a relevant tool to facilitate decisions about projects in the municipality. Finally, by involving the community in the project evaluation, various land users and stakeholders were able to contribute, citizens developed a sense of ownership in the grid and the process, and the dynamics between stakeholders changed.

This evaluation approach did not necessarily result in the social acceptability of this megaproject. It did however enable decision-makers to develop their expertise in the management of social and environmental controversies. In a broader perspective, after using this sustainable development evaluation grid, the evaluation committee, the town council, land users, and members of the community are now better equipped to make decisions integrating sustainable development principles. This expertise may prove useful in the future, by integrating to a greater degree the principles of sustainable development, eventually leading to better development alternatives than those that prevailed during previous economic development booms in Sept-Îles.

SESSION 6

Mining industry and gender equity: Initial steps taken by New Millennium Iron Corporation

ÉLISABETH BENOÎT (NEW MILLENNIUM
IRON CORPORATION)

Women continue to be under-represented in non-traditional occupations, technical and scientific professions, and engineering fields. NML believes that implementing effective measures to promote gender equity is critical, so as to ensure that the benefits and opportunities generated from its projects are equally accessible to all residents, male and female, of Québec and Newfoundland-and-Labrador. To do so, its first step was to develop an integrated gender equity policy and to implement long-term initiatives, to ensure the well-being of female employees, increase their numbers in non-traditional occupations, and their retention rate. NML has the added advantage of time on its side, since it is in the feasibility stage for its Taconite Project.

SESSION 6

Mining, agriculture and water: The case of Eldorado Gold in Turkey

ADAM McENIRY (WAYNE DUNN & ASSOCIATES)

This presentation describes how an approach and a strategy based on common values ensured social acceptability for Eldorado Gold in the development of two mines near agricultural communities in Turkey.

In the late 1990s, Eldorado Gold had ambitious plans to develop two properties in Turkey, Kislidağ and Efemçukuru, which would raise it from the rank of a junior to an intermediate mining company. However, it was first necessary to overcome enormous challenges in terms of social acceptability given that no other company had been able to successfully develop and operate a gold mine in modern-day Turkey. The only recently opened mine, Ovacik, belonging to Eurogold, had its mining permit revoked soon after due to opposition from the community based on environmental concerns. Eldorado's two properties were near the Ovacik mine.

Eldorado recognized that in order to develop the mining project and create value for its shareholders, it would have to find a way to gain social acceptability. In these difficult circumstances, Wayne Dunn & Associates (WDA) was hired to help the company foster conditions that would allow it to successfully develop and mine Kislidağ and Efemçukuru.

A number of factors allowed the company's strategy to succeed:

- ▶ a strong local team that understood the importance of community relations and who recognized the need to create value for local stakeholders;
- ▶ acknowledgement that agriculture is both an economic and cultural pillar for many of the local people in the region;
- ▶ the creation of a venue where people could engage in dialogue and discuss the project;
- ▶ collaborating with development partners at different levels of government, with international organizations, and with university groups and others, in order to engage their expertise and share the credit with them;
- ▶ strategic social investments that supported the traditional agricultural sector and responded to community needs, such as water.

Fifteen years later, the evidence is clear that instead of destroying the agricultural cornerstone of a region, responsible mining practices and strategic community investments created conditions that bolstered the agricultural sector. The successful implementation of this strategy led to social acceptance for Eldorado and for the development and operation of its Kislidağ et Efemçukuru projects.

SESSION 7

Evolution of the IsaMill into magnetite processing

GREG RASMUSSEN (XSTRATA TECHNOLOGY)

IsaMill technology was developed from the stirred milling technology of Netzsch Feinmahltechnik GmbH in the 1990's for use in the fine grained lead zinc ore bodies of Northern Australia in a drive to bring about a step change in grinding efficiency required to make these ore bodies economic to process. The following two decades have seen the technology evolve from its development in relatively small tonnage, ultrafine grinding duties to a technology that is equally at home in large throughput, standard coarse regrind and mainstream grinding duties. With this evolution has come the realisation that more energy efficient circuits are achievable by using technology that is tailored to the grinding duty.

The expansion of magnetite projects in Australia has embraced the opportunity to take advantage of newer technologies that were not necessarily available when the magnetite industries of North America and Europe were maturing. Among these has been IsaMill technology which has allowed the Australian Magnetite industry to take advantage of improved energy efficiency coupled with tight product size distributions that originally made the IsaMill so attractive to the base metals processing industry. This paper investigates the effect of the IsaMill grinding technology on the full scale Australian Magnetite operations at Ernest Henry Mining along with pilot and lab scale demonstrations of optimization.

SESSION 7

High pressure grinding roll (HPGR) familiarization seminar

BRUCE CHRISTENSEN (WEIR MINERALS)

High Pressure Grinding Rolls (HPGRs) Technology has been in the mining industry for over 16 years, but it is still viewed as a relatively new method of comminution. Many people in the mining industry do not understand how this piece of equipment is applied in the comminution circuit and as a result, there is confusion as to the capability of HPGR technology. The purpose of this presentation is to provide familiarization with High Pressure Grinding technology and information on the different types of machines in the market place. A brief description of several applications will be reviewed along with a description of the design of the machines currently used in the mining market. An open discussion will be held at the end of the presentation to answer any questions.

SESSION 7

Benchmarking the energy efficiency of fine grinding in the mining industry

MICHEL BRISSETTE AND JOHN STARKEY
(STARKEY & ASSOCIATES)

In recent years, the mining industry has shifted toward mining orebodies with decreasing grades in economic minerals and increasing metallurgical complexity, in order to meet the growing demand for certain metals. One of these complexities concerns liberation of these minerals when it is achieved below 45 microns. Conventional technologies consume tremendous amounts of energy to reach the targeted grain size. These projects consequently require higher capital costs due to the larger equipment requirements but mainly due to the higher operating costs resulting from increased energy needs and consumables such as grinding media, thus impacting the profitability of many projects. Successful grinding of these minerals thus requires the development of new technologies.

There are currently five technologies available from four different manufacturers, one of which exists since... 1956! These technologies are used in the mineral industry outside of base and precious metals, in refineries, the chemical industry and the energy sector, namely for scoria grinding, slaking, and flue gas desulfurization. The nameplate capacity of these types of equipment has increased nearly tenfold from 1998 to 2012.

The efficiency of a conventional technology, long considered inefficient, may be reduced by close to 40% when used with an innovative product. Surprisingly, this combination may be as energy efficient as a new technology! The combination of several technologies may further reduce energy consumption by 60%, and potentially 75% relative to conventional technologies, based on industrial results obtained in the mining sector.

The problem is that these results cannot be predicted through conventional metallurgical testing.

This presentation will focus on the new technologies available and on results obtained in the mining industry. New testing procedures must be developed to reflect industrial performances needed and requested by the mining industry.

SESSION 7

An overview of the HPGR and fine grinding technologies to characterize ore grindability

FRANÇOIS-OLIVIER VERRET (SGS)

Several grindability tests were developed over the years to design grinding circuits or optimize existing operations. Each test has its own strengths and weaknesses and purposes. It is imperative to select the proper test procedure(s) to meet project deliverables and minimize the risk of a project.

This presentation summarises the requirements and deliverables of selected bench-scale test procedures, namely the HPGR and fine grinding, applications and presents examples of test results.

SESSION 7

Stirred milling machine development and application expansion

JON ALLEN (METSO MINING AND CONSTRUCTION TECHNOLOGY)

Rising energy costs, requirements to minimize energy consumption, and a commitment to sustainable solutions in the mineral process industry is demanding technology breakthrough. To confront these challenges Metso has invested heavily in the application and machine development of our stirred milling technologies for both coarse and fine grinding. Stirred milling has a long and successful history of grinding application in metallic mineral industry, most often in regrinding roles, and has yielded significant energy consumption reductions. Recent advances in machine design and a better understanding of the benefits of stirred milling in coarser applications is yielding even greater benefits.

This presentation will discuss Metso's envelope pushing applications including an update on the 3000 HP VERTIMILL® Grinding mills and the planned first 4500 HP Vertimill at Northland Resources' Kaunisvaara project, the first SMD-1100 Stirred Media Detritor, and the application of Vertimills following high pressure grinding rolls. It will also discuss the larger machine design philosophy to cope with the challenges of larger machines and features to improve the maintainability while maintaining safe and reliable equipment operation. Additionally, this presentation will provide an update on collaborative research initiatives between Metso and our partners such as the Julius Kruttschnitt Mineral Research Centre (JKMRC).

SESSION 8

Diesel and ventilation in underground mines – Challenges and best practices

MICHEL GRENIER (CANMET MINES)

Modern mines face many challenges related to the proper management of ventilation networks. With the exception of deep mines where heat is the dominant factor in designing and setting up ventilation networks, diesel emission control is the deciding factor when determining the quantity of air and its management in the workplace. Most Canadian provinces regulate ventilation needs, in a general way, using a rule of minimum air volume per unit of diesel motor power, or, in the case of Québec, according to a certificate of engine registration that defines the required volume of air, in order to dilute emissions using an air quality index calculation.

This presentation will identify the challenges faced by Québec's mines regarding the use of diesel engines and will provide, where possible, solutions based on sound practices. These include new technologies for engines and cleaning systems as well as best practices in ventilation that aim to reduce worker exposure. Finally, we will discuss the challenges related to the eventual reduction in exposure limits for exhaust components, either diesel dust or nitrogen dioxide (NO₂).

SESSION 8

Operational challenges at the Canadian Malartic Mine

CHRISTIAN ROY (OSISKO MINING CORPORATION)

The Canadian Malartic mine belonging to Osisko Mining Corporation has been in commercial production since May 2011. The mine's proximity to the town of Malartic has made it a challenge to operate this open pit mine with high daily tonnages. From the exploration phase in 2005 to the mining phase of today, both management and workers have had to constantly develop innovative ways to lessen the impact of integrating a world-class mine into the lives of the surrounding population.

In addition to the normal operational constraints of a mine, the town's proximity imposes a number of additional constraints. Most of these problems were resolved by the feasibility study before they even materialized. Nevertheless, the town's proximity coupled with mining productivity requirements regularly yield unexpected problems that necessitate fast, reliable and safe solutions.

Furthermore, the ultimate extent of the pit at the Canadian Malartic mine will overlap four former underground mines that were exploited from the 1930s to the 1980s. This situation leads to even more operational constraints that, when added to the closeness of the town, become major challenges that must be overcome in order to ensure the project's success.

The geographic and historical mining context at the Canadian Malartic mine thus presents considerable challenges, of which the principal concerns are relations with the host community, rock fragmentation, and noise and dust management. To this we can add the additional challenges faced by all mines, which are manpower recruitment and training, and reaching production objectives.

It goes without saying that all mines have their assortment of challenges and Canadian Malartic is no exception. Even so, the proximity of a town and the presence of old underground workings could multiply the constraints to the point of making it very difficult for workers to find solutions for the daily challenges they face.

SESSION 8

Recovery of secondary stopes in unconsolidated ground

HERMAN DE LOS RIOS AND BENJAMIN BERSON
(HECLA QUÉBEC)

During transverse development to access secondary stopes, the intercepted backfill was not consolidated. This presentation will demonstrate the steps taken to access these stopes in unconsolidated ground conditions.

- ▶ Presentation of the steps of standard development in lower backfill zone 113
- ▶ Background on the interception of unconsolidated material during development
- ▶ Explanation of the impact on production and the mine sequence
- ▶ Presentation of a new strategy for development in unconsolidated material (DSI resin tests)
- ▶ Explanation of orepass excavation in the unconsolidated material, through development testing
- ▶ Establishment of an orepass interception strategy in the upper level
- ▶ Design of the backfilling and consolidation of the orepass
- ▶ Establishment of a two-drawpoint strategy to optimize recovery from the richest part of the stope
- ▶ Presentation of the support and the instrumentation set up in the lower level
- ▶ Design of the pillar to support the unconsolidated material from the orepass
- ▶ Design of simultaneous ascending and descending blasting
- ▶ Presentation of the two-drawpoint sequence and stope backfilling

SESSION 8

LaRonde - The challenges of a deep mine

DANIEL PARÉ (AGNICO EAGLE MINES)

The LaRonde mine has been in operation for over 25 years in the Preissac area and has been in constant evolution during this time. Several phases of expansion have transformed operations, ultimately leading the division to a production rate of 7,000 tonnes per day. The quality of its workforce and its polymetallic orebody have made it Agnico Eagle's flagship operation.

As the mining sequence reaches greater and greater depths, and as the orebody's inherent characteristics evolve, a number of technical challenges and adaptation requirements have led to the development of new innovations. The development, construction, and start-up of production at the deep mine, LaRonde Extension, will bring underground operations to a depth of 3 kilometres.

This presentation will focus on the technical and operational challenges related to the start-up of production at the deep mine, LaRonde Extension. Operational challenges, ground control, and thermal constraints will be discussed, as well as the control measures implemented to address these issues.

SESSION 8

The Westwood mine: A lode gold deposit from exploration to the start-up of production

DANIEL VALLIÈRES AND GUY GOSSELIN (IAMGOLD)

The Westwood mine is located on the Cadillac Fault between the Doyon and Laronde mines. The Westwood lode gold deposit comprises more than 130 distinct veins. The multiple veins are spread over a depth of more than 2 km, forming a highly complex deposit. Since the beginning, mining operations have followed, and will continue to face, a tight mining sequence in order to produce the ounces required to make the mine profitable.

The property has been the subject of intensive exploration work since 2002. An exploration drift, excavated from the Doyon mine, combined with diamond drilling, successfully identified a sufficient quantity of resources to initiate development work. In 2008, six years later, IAMGOLD made the decision to sink a shaft and an access ramp.

This presentation will address the challenges and accomplishments that led to the commissioning of the Westwood mine. Production start-up is scheduled for October 2013.

SESSION 9

The Research Institute of Mining and Environment and the management of mine tailings

**MICHEL AUBERTIN (ÉCOLE POLYTECHNIQUE)
AND BRUNO BUSSIÈRE (UQAT-ÉCOLE POLYTECHNIQUE)**

The presentation will provide an overview of the work carried out over the last 12 years by the NSERC-Polytechnique-UQAT Industrial Research Chair in Environment and Mine Waste Management.

These projects are part of the Research Institute on Mines and Environment (RIME UQAT-Polytechnique), which was recently created in collaboration with mining companies. A brief overview of the work to be carried out at RIME over the next few years will also be presented.

SESSION 9

Reclamation of concentrator waste piles in northern conditions

BRUNO BUSSIÈRE (UQAT-ÉCOLE POLYTECHNIQUE)

The reclamation of tailings impoundments is a major environmental challenge in the mining industry, particularly when the waste has acid generating potential (AGP). The challenge is even greater when the mine sites are located in northern environments characterized by a harsh climate, limited availability of borrow materials with favourable properties, and climatic changes that could affect the long-term performance of the selected methods. In this presentation, the focus will be on the principal reclamation techniques currently applied in northern conditions, which typically involve encapsulating the waste in permafrost. We will then discuss the challenges associated with this type of material when applied over mining waste. Lastly, we will present new options that can provide a more robust cover for tailings impoundments in northern conditions.

SESSION 9

Geoscience techniques in resolving challenges of environmental risk assessment downstream of metal mines: An example from receiving environments at the Aldermac site in Abitibi, Québec

SAM ALPAY, RICK J. MCNEIL AND ALAIN GRENIER (GSC)

The main geoscience objectives of the Lac Dasserat study, downstream of the Aldermac site, include optimizing techniques for environmental risk characterization: lake sediment coring, and surveys of surface water and bottom sediments. Initial results allow us to: determine the spatial extent of metal contamination, assess pre-development metal distributions in receiving environments and capture an early environmental response to a restored former mine upstream. Deployment of portable total X-ray fluorescence for metal analysis of surface waters and portable X-ray fluorescence for metal analysis of sediments provided rapid analytical results while in the field; results showed good correlation with traditional laboratory analyses (e.g., inductively coupled plasma mass spectrometry). Additionally, regionally-distributed sediment coring sites provided the basis to estimate local naturally-occurring background metal concentrations.

Results demonstrate that typical baseline studies of sites to be developed for mining can be inadequate to assess: pre-development conditions, environmental effects of additional effluent from new development or the accumulation of effects from previous contamination in receiving environments. Identification of contaminant sources, that include natural mineralization and historical and current mining activities, can be obscured in areas of multiple mining developments. Cumulative effects studies would benefit from lake sediment coring as a complement to surface water surveys coupled with bottom sediment surveys.

The former Aldermac mine (Cu, Zn, Au and Ag), located 15 km west of Rouyn-Noranda, operated from 1932-1943 and discharged acid mine drainage to the watershed downstream that includes Lac Dasserat. The watershed is an ideal field location to develop geoscience techniques for environmental risk assessment. It is representative of both a common mineral deposit and the legacy of historical mining practices. Contamination and adverse effects on aquatic habitats were demonstrated to the point where the Aldermac property was the subject of a government-led environmental restoration. Further mining development within the watershed is foreseeable. Environmental protection practices, that are becoming universally necessary before any new development begins, can take advantage of the geoscience tools developed in this study.

SESSION 9

Environmentally sensitive transportation systems for base-metal mines

DOUG MORRISON (CENTRE FOR EXCELLENCE IN MINING INNOVATION)

The sensitive environmental conditions in the Far North Regions of Canada will require a different approach to managing the impact of industrial developments on the environment.

The same is true for transportation. The industrial development of the temperate zone had an irretrievable impact on the flora and fauna and although the example of Sudbury demonstrates that recovery is possible, it becomes significantly more difficult in the Northern Zone where the growing season is so much shorter. The industrialisation of the North will require the importation of millions of tonnes of matériel, well beyond the capacity of seasonal roads. But the majority of mineral developments in the North will be short-lived and should not attract permanent fixed infrastructure that will be slow and expensive to implement and will long outlive the mining operation itself. An alternate approach is to employ transportation systems that minimize environmental impact, including not impeding migratory routes and can be temporary, adjusting to the needs of the population and developments alike. Some alternative transportation alternatives are presented.

SESSION 9

The responsible mining management toolbox

LOUISE GRONDIN (AGNICO EAGLE MINES)

The social context of mining has changed dramatically over the last twenty years. In the past, mining companies needed only adhere to the requirements laid out in their permits, whereas the companies of today must also meet the expectations of legislators and the general public in order to gain social licence. How has this change manifested itself in our organizations? What do we find in today's toolbox for responsible mining management? This presentation will address these issues and will provide an overview of the changes that affect organizations and the way we conduct mining management.

SESSION 10

Modern glacial process and dynamics applied to mineral exploration

ROGER C. PAULEN AND M. BETH McCLENAGHAN (GSC)

Drift prospecting in glaciated terrain is based on the premise that geochemical, mineralogical, isotopic and lithological indicators of economic mineralization recovered from sediments can be traced back to their primary bedrock source by reconstructing the glacial flow history. It is increasingly recognized however, that simple linear, one or two dimensional reconstructions of past glacial flow direction(s) do not capture the complex history of glacial erosion, entrainment and deposition. Greater understanding of what is often a palimpsest glacial history, means of entrainment, and variations in the nature of glacial dispersal such as glacial sediment thickness, bedrock topography, bedrock erodibility, and basal glacial flow velocities are required to accurately determine an up-ice bedrock source.

Development of complex ice sheet models, and the acquisition of empirical ice-flow records, drift composition, and glacial history over the last two decades have increased the accuracy and efficiency of drift prospecting in Canada. Increased attention to the dynamic nature of glacial dispersal centers and related ice-flow complexes has become increasingly important. Recognition of relict ice-flow trajectories from multiple glaciations puts in perspective the complexity of the former Laurentide Ice Sheet and has important implications for the interpretation of compositional data generated by regional till surveys.

Continental-scale interpretations and small-scale remote sensing imagery of the glacial system of North America are lacking in the deciphering of glacial dispersal trains and property-scale mineral exploration, often failing to recognize the key details that field investigations have revealed. Regional and local-scale mapping of all glacial flow indicators, sediment stratigraphy and derived interpretations are proven to be most effective. The message for exploration is that relations among bedrock, drift composition and ice flow history must be inferred in both regional and local context of the ice sheet and glacial history in order to successfully decipher drift prospecting data.

SESSION 10

New challenges in glacio-sedimentary exploration: Complex glacial zones and deeper targets

MARTIN ROSS (UNIVERSITY OF WATERLOO)

Significant progress over the last few years has improved our understanding of the geological record of glacier dynamics and the evolving conditions at the base of glaciers, such as rapid ice flow, changes in the thermal regime, the amount of water along the glacier base, and other properties of the ice-sediment interface. Most of the research on the dispersal patterns of glacial sediments was carried out before these major breakthroughs in the field of glacial geology. This is why we know so little about the net effect, at various scales, of a number of sub-glacial processes on dispersal patterns and their implications for mineral exploration. Furthermore, until now, the focus has been on tracing subcropping mineralization using indicator minerals. Exploration is now increasingly focused on deeper targets, sometimes beneath thick sediment cover containing multiple till units above the altered rocks. Research should therefore adjust to these developments and better integrate the recent advances in glacial geology, geochemistry, geophysics, remote sensing, and geomodelling. A few case studies, recent and ongoing, will be presented to illustrate some of the advances in glacial geology and glacio-sedimentary prospecting in northern regions for various metals of economic interest.

SESSION 10

Indicator minerals and till geochemistry near porphyry deposits in the Canadian Cordillera

ALAIN PLOUFFE (GSC), TRAVIS FERBEY (BRITISH COLUMBIA GEOLOGICAL SURVEY), BOB ANDERSON (GSC), SARAH HASHMI AND BRENT WARD (SIMON FRASER UNIVERSITY, B.C.)

A study focussing on the geology of surficial deposits, aimed at developing innovative techniques to detect buried porphyry deposits, was undertaken on four porphyry systems in south-central British Columbia: at the Highland Valley, Gibraltar, and Mount Polley mines as well as the potentially economic Woodjam district. In each of these areas, the till cover is thin (<2 m) to thick (>2 m), locally reaching at least 10 m, as indicated by drilling data. Exceptionally at Highland Valley, part of the mineralization is covered by more than 300 m of glacial and non-glacial sediments associated with a buried valley. The objectives of this project are to reconstruct ice-flow directions from the last glaciation and to study till compositions, in an effort to target buried porphyry deposits more effectively. This project is part of the Targeted Geoscience Initiative 4 (TGI-4) of the Geological Survey of Canada (Natural Resources Canada). Interpretation of results takes into account the geology of the bedrock and of known mineralized zones as well as ice-flow reconstructions.

Geochemistry and mineralogy data from 282 till samples indicate that the copper content of the clay fraction (<0.002 mm) in tills from the four study areas is elevated near mineralized zones relative to surrounding areas. Chalcopyrite grain counts in heavy mineral concentrates from till (0.25 – 0.5 mm; specific gravity >3.2) are high near mineralized zones at Highland Valley, Gibraltar, and Woodjam. Although the chalcopyrite grain count in heavy mineral concentrates is not high at Mount Polley, the gold grain count in the 0.015 – 0.150 mm till fraction is enriched. Fine gold grains in till are probably derived from mineralized zones at Mount Polley, which are also characterized by the presence of fine gold. The epidote content in heavy mineral concentrates is elevated near propylitic alteration zones at Woodjam and Mount Polley relative to the regional background. The distribution of all these indicators in till is the net result of glacial erosion and dispersal of debris derived from mineralized zones and surrounding alteration zones. These results demonstrate that till geochemistry combined with till mineralogy are effective tools to detect porphyry deposits buried under glacial sediments.

SESSION 10

Glacial dispersal and till provenance in Northern Québec and Abitibi – New constraints on the Late Quaternary glacial record of the Laurentide Ice Sheet

MICHEL PARENT (GSC), TROY E. RASBURY (STATE UNIVERSITY OF NEW YORK, STONY BROOK, N.Y.), SIDNEY R. HEMMING (COLUMBIA UNIVERSITY, N.Y.), PIERRE RHÉAUME(MRN) AND ÉRIC BOISVERT (GSC)

While most of the eastern sector of the former Laurentide Ice Sheet (LIS) is underlain by a single sheet of thin and discontinuous till overlying crystalline rocks, tills of the Abitibi region of Quebec and Ontario are relatively thick and continuous and are capped by glacial Lake Ojibway sediments. Nearly 1150 m of continuous Rotosonic cores provide a comprehensive regional Quaternary record. This record includes 3 regional till sheets separated by 2 units of non glacial sediments. 918 till samples were submitted to extensive lithologic, mineralogical and geochemical analyses to establish a provenance record.

The upper till has a characteristic light grey sandy matrix due to derivation from large Archean plutonic bodies lying north of the study area. In contrast, the middle till has a characteristic eastern provenance revealed by its dark greenish gray, slightly calcareous matrix which reflects its high content of debris derived from east-west trending Archean greenstone belts. These two unweathered till sheets overlie organic-bearing lacustrine and alluvial sediments of presumed Sangamonian age. The underlying till, presumably Illinoian in age, is characterized by subtle to moderate weathering features and local provenance.

In an effort to further assess the short and long distance provenance characteristics of the glacial succession, we measured Ar/Ar ratios in hornblende and feldspar grains, and Pb isotope ratios of the dated feldspar grains. While all three till units yielded predominantly Archean ages (~ 2.5 Ga) typical of local rocks, the Ar/Ar data from the middle till also yield ages from 1.7-2.4 Ga, which we initially thought might point to a Churchill source and thus indicate a somewhat unexpected long distance transport record. However the feldspar Pb isotope data solve this problem by showing that the Ar/Ar ages are best explained as Archean with Grenville (~1 Ga) partial overprint. This indicates that the middle till contains grains derived from the distant parautochthonous belt along the Grenville Front, which in turn suggests that this till reflects long-term northwestward transport during early and middle Wisconsin stages of the LIS history. Pre-LGM flowlines reconstructed from multiple datasets suggest that the main divide of the eastern LIS during its early development lied slightly east of the Grenville Front. This indicates a marked provenance contrast between the northwestward ice-flow phase and the major southward flowlines associated with the upper till Late Wisconsinan).

SESSION 10

Examples of tracking indicator minerals in glacial sediments

RÉMI CHARBONNEAU (INLANDSIS CONSULTANTS)

The study of surficial deposits has contributed to the discovery of mineral deposits in glacial environments since the 18th century (Sweden). Prospecting in such environments may involve the examination of fragments (erratic blocks) and minerals, or geochemical sampling. Because the analyzed material may have been transported over significant distances, the concept of tracing was developed: following the up-ice direction to the source.

In the past, reviews were published of discoveries made using erratics, thereby demonstrating the usefulness of erratic blocks in mineral exploration (Nova Scotia, Kirkland Lake, Lamaque mine). In the 1980s and 1990s, indicator minerals became the focus of attention following the discovery of diamonds at Lac de Gras (Dia Met and Aber), although the contribution of erratics to this classic case is perhaps less well known. In fact, it was the study of bedrock erratics that initially guided the regional sampling program toward the Slave Province where the discovery of a small kimberlite fragment in glacial deposits immediately down-ice from Point Lake prompted the first drill holes.

Among the examples of technical successes using erratics are the noteworthy cases of sub-in situ blocks (Vermillon Project, Cleopatra and Ilto blocks) and cases of up-ice tracing over long distances assisted by favourable lithologies (Strange Lake - Éléonore). In the case of the Nelligan Project, near Desmaraisville, abundant gold-bearing quartz float was followed to its source parallel to the ice flow direction. Some discoveries were based primarily on geochemistry (Clear-Water, Yukon). And although discoveries elsewhere have been made by tracing indicator minerals (Aber, Bakos, Rainy River, Ti-Pa-Kaa-Ning), in many cases, erratic blocks assisted the tracing work and were used to confirm the nature of the in situ source rocks (Remick Dyke). In conclusion, the method is still relevant today and has experienced recent success (Isok Lake, Hope Bay).

SESSION 10

Provenance of mineral indicators in the James Bay Lowland: Diamond exploration in challenging terrain

NICOLE JANUSZCZAK AND JOHN DELGATY
(DE BEERS GROUP OF COMPANIES)

The Attawapiskat kimberlite field is located 90 km west of the coastal community of Attawapiskat in the James Bay Lowlands of Ontario, Canada. Victor kimberlite was discovered in 1988 and commercial production began in 2008. Victor Mine is one of 21 kimberlites in the Attawapiskat kimberlite field. The region is a brownfields exploration site with potential to extend the 10 year mine life of Victor Mine from additional kimberlite resources.

The Attawapiskat kimberlite field is located within the Archean Superior Craton. The kimberlites are emplaced into flat-lying Paleozoic sedimentary rocks which unconformably overlie rocks of the 2.7 Ga Oxford Stull Domain. The Paleozoic strata are approximately 175 m thick and are characterized by Silurian and Ordovician limestone and dolostone with minor siliciclastics. It is estimated that approximately 200 m of sedimentary strata have been eroded based on the presence of Devonian xenoliths recovered from kimberlites.

The kimberlites are Early to Middle Jurassic in age. They are overlain by a Quaternary sequence characterized by clay-rich till, overlain by massive marine clay, nearshore sands, and capped with organic material (muskeg). Quaternary sediment thickness ranges from 0 m to 40 m. The Attawapiskat area has been impacted by Pleistocene glaciation. As the Wisconsin ice sheet retreated, the land surface was inundated by the Tyrrell Sea. Marine clays inhibit drainage of surface waters causing the characteristic swampy terrain of the lowlands. Sampling effectiveness in this terrain is poor. First-order rivers in the lowlands are large and sluggish with little carrying capacity. Present-day fluvial systems and seasonal river ice play a role in excavating mineralized till and concentrating heavy minerals in trap sites along rivers.

The glacial history in the vicinity of the Attawapiskat kimberlite field has been deduced from ice flow indicators including striations, grooves, crag and tails, and whalebacks observed and mapped from the surface of Victor kimberlite and from fabric analyses of till sections exposed along local rivers and above Victor kimberlite. Ice flow indicators record an older south ice flow overprinted by a younger southwest ice flow. Clast fabric measurements support directions obtained from ice flow indicators. Clast fabrics exhibit both unimodal and multimodal distribution suggesting deposition by both lodgement and deformation processes.

A thorough understanding of the post-emplacement, glacial and present-day factors controlling kimberlite indicator mineral dispersion and the application of an appropriate sampling methodology is critical when exploring for new kimberlite clusters in challenging terrain.

SESSION 10

Technological advances in Quaternary mineralogy

RÉJEAN GIRARD (IOS SERVICES GÉOSCIENTIFIQUES)

The interpretation of mineralogical indicators in Quaternary sediments has progressed tremendously in terms of deciphering their geological and metallogenic significance. These advances are based on technological developments, not widely known perhaps but critical, that enable the acquisition of high-quality data on a routine basis. Firstly, for the characterization of glacial material, the laser scattering particle sizer can be used to determine particle size distribution curves for fine fractions, which are indicative of specific depositional environments. For heavy mineral concentrates, an arsenal of new devices is now available, providing flexibility and clean concentrates, namely magnetic barrier separators, polytungstate-based dense media, elutriation centrifuges, etc. With these devices, the parameters of separation such as density or magnetic susceptibility, may be adjusted very precisely and in great detail, separating for example pyropes from almandines. Finally, the most remarkable advances have to do with mineral identification techniques. Various ancillary optical techniques have been introduced such as epifluoroscopy and digital imagery processing. However, the true revolution lies in the advent of third-generation electronic microscopes equipped with variable pressure chambers, high beam currents, and silicon drift detectors, not to mention computerized tools that enable automated phase recognition. Referred to as “Qemscan” and “MLA” in metallurgy, these technologies adapted to the study of heavy minerals can namely be used to identify minerals that would otherwise be undetectable using conventional visual techniques, thus bypassing a historical limitation.

SESSION 11

The direct economic impact of gold in the world's major gold producing and consuming countries

JANICE PLUMSTEAD (PWC)

In today's changing world, the mining sector is facing a convergence of challenges that includes increasing costs, higher expectations from stakeholders and for gold miners, a gold price which could affect the viability of some projects and lead to a contraction of supply. Demand however is increasing. An expanding middle class in Asia, diversification of reserve assets by central banks and a growing desire for physical gold among Western savers is fuelling demand. Gold continues to demonstrate that it plays a fundamental role in advancing economic development and the needs of society.

This session will look at the gold value chain, including gold mining, refining, and fabrication and consumption in terms of the estimated direct economic benefits of gross value added (GVA) to the global economy. GVA is used as it measures the value of an activity in a way which lends itself to direct comparison with Gross Domestic Product (GDP) which is used worldwide to measure economies' economic output. In addition to measuring the direct economic contribution of the gold value chain, the economic analysis reflects the contribution to the economies in which they operate through taxes paid and employment of people.

An outline of the key stages in the value chain for gold from its extraction from the ground through processing to its application in diverse uses will be outlined. The analysis of the supply of gold will focus on mine production and recycling of gold while the demand side analysis will focus on gold fabrication (primarily for jewelry and technology) and certain forms of investment (primarily bars and coins).

The presentation will focus on the 15 largest producers and 13 major gold consuming countries which together accounted for at least 75% of global gold mine production and gold demand in 2012. The analysis covers the year 2012, the most recent year for which there is data.

SESSION 11

What value sustainability brings to the mining sector?

MILLA CRAIG (DELOITTE)

While sustainability initiatives seek to provide solutions to the environmental and social impacts of the mining sector, one too often forgets (or ignores) the economic and financial benefits associated with such engagements.

Today, three main trends deserve particular attention: the evolution of the reporting process, the consideration of environmental, social and governance (ESG) factors by investors and the increasing involvement of executives in companies' sustainability activities.

Regarding reporting, two evolutions should be noted: the launch of the new Global Reporting Initiative's (GRI) guidelines (G4) and the development of a framework for integrated reporting. These two international standards both have a particular focus on *materiality*, i.e. the relevance of data that companies chose to publish. This evolution also reflects the strengthening of a trend in the investing world, namely: the greater importance given to non-financial performance – based on ESG indicators – as defined by the G4 and targeted by integrated reporting. In this respect, we can observe a shift as to whom is responsible for sustainability; it is more and more directed toward CFOs and COOs. This evolution is a sign that sustainability is increasingly integrated into corporate strategies and operations, which will be reassuring for financial partners and potential investors.

Finally, the strengthening of mandatory social and environmental regulations, as well as civil society's concerns, outline the importance of taking into account these issues when designing a mining companies' strategy.

During this presentation, Milla Craig will address the economic and financial risks that mining companies could be facing if they do not properly integrate sustainability issues into their business strategy. This would require complying with new standards (G4 and integrated reporting) which quickly are becoming unavoidable for companies.

SESSION 11

The Québec City region: an asset for Québec's mining development

LOUIS GAGNON (QUÉBEC INTERNATIONAL)

The city of Québec region is a dynamic region with significant growth that provides an excellent gateway into the development of mining projects in Northern Québec. Many well-known businesses are established in the region and regularly play a role in mining development.

Mining development in Northern Québec offers a wide range of abundant opportunities that can contribute to the level of development in areas such as the city of Québec region. The region is a leader in several initiatives that respond to the needs of many stakeholders in the mining sector.

SESSION 11

Manpower training in a sustainable development context

LUC BAILLARGEON (CSMO MINES)

Employee training represents an added value for everyone, in the short, medium and long term.

Recent studies estimating manpower needs in the mining sector have shown that 90% of employees that will be hired in coming years will need at least a vocational diploma (DEP).

Formal training will thus constitute a hiring criteria for a number of new employees; this training will also attest to their ability to continue learning, in order to keep their job or to face new challenges. Continuing education has become an integral part of the mining industry, where technological advances are introduced on a regular basis.

Despite the strong influence of secular trends in terms of manpower needs, the cyclical nature of the mining industry will undoubtedly lead to layoffs in the short term. In this context, workers with formal training will be able to turn to other economic sectors during sluggish periods, as they will have recognized and transferable training.

Training thus represents an essential element for the sustainable development of our economy.

SESSION 11

Mining in Québec: 100 years of history, 100 years into the future

JEAN-MARC LULIN (AZIMUT EXPLORATION)

A systematic analysis of past discoveries can reveal the underlying mechanisms of a nation's mining development and provide a vision for the future. This approach is not only critical for optimizing exploration strategies, but also for supporting and frameworking economic development.

Discovery analysis allows us to examine the future of our mineral resources in a rational manner. The concept of resources as "non-renewable" can mistakenly lead to the belief that mining will inevitably bring a nation, even the entire planet, to a point where resources will be completely depleted. The "non-renewable" status is often seen as direct opposition to the idea of sustainable development. In reality, Québec has considerable power to ensure the longevity of its industry by encouraging the discovery of new deposits and their commercial production.

100 years of history

Since the beginning of the 20th century, about 325 deposits have been discovered and brought into production in Québec. Disregarding the complex set of factors related to each individual discovery, a statistical analysis was applied to selected basic parameters (year of discovery, geographic location, depth of orebody from surface, discovery method, contained metals) to better understand the dynamics of mineral potential development at the provincial scale.

Mineral potential development follows distinct cycles, and the emergence of these cycles appears related to three main factors that may or may not act in synergy:

- ▶ a major fortuitous discovery is made, which leads to a regional exploration boom;
- ▶ new methods and new exploration concepts appear;
- ▶ favourable market conditions and an increase in demand and metal prices.

The first factor underlies the discoveries made during the 19th century until the 1950s. The second factor dominated the next 50 years and led to a series of new discoveries, mostly in the Abitibi mining camps. Starting in the 1990s, higher market demand and a concomitant increase in competition from abroad became the determining factor for Québec's mining scene, even though the role of the other two factors continues to endure.

100 years into the future

There have been a number of predictions over the last decade, some with catastrophic overtones, about the depletion of mineral resources. Although events and time have demonstrated the fallacy of these predictions, they can nonetheless be damaging if used to build political policies that guide resource development.

In fact, the surest way to avoid the depletion of mineral resources is to explore. The demand is assured thanks to advancements in scientific knowledge and to technical and conceptual innovations, but it is also linked to market changes and pressures. In addition, from a geological point of view, the volumes that remain to be discovered are immense. Based on these factors, "non-renewable" mineral resources should be seen as "replaceable" resources.

According to the proposed analytical grid, Québec's mining future depends on:

- ▶ continued exploration, not only in active mining regions where most of the known resources have been discovered, but also in emerging mining regions (Eeyou Istchee, Nunavik) where exploration can focus on major deposits that could serve as founding discoveries for new mining camps;
- ▶ a suitable political and fiscal framework to strengthen Québec's position in a globally competitive environment.

SESSION 11

Historical mining development dynamics in the Baie-James region (1975-2012)

Companies and mining titles

ROBERT EDGARD NDONG, MICHEL JÉBRAK (UQAM), MEHDI GAMACHE AND ANDREA AMORTEGUI (MRN)

From the *Plan Nord* to "*Nord pour tous*", political figures continue to stress the potential economic importance of the Nord-du-Québec region. Since its creation, mineral exploration has played a pioneering role in the region's economic development. Since 1975, we have witnessed an increasingly strong interest from companies for the Baie-James region. Statistical data compiled by the *Ministère des Ressources naturelles*, combined with information on companies, were used to draw a dynamic portrait of the presence and activity of various players in the exploration industry over a period of more than 30 years.

From juniors to majors and including state-owned companies, all types of companies have been involved in the Baie-James region, specifically acquiring exploration titles between 1975 and 2012. Over this time span, their presence may be described in three periods of differing intensity: a timid presence from 1975 to 1984, shifting to more intense activity from 1985 to 2000, and stepping up to an even higher level from 2001 to 2012. Companies active in the Nord-du-Québec region are based in Québec, in Canada, and abroad. The Baie-James region, open to mineral exploration, is dominated by companies based in Québec and by juniors, primarily non-producing juniors. These companies, and to a certain extent individual juniors themselves, dictate the evolving profile of companies active in the region.

Mining title acquisition has evolved from a period marked by domination of South versus North (1975-2000) followed by a period where the North emerged (2001-2012). This evolution can also be divided into two broad periods of unequal length: quasi-growth from 1975 to 1986, and a period of contrasts from 1987 to 2012. Over the entire time span from 1975 to 2012, mining companies based in Québec and juniors were the most active in terms of mining title acquisition.

SESSION 12

Controls on the formation of rare earth element ore deposits

ANTHONY E. WILLIAMS-JONES (McGILL UNIVERSITY)

Economic or potentially economic REE deposits are hosted by or genetically associated with alkaline to peralkaline igneous rocks and carbonatites. Commonly these rocks are found in failed rifts, such as the Gardar rift in Greenland and its inferred extension in northern Québec and Labrador, where they formed as the result of partial melting of a REE-enriched mantle and/or a lower crust metasomatised by REE-enriched mantle fluids. In such environments, primary REE enrichment in silicate magmas depends on the highly incompatible nature of the REE, may be facilitated by fluoride complexation, and occurs at late stages of magma evolution through crystal settling and crystallisation of residual, fluid-saturated pegmatitic liquids and, in some cases, immiscible fluoride melts. Carbonatite magmas likely owe their REE enrichment to the high solubility of the REE, and their preference for the LREE to the similar ionic radii of Ca^{2+} and Ce^{3+} ; HREE are smaller. Silicate rocks, such as nepheline syenites and peralkaline granites, should therefore be the preferred targets in the exploration for heavy REE deposits, and carbonatites in the exploration for light REE deposits.

Hydrothermal mobilisation may be essential to the economic viability of many REE deposits. Indeed, the World's largest deposit, Bayan Obo, China, is dominantly hydrothermal and in deposits, such as those at Strange Lake, Québec, where magmatic processes concentrated the REE to economic levels, the REE mineralisation is almost entirely secondary. Although aqueous fluoride complexes are widely thought to be the main agent of REE transport, modelling of natural systems suggests that this is not the case. Instead, chloride complexes appear to be responsible for REE transport in many REE ore-forming hydrothermal systems. Moreover, our experimental data suggest that the higher stability of light REE chloride complexes relative to heavy REE chloride complexes may cause the preferential mobility of the LREE observed in many REE ore-forming deposits. Hydrothermal concentration of the REE occurs when interaction of acid REE-Cl-bearing fluids with pH-buffering rocks, or mixing with pH neutral fluids, and/or decreasing temperature, induces REE mineral deposition. Owing to the greater mobility of the light REE, deposits of dominantly hydrothermal origin will tend to be light REE-rich and their grades highest in rocks, such as limestones or marbles, that efficiently neutralise acidity, and/or in environments where mixing with cool meteoric fluids is facilitated.

SESSION 12

The Nb-Ta-REE-enriched Crevier alkaline Intrusion: New geochronological, isotopic, geochemical and mineralogical data

PIERRE-ARTHUR GROULIER, DANIEL OHNENSTETTER, ANNE-SYLVE ANDRÉ-MAYER (UNIVERSITÉ DE LORRAINE, FRANCE), FABIEN SOLGADI, ABDELALI MOUKHSIL (MRN) AND ARMIN ZEH (GOETHE UNIVERSITÄT, FRANKFURT, GERMANY)

The Crevier Alkaline Intrusion (CAI) is located north of Lac Saint-Jean in the Grenville Province. It lies along the Waswanipi-Saguenay crustal lineament associated with the Saguenay Graben, where another intrusion enriched in Nb and REE is also present, at the Niobec mine in Saint-Honoré.

The CAI is divided into three major units: (i) a main unit comprising massive nepheline syenite with variable textures; (ii) a banded syenite consisting of sheeted dykes of nepheline syenite, biotite syenite, biotite-carbonate syenite, carbonatite and lamprophyre; and (iii) pegmatitic nepheline syenite dykes. Field observations focussing on the relative timing of these units suggest the first unit is intruded by the second, whereas the pegmatitic dyke swarms intrude the first two units. The relative timing of carbonatites versus pegmatites remains unclear. The carbonatites may be coeval to or post-date the pegmatites.

The pegmatitic dykes occur at the centre of the CAI and are oriented N320°. Detailed mapping has shown that these dykes were emplaced in a dextral shearing system and generally exhibit symmetry, with albite and nepheline crystals reaching ten centimetres in size, crystallizing perpendicular to wall rocks toward the centre of the dyke, composed of fine-grained nepheline syenite.

A study of the economic potential in Nb and Ta in the CAI is focused on these pegmatitic dykes, the extensions of which remain open to the north and south. Pyrochlore is the main mineral of economic interest. This study has outlined the existence of two generations of pyrochlore derived from crystal fractionation processes: a Nb-Ti-enriched generation and another enriched in Ta, associated with later phases. Pyrochlores either have a primary magmatic origin or a late magmatic secondary origin associated with fluid circulation. The largest pyrochlores (>1 mm) are associated with late veins of sodalite-bearing nepheline syenite. Primary magmatic pyrochlores are, on the other hand, commonly associated with Sr-enriched fluorapatites and almost always exhibit dissolution and recrystallization textures associated with Na-Ti-Nb depletion and F-Si-K-Fe-Mn enrichment due to interaction with a fluorine-rich fluid. Secondary pyrochlores are always located in fracture networks, they are small, xenomorphic but more homogeneous than their magmatic counterparts. They are spatially associated with fluorapatite, pyrrhotite, ilmenite, and occasional rare earth carbonates.

Geochemical analyses provide some insight on the occurrence of an immiscibility process between silicate and carbonate phases. This process presumably played a role in the distribution of economic minerals (Nb-Ta-REE).

Age determinations (U/Pb on zircon) on the nepheline syenite indicate a Late Grenvillian age (957.5 ± 2.9 Ma) probably associated with a phase of orogenic collapse coupled with extension. Lu-Hf age determinations on the same zircons from the same syenite yielded an age of 1700 Ma. This Labradorian age is interpreted as corresponding to the initial extraction event from the upper mantle.

SESSION 12

Preliminary characterization of rare earth mineralization in the Saint-Honoré ferrocarbonatite (Québec, Canada)

ALEXANDRE NÉRON, PAUL BÉDARD, DAMIEN GABOURY (UQAC) AND STEVE THIVIERGE (IAMGOLD)

Rare earth element (REE) exploration has experienced a resurgence over the last few years. A good understanding of the economic geology of REE deposits is necessary to generate solid exploration targets. As an active niobium mine (Niobec) and a world-class REE deposit, the Saint-Honoré alkaline complex offers an exceptional study area. The complex, located in the Saguenay region, is associated with the Saguenay graben. It is covered by Ordovician carbonates. The age of the alkaline complex is approximately 650 Ma. It is in the form of a vertical chimney in which the petrographic units progress from a calcitic carbonatite along the margins to a ferrocarbonatite at its centre. The brecciated ferrocarbonatite contains mineralization consisting of carbonates (calcite, dolomite and siderite), barite, rare earth minerals (bastnaesite with small amounts of monazite), quartz, halides (halite and sylvite) and chlorite. It is subdivided into two units: massive and brecciated. The massive ferrocarbonatite consists mainly of coarse-grained carbonates (dolomite, ankerite and siderite) and small amounts of barite. The REE minerals occur as purplish centimetre-scale grains with amoeba-like texture. Although the proportion of these amoeba-textured minerals varies within the unit, the minerals are always bastnaesite, monazite, hematite, quartz, halite, barite and carbonates. The brecciated ferrocarbonatite is characterized by subangular millimetre-scale fragments of carbonates and barite. The mineralogy of the interstitial material between the fragments is similar to that of the purplish amoeba-textured portion. The contact between the brecciated and massive units is sharp in some zones and gradual in others. The ferrocarbonatite is subdivided at depth into two zones based on the presence or absence of halides, quartz, and/or barite in association with mineralization. Some authors have postulated that the correlation between barium and REE contents reflects a magmatic source. The high barium content of the mineralized Saint-Honoré ferrocarbonatite (more than 5%) would suggest a significant magmatic component for the REE mineralization. In addition, there is a relationship between the presence of halite and REE mineralization, suggesting a chlorine-rich hydrothermal component. The relationship between halides and REE minerals and the abundance of barite suggest a REE-rich magmatic source enriched by late hydrothermal remobilization.

SESSION 12

Progressive reclamation of tailings ponds at Niobec – A sustainable development approach

THIERRY TREMBLAY (IAMGOLD)

In production since 1976, the Niobec mine has two accumulation areas: tailings pond No. 1 that was used from 1976 to 2005, and tailings pond No. 2 that has been in use since 2003. Mindful of its host community, Saint-Honoré-de-Chicoutimi, the Niobec mine is implementing an innovative approach of progressive reclamation for its tailings ponds, with the aim of transforming these accumulation zones into useful areas for the community and the environment.

In an effort to continuously improve its progressive reclamation practices, Niobec joined forces with the Eco-Consulting Chair at Université du Québec à Chicoutimi (UQAC) and the Agrinova Centre for Research and Innovation in Agriculture. The joint research projects with these organizations will allow Niobec to develop an optimized strategy for the restoration of pond No. 2 and to eventually apply this strategy to the next tailings accumulation area, starting in its first year of use. Based on the guiding principles of sustainable development, the “accelerated” progressive reclamation strategy will sequester atmospheric CO₂ (a greenhouse gas), help control water and wind erosion, establish a productive and diversified ecosystem, harmonize the site into the landscape, and make the project socially acceptable to the municipalized environment of Saint-Honoré-de-Chicoutimi.

This conference will present the key features of Niobec's approach for the progressive reclamation of its tailings ponds and will highlight the most notable research findings to date. It will provide an opportunity to share the company's vision for the future of its accumulation areas.

SESSION 12

Geological update and mining development of the Montviel REE project, James Bay, Québec

SIMON BRITT AND ALAIN CAYER (GÉOMÉGA RESOURCES)

The Montviel property is wholly owned by GéoMégA Resources and is located in the Jamésie region about 100 km north of Lebel-sur-Quévillon and 45 km west of the Cree First Nation of Waswanipi. The property benefits from permanent access, public infrastructure, and experienced workers in the immediate area.

The property is underlain by Archean rocks of the Abitibi Subprovince, in which the Proterozoic Montviel Alkaline Intrusion was emplaced. The core of the intrusion consists of carbonatite, with the central part composed of Fe-carbonatite containing high concentrations in rare earth elements ("REE") and niobium. The main REE-bearing mineral phases are fluorocarbonates of the bastnaesite-synchysite series, whereas pyrochlore is the main niobium-bearing phase. To date, the Company has delineated the mineralized Fe-carbonatite over an area of 900 m by 650 m and to a depth of 750 m. This work defined a zone enriched in REE and niobium in the western part of the Fe-carbonatite and also outlined two distinct zones enriched in heavy REE.

The publication of an updated mineral resource estimate and of the preliminary economic assessment is expected before the end of 2013. The cut-off grade in total rare earth oxides for the resource estimate will be based on an open pit mining scenario, using an access ramp, and taking into account the following economic elements: neodymium, europium, dysprosium, praseodymium, terbium, yttrium, and niobium. An initial annual production rate on the order of 2,000 tonnes of neodymium oxide is considered. The process flowsheet includes flotation, leaching, hydrochloric acid regeneration, and precipitation. In parallel, GéoMégA is developing a rare earth element separation technique based on their respective physical properties.

SESSION 12

Petro-metallogenesis of the carbonatic alkaline system (REE-Nb) of Montviel, Abitibi

OLIVIER NADEAU (UQAM), ALAIN CAYER, MIA PELLETIER (GÉOMÉGA RESOURCES), DAVID SÉGUIN, ROSS STEVENSON AND MICHEL JÉBRAK (UQAM)

The Montviel Alkaline Intrusion in Abitibi, Québec, hosts one of the most promising rare earth deposits in Québec. The Paleoproterozoic magmatic system was dated at 1894 ± 4 Ma (U-Pb on zircon in ijolite; David *et al.*, 2006) and is composed of peridotite, pyroxenite, syenite, melteigite, ijolite, urtite, sodic granite, Si-carbonatite, Ca-carbonatite, Fe-carbonatite, and polygenic carbonatite breccia (Goutier, 2006; Nadeau *et al.*, 2013). Advanced studies involving drilling, mapping, 3D modeling, petrography, electron microprobe analyses of minerals, and trace element analyses by LA-ICP-MS, as well as $\delta^{13}\text{C}$, $\delta^{18}\text{O}$, Rb-Sr and Sm-Nd isotope analyses were carried out to study the petrogenesis of the alkaline system as well as the metallogenesis of the REE-Nb ore deposit. Preliminary results indicate that ultramafic to mafic silicate magmas were initially derived from the sub-lithospheric depleted mantle and gradually assimilated crustal material. A second mantle pulse subsequently injected Ca-carbonatites, which evolved to Fe-carbonatites as a result of continental crust assimilation, crystal fractionation, and metasomatism. The first mineralized phases are magmatic Ca-Sr-REE carbonates, whereas F metasomatism produced Ca-REE fluorocarbonates (such as parisite and synchysite), and Ba metasomatism produced Ba-Sr-REE carbonates (for example, carbocernaite). The combination of Ba and F metasomatism finally produced Ba-REE fluorocarbonates such as qaqarssukite. A third mantle pulse appears to have enriched certain parts of the deposit in middle to heavy rare earth elements (heavy REE), namely forming ewaldite ((Ba,Sr)(Ca,Na,REE)(CO₃)₂·10-12H₂O). Finally, contamination of the magmatic-carbothermal system by an aqueous fluid resulted in a phreatomagmatic explosion that created the polygenic carbonatite breccia enriched in heavy REE. Although auto-metasomatism and mantle fluid pulses have successfully explained certain aspects about the origin and genesis of the system, many questions remain, namely concerning sulphidation and oxidation processes. For example, certain observations seemingly demonstrate the presence of an immiscible sulphide liquid. Oxygen fugacity fluctuations also appear to have played a significant role in the crystallization of magmatic and carbothermal phases.

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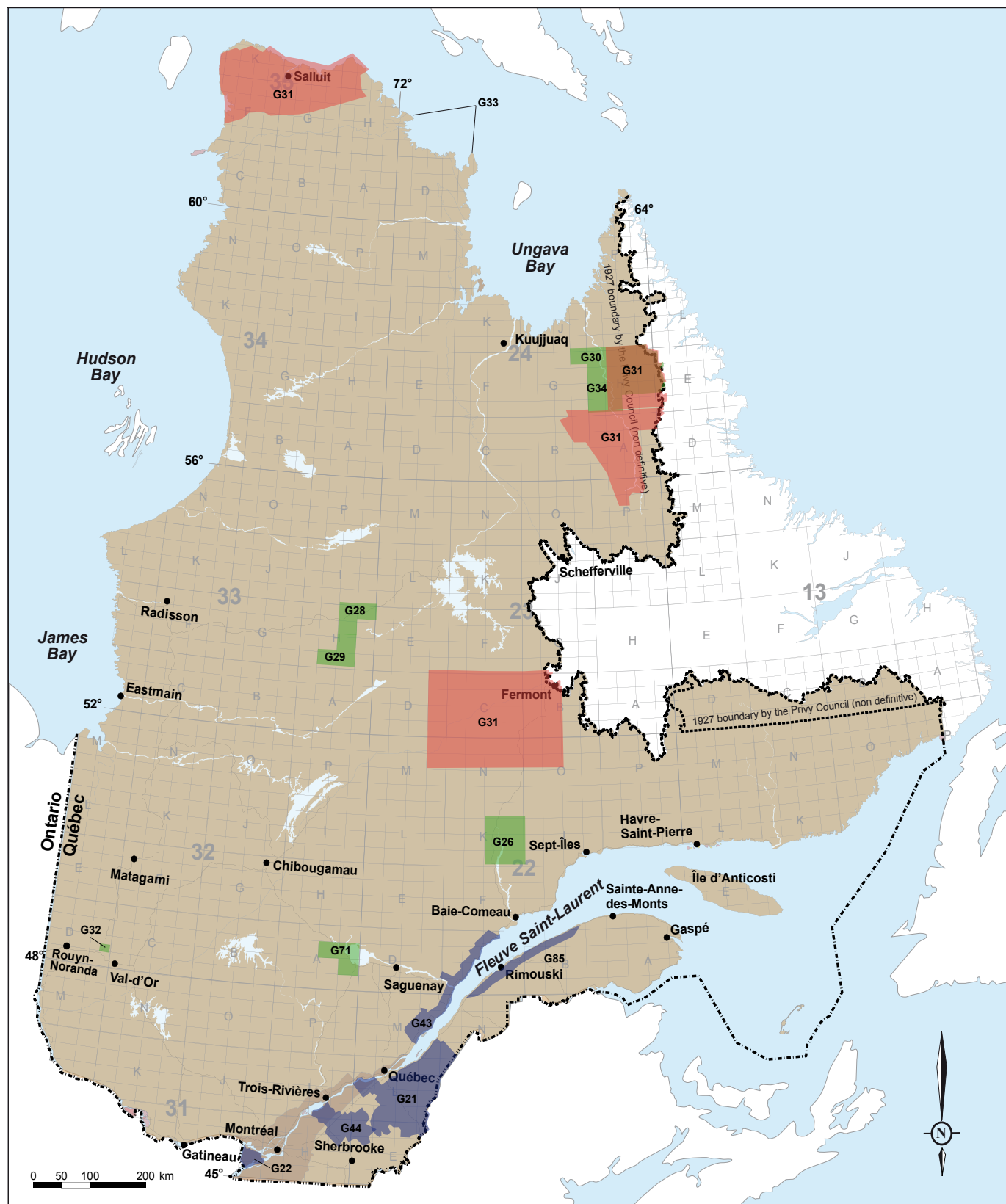
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ABSTRACTS OF POSTERS

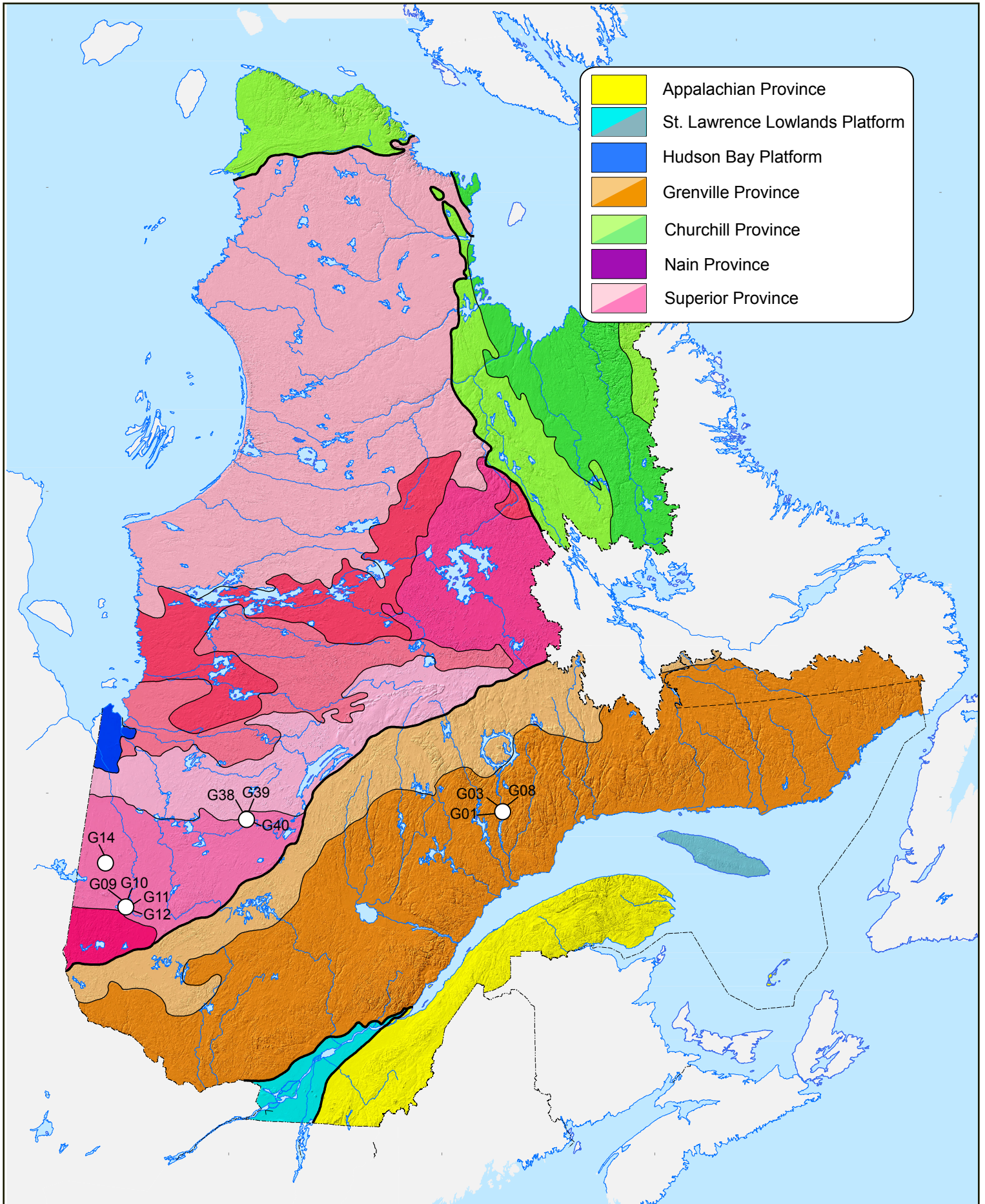
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LOCATION OF PROJECTS AT GÉOLOGIE QUÉBEC



LOCATION OF UNIVERSITY PROJECTS



G01

Deformation related to the burial and exhumation of the Parautochthonous Belt southwest of Manicouagan Reservoir, central Grenville Province, Québec

SOPHIE JANNIN, FÉLIX GERVAIS (POLYTECHNIQUE MONTRÉAL) AND ABDELALI MOUKHSIL (MRN)

This doctoral project aims to define a model that explains the burial and exhumation of the Parautochthonous Belt in the central Grenville Province, south of the Manicouagan Reservoir (NTS map sheets: 22N03, 22N02, 22K14 and 22K15).

The Parautochthonous Belt constitutes deformed North American craton. It is overthrust by the Allochthonous Belt composed of exotic rocks. The Allochthon Boundary Thrust (ABT) is a thrust belt separating these two entities. In the western Grenville, this fault is known to have undergone reverse movement that buried the Parautochthonous Belt, followed by normal movement causing its exhumation.

In the central Grenville, south of the Manicouagan Reservoir, the Allochthonous Belt was metamorphosed between 1080 and 1030 Ma in the sillimanite field. The Parautochthonous Belt was metamorphosed between 995 and 980 Ma in the sillimanite and kyanite fields.

The MRN mapped the region in 2011. A compilation of the data, as well as the work during a field program in 2012, demonstrated three phases of deformation in the Parautochthonous Belt. The first, documented in the northwest part of map sheet 22N03, is represented by a NW-SE foliation. This first phase was likely transposed by D2 deformation characterized by: NE-SW foliation, a south-plunging lineation, and reverse sinistral movement. This second deformation yielded U-Pb ages of approximately 985 Ma near the ABT and approximately 1010 Ma further west. This deformation likely caused the burial of the Parautochthonous Belt.

A third phase of deformation, locally present in the south, folded the lineation and reoriented its plunge to the southwest instead of to the south. Dextral normal shearing is associated with this phase. This deformation may have been responsible for exhuming the Parautochthonous Belt. Nevertheless, in 2012, we did not observe any normal faults postdating D2 deformation in the Parautochthonous Belt along the southern shores of the Manicouagan Reservoir. The deformation responsible for exhuming the Parautochthonous Belt has not yet been characterized in this area.

Data collected in the field in 2013 demonstrate that in the core of the Allochthonous Belt, near the ABT, the lineation plunges to the south and the shear zones are reverse. This deformation may correspond to D2 deformation documented in the Parautochthonous Belt.

Further west, south of Manicouagan Island, a 4-km zone is characterized by: 1) the presence of two different lineations in the same outcrop, and a foliation with an overall trend of N045; 2) kinematic indicators displaying evidence of reactivation; and 3) the presence of numerous late pegmatites. The first lineation plunges to the south and displays reverse movement, whereas the second plunges N130 with normal movement. Kinematic indicators observed in the host rock display an initially reverse movement overprinted by normal movement. The pegmatites cut the foliation and in places display a lineation plunging to the N130 with normal kinematic indicators. The normal shearing thus postdates the reverse shearing.

This zone of normal shearing was likely responsible for exhuming the Parautochthonous Belt. Did the part of the Allochthonous Belt between this zone and the ABT remain buried while the rest of the Allochthonous Belt was exhumed, or was it exhumed and then reburied with the Parautochthonous Belt? Dating this deformation and studying the metamorphism in the region as well as obtaining estimated ages and cooling conditions for the Parautochthonous and Allochthonous belts may be key to answering this question.

G02

The Nb-Ta-REE-enriched Crevier alkaline intrusion: New geochronological, isotopic, geochemical and mineralogical data

PIERRE-ARTHUR GROULIER, DANIEL OHNENSTETTER, ANNE-SYLVE ANDRÉ-MAYER (UNIVERSITÉ DE LORRAINE, FRANCE), FABIEN SOLGADI, ABDELALI MOUKHSIL (MRN) AND ARMIN ZEH (GOETHE UNIVERSITÄT, FRANKFURT, GERMANY)

The Crevier Alkaline Intrusion (CAI) is located north of Lac Saint-Jean in the Grenville Province. It lies along the Waswanipi-Saguenay crustal lineament associated with the Saguenay Graben, where another intrusion enriched in Nb and REE is also present, at the Niobec mine in Saint-Honoré.

The CAI is divided into three major units: (i) a main unit comprising massive nepheline syenite with variable textures; (ii) a banded syenite consisting of sheeted dykes of nepheline syenite, biotite syenite, biotite-carbonate syenite, carbonatite and lamprophyre; and (iii) pegmatitic nepheline syenite dykes. Field observations focussing on the relative timing of these units suggest the first unit is intruded by the second, whereas the pegmatitic dyke swarms intrude the first two units. The relative timing of carbonatites versus pegmatites remains unclear. The carbonatites may be coeval to or postdate the pegmatites.

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The Manicouagan astrobleme (Québec): New petrological data

PIERRE-ARTHUR GROULIER, ABDELALI MOUKHSIL
AND FABIEN SOLGADI (MRN)

Québec is among the best places to find preserved meteorite impact craters since the Superior craton, a geologically and tectonically stable province favourable for the preservation of astroblemes, forms a large part of its landmass. There are nine impact structures inventoried in Québec: Charlevoix (342 ± 15 Ma), Île Rouleau (<300 Ma), Lac à l'Eau-Claire (double impact dated at 290 ± 20 Ma), Lac Couture (425 ± 25 Ma), Nouveau-Québec (1.6 Ma), Lac La Moinerie (400 ± 20 Ma), Presqu'île (<500 Ma) and lastly, the Manicouagan Impact Crater (MIC). The MIC covers a surface area of $2,000 \text{ km}^2$ with an estimated diameter of 100 km and has a Triassic age (214 ± 1 Ma). It is located in Proterozoic rocks of the Grenville Province and corresponds to the 5th largest impact crater known on Earth. A mapping project undertaken by the *Ministère des Ressources naturelles* (MRN) in 2011 subsequently led to a petrographic study of the various facies of the structure. The crater has a complex morphology characterized by a central peak; its shape is beautifully outlined by the Manicouagan Reservoir behind the Daniel-Johnson Dam.

The MIC is characterized by the presence of six geological units: Tcim1, which corresponds to the country rocks including the Mont de Babel anorthosite and gneisses of the Manicouagan Imbricate Zone, which sustained the impact; Tcim2, consisting of suevites (impact breccias); Tcim3, formed of occasionally spherulitic basalt; Tcim4, a latite; Tcim5, a monzonite; and Tcim6, composed of basement rocks that underwent shock metamorphism due to the impact and the high temperatures induced by magma generation.

Previous work on the MIC has outlined the presence of pseudotachylite (abundant in Mont de Babel rocks), clastic matrix breccias, maskelinite (vitrified plagioclase), shocked quartz and plagioclase, as well as shatter cones. The impact was so violent that a significant volume of melt was generated (a hemisphere with an 8-km radius, corresponding to a volume of $1,000 \text{ km}^3$), the amount of lava averaged about 400 m in thickness, reaching more than 1 km at its thickest location and exhibiting crystal fractionation processes. Ni-Cu $\pm$ PGE mineralization is observed in certain locations in the vicinity, but most likely predates the impact.

A study of ultramafic intrusions in the Lac Richardie area, Baie-James

DONALD GRZELA (UNIVERSITY OF OTTAWA),
JEAN GOUTIER (MRN), JONATHAN O'NEIL (UNIVERSITY
OF OTTAWA) AND MICHEL G. HOULÉ (GSC-Q)

Several ultramafic intrusions were inventoried during a mapping program carried out in the summer of 2013 by the MRN in the La Grande and Opinaca subprovinces, in the Lac Richardie area located south of La Grande 4 Reservoir in the Baie-James region. Field observations indicate the intrusions are generally metamorphosed to the amphibolite and the granulite facies but are only weakly deformed, suggesting late emplacement. In addition, our preliminary work also indicates the existence of different types of ultramafic intrusions in the area, one of which contains centimetre-scale chromite layers in peridotite and anomalous PGE grades (87.9 ppb Pd; 51.4 ppb Pt). This type of mineralization may be comparable with occurrences observed in the Menarik Complex (Lac Yasinski area) or in the Lac des Montagnes intrusions (Nemiscou area). Another type of ultramafic intrusion is distinguished by the presence of significant phlogopite; this type may be related to alkaline ultramafic intrusions such as the Lac Pelletan intrusion. The objective of this project is to characterize the petrography and geochemistry of these ultramafic intrusions, to categorize them and compare them. This project is part of a joint project by the Geological Survey of Canada and the *Ministère des Ressources naturelles du Québec*, under the Targeted Geoscience Initiative 4 (TGI-4), focusing on the study of mafic to ultramafic intrusions in the Bird River area in Manitoba, the McFaulds Lake area in Ontario, and the Nemiscou, Lac Yasinski and Lac Richardie areas in the Baie-James region of Québec.

G05

Gold mineralization at the contact between the Opinaca and La Grande subprovinces: the Quentin showing, Baie James (NTS 33H04)

SIMON BACHAND (UQAM), JEAN GOUTIER (MRN)
AND ALAIN TREMBLAY (UQAM)

Fieldwork was carried out on the Quentin showing during the summer of 2013, within the scope of a regional mapping project of the area south of the La Grande 4 Reservoir, in the Baie James region. This work is part of an undergraduate project undertaken at the Université du Québec à Montréal (UQAM). The Quentin showing was discovered in 2012 during a mapping program covering map sheet 33H04 by the *Ministère des Ressources naturelles*. It is a gold occurrence (one sample grading 2.17 g/t) located directly at the contact between mafic amphibolites of the La Grande Subprovince and Opinaca paragneisses. The outcrop was stripped during the summer to extend the exposure further west. Detailed mapping of the area also provided a better understanding of interactions between the various lithologies. Results indicate that strongly deformed amphibolites are intruded by mylonitic felsic dykes parallel to the main schistosity (WNW-ESE). Paragneisses are locally cut by a massive granitic intrusion with centimetre-scale tourmaline. They also host several metre-scale boudins of ultramafic amphibolite oriented parallel to the main schistosity. As for the gold occurrence itself, the initial description provided in 2012 of a sulphide-bearing quartz vein, has been reinterpreted as a decimetre-scale to metre-scale silicate-facies iron formation horizon. Recent stripping has extended the mineralized zone further west and has exposed a second mineralized horizon, parallel to the first and located southwest of the latter. The first horizon, along the extension of the gold-bearing zone discovered in 2012, exhibits diopside, pyrite, pyrrhotite, and local chalcopyrite mineralization. The second horizon is similar to the first, with the local presence of garnet and arsenopyrite. In terms of structural setting, the presence of these two parallel iron formation horizons suggests a decametre-scale isoclinal fold with the hinge located slightly east of the study area. In addition to detailed mapping, the results of geochemical analyses and microscope studies of the various lithologies will be used to better define the mineralization at the Quentin showing. In parallel, the study of kinematic indicators observed in the various mylonites may lead to a better understanding of the nature of the contact between the Opinaca and La Grande subprovinces in this area.

G06

Petrographic study of the Lac des Montagnes chrome-bearing ultramafic intrusion, Baie-James, Québec

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RÉJEAN HÉBERT (ULaval) AND JEAN GOUTIER (MRN)

The Lac des Montagnes chrome-bearing ultramafic intrusion was initially identified in the 1960s during a regional mapping program undertaken by the *Ministère des Richesses naturelles* in the Nemiscau area. This intrusion is part of a series of ENE-trending ultramafic intrusions found in the Lac des Montagnes volcano-sedimentary belt in the Opinaca Subprovince, near the southern contact zone with the Eastmain Domain in the Superior Province.

The Lac des Montagnes intrusion was emplaced in a biotite paragneiss sequence, which is 185 m thick and extends over a strike length of about 1,100 m. It is mainly composed of peridotite, olivine pyroxenite, and pyroxenite, showing variable degrees of metamorphism ranging from pseudomorphic serpentinization and talcification to complete obliteration of primary cumulate textures. Several chromite-rich layers are also observed in the ultramafic sequence; these may be divided into three main zones. The first zone is 23 m thick and occurs in the basal part of the intrusion. It consists of several centimetre-scale beds with up to 30% net-textured chromite, alternating with serpentinized peridotite. The second zone is about 10 m thick and consists of several semi-massive chromitite (75-85% chromite) beds ranging from about 10 cm to 3 m in thickness and alternating with peridotites altered to talc but with well-preserved cumulate textures. The third chromite-rich zone consists of nearly a dozen centimetre-scale beds with strongly disseminated to net-textured chromite (12-20% chromite) over a total thickness of about 12 m. Chromite-rich layers alternate with peridotites altered to talc and serpentine but with preserved cumulate textures, where an increasing pyroxene content marks the base and the top of the chromite-rich zone.

Although primarily ultramafic, the Lac des Montagnes intrusion may be overlain by a mafic sequence composed of mesocratic and melanocratic gabbro locally exhibiting pegmatitic zones, based on reconnaissance work carried out in the summer of 2013. However, the relationship between the two sequences remains unclear given the presence of intense deformation and/or late mafic injections near the contact zone. The objective of this project is to establish the stratigraphy, the distribution of chromite-rich layers, and the possible link between the mafic and ultramafic sequences in the Lac des Montagnes intrusion.

G07

Detailed mapping of the South Whip gold showing, James Bay

MARILYNE ADAM (UQAM)

The objective of this undergraduate final year project is to conduct detailed mapping and a metallogenic study of the South Whip gold showing.

The South Whip showing is located in the James Bay region, southeast of the LG4 Reservoir, in map sheet 33H09. It is about 30 km southwest of the Mirage Adventures outfitter's camp at kilometre 358 along the Trans-Taïga Road. The showing is found in a volcano-sedimentary belt of the La Grande Subprovince, which is part of the Superior Province. Rocks of the Canadian Shield range in age from 4 to 2.5 billion years.

The South Whip gold showing was worked in 1995 by the exploration company Sirios and was named "Lac Sirios South #1". One of their samples yielded a gold grade of 1.07 g/t. Following this, in the summer of 2008, the company Midland Exploration conducted new studies on the showing and renamed it "South Whip". Their work yielded gold grades of 1.1 g/t and 1.9 g/t. It was only in the summer of 2013 that additional work was carried out, including the chemical analysis of 17 samples, in order to satisfy the objectives of this project, namely the detailed and mapping metallogenic assessment of the area where these samples were taken.

The study area covers about 1100 m². A dominantly east-west fault crosses the study area. Fine-grained and highly deformed amphibolites to the north of this fault display rusty zones with high concentrations of sulphides. In one such zone, pyrrhotite and pyrite are the dominant sulphide phases (roughly 40%), present as millimetre- to centimetre-scale veins and accompanied by traces of chalcopyrite. This zone yielded a gold anomaly of 444 ppm and a copper anomaly of 0.11%. Three lithologies were recognized south of the fault: an ultramafic unit, deformed amphibolites, and a felsic volcanic. A sample collected from a rusty zone at the southern boundary of the study area contained pyrrhotite (about 8%) as disseminations and geode fillings, as well as chalcopyrite (about 4%) as vein infillings and disseminations. An assay yielded a gold anomaly of 23 ppm and a copper anomaly of 0.12%. Although the grades are lower than those obtained during earlier work, they nonetheless confirm the presence of a gold anomaly at this location.

G08

Southeast Churchill Province, Torngat sector: How many tectonometamorphic overprints are recorded in the roots of the Paleoproterozoic orogeny?

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The Southeast Churchill Province is composed of three geological entities (from east to west): the Torngat Orogen, the Core Zone and the New Québec Orogen. This arrangement, with an Archean craton bordered by two Paleoproterozoic orogens, is the product of complex geodynamics between the Nain, Core Zone and Superior cratons, beginning at about 2.2 Ga and involving rift formation, oceanization and oblique convergence. Occurring in succession at 1.87-1.86 Ga and then 1.82-1.77 Ga, the collisions of the Core Zone, first with the Nain craton and then with the Superior, respectively formed the Torngat and New Québec orogens. This multiphase tectonic activity during the early Proterozoic produced major shear zones that dissect the Core Zone, dividing it into metamorphic domains characterized by amphibolite to granulite facies with evidence of anatexis, such as is present throughout the Churchill Province. Despite recognizing these overprints, it is difficult to assign with certainty the observed metamorphic or structural features to any particular orogeny due to insufficient knowledge about the evolution of the Torngat Orogeny and the Archean history of the Core Zone. This gap, which is more pronounced for the Torngat sector, represents a period for which we have no quantitative estimates for the heat generated (temperature) or the amount of crustal thickening (pressure), and it presents a major obstacle in understanding the geodynamic evolution of the Churchill Province.

In order to characterize the Torngat Orogeny and elucidate its influence on the development of the Churchill Province, the objectives of our ongoing tectono-metamorphic study are to map the metamorphic parageneses and grades in the region and to quantify the pressure and temperature conditions generated during the orogeny. It also aims to temporally constrain its metamorphic and structural evolution. The 2013 mapping program of the *Ministère des Ressources naturelles du Québec* followed a 50-kilometre traverse across the orogen and the eastern margin of the Core Zone. The data reveal a sharp boundary between a transpressional orthopyroxene-bearing domain and a less deformed amphibolite facies domain. Furthermore, the detailed mapping of key outcrops identified an anatectic event related to peak metamorphism. Following this field work, we applied an innovative methodology combining petrology and equilibrium phase calculations (pseudosections), as well as U-Pb, Lu-Hf and Sm-Nd geochronology on zircons, monazites and garnets, in order to better constrain the Pressure-Temperature-Time-Deformation path of the Torngat Orogeny, thereby improving our understanding of the Churchill Province.

G09

Geology of the Marbridge area (NTS 32D08-0102)

VÉRONIQUE LAFRANCE (UQAC), PIERRE PILOTE (MRN)
AND RÉAL DAIGNEAULT (CERM-UQAC)

The Marbridge area is located in the southeast part of the Abitibi Subprovince, to the northwest of Lac Malartic and about 60 km from the city of Val-d'Or. It is in NTS map sheet 32D08-0102 and was mapped by Pierre Pilote and his team in the summer of 2013.

The study area is wedged between the plutons of La Motte to the north, Preissac to the south, and La Corne to the east. The Marbridge mine was active from 1962 to 1968. It produced more than 700,000 metric tonnes of ore from four distinct lenses, at a grade of more than 2% nickel and 0.17% copper. The Marbridge mine property has belonged in part to Falconbridge Nickel Mines and Marchant Mining Company since it went into production. In July 2009, Royal Nickel Corporation acquired the rights to the property.

The geology of the Marbridge area is essentially composed of ultramafic rocks (komatiites and peridotites), mafic volcanic rocks (basalts) and felsic volcanic rocks. A sedimentary unit was also observed in places. These lithologies belong to the La Motte-Vassan Formation, at the base of the Malartic Group, and an age of 2714 ± 2 Ma was obtained for a felsic unit.

The rocks of the area form part of an intense deformation zone characterized by strongly developed stretching lineations plunging moderately to the east. A NW-trending S1 schistosity is folded by a S2 cleavage generally trending E-W. The Marbridge mine area was metamorphosed to amphibolite facies. Metamorphic minerals (hornblende and garnet) are best developed in the units affected by pre-metamorphic alteration. The rock hosting nickel mineralization is typically komatiite. However, some nickel mineralization also displays vein-style geometry at an angle to structural fabrics. Remobilization is therefore a possibility.

As part of this project, we will conduct an in-depth study on deformation, metamorphism and structures in order to determine the context of the mineralization. Furthermore, detailed mapping of the area will also be carried out, coupled with lithogeochemistry.

G10

Geology and gold mineralization at the Malartic Hygrade mine – The Orion N° 8 ore zone

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This Master's project is carried out in collaboration and with the support of the MRN and NioGold. This study is part of an MRN mapping project (Pilote *et al.*, 2012) covering the Malartic area (NTS 32D01-NE).

This study focuses on the Orion N° 8 ore zone adjacent to the Malartic Hygrade mine, where mining operations took place from 1962 to 1992. The Orion deposit was discovered in 1985 and a total of 131,000 t were mined from 1987 to 1990, at an average grade of 5.31 g/t. The objectives of this study are to document and characterize the Orion N° 8 ore zone. To do so, the local geology will be updated and the role and importance of major fault zones such as the Norbenite Fault will be investigated. A broader objective consists in positioning the Orion zone relative to the various gold ore-forming episodes that are recognized in the Val-d'Or-Malartic area.

Gold mineralization in the Orion N° 8 zone is oriented 310° and dips to the NE. It may be divided into three facies: 1) pyritized pillowed basalts altered to chlorite and albite and containing actinolite; 2) N-S-trending quartz veins from 3 to 8 cm wide and a network of irregular quartz veins that brecciate the host rocks, both accompanied by strong albite alteration; and 3) a complex of fine-grained massive quartz veins with strong albite alteration and visible gold locally observed in the wall rocks. The hanging wall of the mineralized zone consists of coarse-grained basalts and ultramafic flows, whereas the footwall is composed of aphanitic pillowed/brecciated flows and felsic intrusions.

The results of fieldwork including detailed mapping, thin section studies, and structural data analysis were used to establish the relative timing of the various geological events associated with the Orion N° 8 ore zone. Firstly, following emplacement of the mafic/ultramafic volcanic edifice, N-S-trending quartz veins were emplaced by hydraulic fracturing, along with a network of brecciated and irregular quartz veins associated with strong proximal pyritization and albitization as well as peripheral chloritization of enclosing basalts. NW-trending massive quartz vein complexes include enclaves of pyritized basalts. The bulk of the gold mineralization appears to be associated with quartz veins. Tonalitic intrusions cross-cut the veins and pyritized basalts. The dominant E-W schistosity affects and overprints alteration halos as well as dykes. Regional metamorphism is responsible for the formation of actinolite halos with no preferential orientation but occurring only in areas where lithologies were already altered/albitized. Subsequent reactivation of shear zones and faults oriented 310° , longitudinal to or cross-cutting mineralization in the Orion zone, produced apparent dextral dragging of the main schistosity along these faults.

Geology of the “Rives du Lac Marlartic” (RLM) gold showing

RÉMI SCHMITT (UQAM), PIERRE PILOTE (MRN)
AND ALAIN TREMBLAY (UQAM)

This Master's project was supported by and carried out in collaboration with the MRN and Golden Share Mining Corporation. The “Rives du Lac Marlartic” (RLM) gold showing is about 10 km northwest of the town of Marlartic. The showing is found in the South Volcanic Zone of the Abitibi Subprovince.

The RLM showing consists of an extensive stripped zone comprising two parts. The west part, about 200 m long by 50 m wide, is mainly composed of deformed pillow basalts affected by a NW-SE schistosity. The east part, 100 m long by 25-100 m wide, is affected by a dextral fault (the Rivière Héva Fault) that juxtaposes basaltic volcanics and felsic volcanics (rhyolitic tuffs).

Gold mineralization is contained in numerous quartz veins up to 1.50 m thick. The veins are composed of quartz, chlorite, albite in places, and smokey quartz. No tourmaline was observed. The veins contain carbonate boxwork structures and pyrite mineralization, and locally chalcopyrite and galena. Gold grades locally reach up to 176 g/t over 0.6 m in surface channels. Galena is only present when gold grades are high, which may indicate a link between these two minerals. Quartz veins are boudinaged and folded. They appear to be early with respect to regional deformation. The veins cut the greenish to bluish gabbroic dykes.

The west outcrop displays a major flexure in the orientation of the main schistosity. This strongly penetrative schistosity varies in attitude from 155°/70° in the north to 112°/70° further south. It then becomes parallel (from a strike of 115° to 165°) to the path of Rivière Héva on the east side. At the present time, we have interpreted this curvature as the moulding of the schistosity around a non-outcropping tonalitic intrusion between the east and west parts. The west part is notable for its numerous dykes that systematically cut the veins. From oldest to youngest, these intrusions are: tonalite dykes, chloritic mafic dykes, granodiorite dykes, and lamprophyre dykes.

The work this summer consisted of detailed mapping on specific zones in order to better understanding the dykes and mineralized quartz veins. We also collected many samples at surface and from drill core to characterize the geochemistry of the different dykes and the host lithologies to the mineralized zones, and to establish quartz vein parageneses. We placed particular emphasis on identifying and documenting the various structural features in order to assess the timing of gold mineralization with respect to regional deformation.

Synthesis and evolution of the Cadillac Fault, Abitibi

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SYLVAIN RAFINI (CONSOREM) AND RÉAL DAIGNEAULT (CERM)

The objective of this Ph. D. project, undertaken at the UQAC and supported by the *Ministère des Ressources naturelles du Québec* is to provide 1) synthetise the structural evolution of the Cadillac Fault (CF), by characterizing the various structural signatures observed along the fault, by establishing relationships between the various deformation events; and 2) by attempting to understand how the orogenic mineralization fits within this structural framework. Fieldwork will include structural sections across the CF, detailed mapping of key areas, and the collection of structural measurements and oriented samples.

The Cadillac Fault (CF) is a major structure broadly trending east-west that separates the Abitibi Subprovince to the north from the Pontiac Subprovince to the south. The fault zone is approximately 10 metres wide although this varies along strike, and is spatially coincident with a lithotectonic volcanic unit: the Piché Group. The CF constitutes a significant regional metalotect, with numerous orogenic deposits occurring in its vicinity.

It has been interpreted by many authors as the remaining trace of the subduction and accretion of the Pontiac underneath the Abitibi, with polyphase deformation involving episodes of shortening, extension, and strike-slip.

Still, many questions remain concerning its structural and metallogenic aspects, namely the relative timing of ore-forming hydrothermal activity and deformation associated with the fault. The various age determinations available suggest several mineralizing events, the most significant seemingly late (ca. 2680 Ma). The latter may coincide with a late strike-slip event. However, several important deposits exhibit mineralized veins with a geometry that is more consistent with a shortening regime. In addition, the CF has mostly been the focus of local structural studies illustrating different deformation styles along the fault. These problems illustrate the complexity observed in the structural style as well as the duality between regional and theoretical observations and those visible on a local scale. Finally, the Piché Group, which constitutes the physical manifestation of the CF, remains poorly known, as well as the nature of its contacts to the south and north.

The first field campaign was carried out in the summer of 2013. Detailed mapping in a few areas has outlined several different structural styles characterizing various segments of the CF. Observed kinematic indicators suggest different movements along the fault even at the scale of an outcrop. These movements may represent different episodes of shortening and strike-slip. A second field campaign will be carried out, namely to study this last aspect in greater detail.

G13

Volcanology of the Waconichi Formation, Lemoine area, Chibougamau (Abitibi Subprovince)

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The Abitibi Subprovince is one of the best districts in the world to explore for volcanogenic massive sulphide (VMS)-type copper, gold, zinc, and silver deposits, particularly gold-rich VMS deposits. The Chibougamau area encompasses the former Lemoine mine, where the second richest VMS deposit in Canada was mined from 1975 to 1983. The main VMS metallotect in the area is the Waconichi Formation (Roy Group), which hosts the former Lemoine mine and the Scott ore deposit. A Master's project underway at INRS-ETE aims to reconstruct the volcanic architecture of the Waconichi Formation on part of the Lemoine property held by Cogitore Resources, northeast of the former mine.

In the study area, the felsic-dominated part of the Waconichi Formation is bordered to the north by the Lac Doré Complex and to the south by transitional basalts of the upper Lemoine member (former Gilman Formation). Petrography and geochemistry data indicate the presence of several felsic units in the study area, namely the Lemoine Rhyolite, the Hangingwall QFP, the Marelle Rhyolite, the Alpha Rhyolite (former high-Zr Marelle Rhyolite) and the Lac Coco Rhyolite (former upper Lemoine Rhyolite). The Waconichi Formation also includes the Lemoine Andesite and the Lemoine Dacite. The ore deposit at the former Lemoine mine sat at the top of the Lemoine Rhyolite and was overlain by the Hangingwall QFP.

A better understanding of the distribution and mode of emplacement of each unit was the main objective of the study during the summer of 2013. Mapping of outcrops and logging of more than 7,000 m of drill core made it possible to establish the distribution of felsic units, better characterize their textures, and identify the main volcanic facies characterizing these units. The results confirm the effusive nature of the Lemoine Rhyolite whereas preliminary results suggest the Lac Coco Rhyolite is intrusive, as it is characterized by a coherent facies and appears at different levels. The Marelle Rhyolite is interpreted as intrusive for the same reasons. The Alpha Rhyolite is effusive however, as indicated by the presence of lobe and breccia facies in drill core. The Alpha Rhyolite is locally strongly altered to chlorite and sericite and appears lower in the stratigraphy relative to the Lemoine Rhyolite, suggesting the presence of active hydrothermal zones lower in the volcanic sequence (predating the formation of the Lemoine ore deposit).

G14

Geochemical classification of the rocks of the Blake River Group (Abitibi Subprovince)

SARANE STERCKX, PIERRE-SIMON ROSS (INRS)
AND JEAN GOUTIER (MRN)

The Abitibi Subprovince, a belt of Archean volcano-sedimentary rocks, is one of the best places in the world to explore for VMS-type copper, gold, zinc and silver deposits. The Blake River Group (BRG), in the Rouyn-Noranda area, contains two major VMS mining camps: the Noranda camp and the Doyon-Bousquet-LaRonde camp, representing almost half the total VMS tonnage from the Abitibi.

The VMS deposits are controlled in part by the stratigraphy, which is why it is important to improve our knowledge on the stratigraphy of the submarine rocks of the BRG. Few marker horizons are known at the regional scale. In the past few years, however, thousands of geochemical analyses, including trace element analyses, have become available. Moreover, many U-Pb ages have been obtained to provide a temporal framework for the volcanic events and the mineralization.

The project commenced in autumn 2012 at INRS-ETE with the support of the MRN. It is based on the compilation of lithogeochemical data and aims to better constrain the stratigraphy of the BRG. The compilation combines the existing data contained in SIGÉOM with new analyses for samples that fill in specific gaps in the lithogeochemical coverage, in addition to reanalyses of old samples for trace elements. This work yielded a geochemical database of almost 2,000 analyses. Our interpretation of these data identified the signature and geochemical homogeneity of the stratigraphic units. Following this step, the spatial coherence of potential geochemical groupings will be examined.

This poster will show how the intense alteration affecting some of the BRG rocks is the first hurdle to overcome in establishing a detailed classification of these rocks. In fact, the classic classification diagram (SiO_2 vs Zr/TiO_2) only applies to the least altered samples since silica is sensitive to alteration. A diagram based on immobile trace elements (Zr/TiO_2 vs Nb/Y) is not entirely satisfactory either, since it does not yield the same classification as the diagram based on silica, even if only the least altered samples are used. In the case of BRG volcanics, it is therefore necessary to propose a new classification diagram.

Gold mineralization associated with the Porcupine-Destor Fault: The Duquesne-Ottoman property, Abitibi, Québec, Canada

SACHA LAFRANCE AND MICHEL JÉBRAK (UQAM)

The gold mineralization of the Archean Abitibi greenstone belt covers a wide range of styles and geological contexts. In the Duparquet mining district (Québec), volcanogenic, felsic porphyry (Beattie mine) and gold shear zone models coexist along the Porcupine-Destor Fault. It is therefore a key area for deciphering the relationships between these different models. The Duquesne-Ottoman property is being explored and developed by Globex for its gold potential.

Rouyn-Noranda is 10 km east of the municipality of Duparquet. The rocks of this region are primarily of volcanic origin and Archean age (2722 to 2718 Ma). The property is located in the heart of the Kinojevis Group, north of the Porcupine-Destor Fault. The Kinojevis Group is interpreted as a volcanic arc that was deformed by continental collision. The study area is primarily underlain by intermediate to mafic volcanic rocks with lesser amounts of felsic volcanics, ultramafics and quartzo-feldspathic porphyries. A large polygenic breccia is also present on the property, evidence of early hydrothermal processes related to high-level volcanism.

A shear zone cuts the volcanic sequence of the property. This fault zone is part of the Porcupine-Destor Fault. It averages 5 to 10 m wide and is generally oriented 070N to 090N with a dip of 75° to 90°. Within this shear zone are slices of quartzo-feldspathic porphyries that distinguish, by rheological contrast, the shear zone from the intermediate to mafic volcanic sequence. This E-W fault underwent dextral reverse movement.

The three main gold zones on the Duquesne-Ottoman property (Liz, Shaft and Fox) are present in the E-W shear zone. The Fox Zone occurs within altered mafic tuffs at the contact with a quartzo-feldspathic porphyry. The Shaft Zone is found in schistose mafic volcanics, proximal to quartzo-feldspathic porphyries and alkaline intrusions. The Liz Zone occurs in sheared and strongly altered mafic volcanic rocks. All three zones are discordant to stratigraphy and associated with an assemblage of sericite, iron-rich dolomite and pyrite. The intensity of alteration is greatest in the intermediate to mafic volcanics, at their contact with the quartzo-feldspathic porphyries.

Mineralogical study of the gold zones of the Augmitto-Astoria segment of the Cadillac Fault, Rouyn-Noranda, Québec

JULIEN LAPORTE, MICHEL JÉBRAK (UQAM)
AND BAPTISTE CHAPON (YORBEAU RESOURCES)

The Cadillac Fault is internationally renowned for its gold mineralization (Dubé and Gosselin, 2007). Different hydrothermal episodes have produced several types of mineralization (Raffini, 2013). Yorbeau Resources owns a mineral exploration property along this fault zone, in the Rouyn-Noranda mining camp. Mineralogical, geological and geochemical comparisons along the Augmitto-Astoria segment have allowed each sector to be characterized. Mineralization occurs: 1) in the hanging wall and footwall sediments of the fault zone, with quartz-carbonate-tourmaline veins cutting the sericitized sediments that are mineralized with arsenopyrite ± visible gold; and 2) in komatiite-type host rocks, with quartz-tourmaline-carbonate veins mineralized with visible gold ± arsenopyrite, cutting the carbonate ± fuchsite-bearing ultramafic rocks.

The work primarily focused on the geology and mineralogy of the footwall of the fault zone. Gangue minerals include quartz, carbonates, tourmaline, chlorite and micas. The sulphide phases are arsenopyrite, galena, pyrite, chalcopyrite and pyrrhotite, and some oxides are present, including magnetite, ilmenite, hematite, monazite and rutile. The rocks locally yield bismuth and antimony values. Proximal zones are defined by mineral associations of quartz, micas, carbonates, tourmaline, visible gold and arsenopyrite. Distal zones are characterized by micas (biotite-sericite) and traces of tourmaline. Several gold-bearing episodes were recorded and these display a strong correlation with arsenopyrite, the dominant sulphide. Free gold is present in the matrix, as inclusions, along grain boundaries, and as infillings in cavities and/or fractures in arsenopyrite. Widely fractured areas filled with arsenopyrite masses and subhedral crystals with inclusions and/or cavities contain the greatest quantities of visible gold. Euhedral crystals with baguette or lozenge shapes and very little fracturing do not seem to be associated with visible gold. Until now, no relationship had been documented between gold habit and grade. The timing of gold appears to be late, with silver contents ranging from several percent to more than 25% by mass.

Along the Augmitto-Astoria segment, metamorphism attained greenschist facies whereas near the dyke, metamorphism attained amphibolite facies. Scanning electron microscope observations of samples from the Astoria area revealed an association between gold, loellingite and arsenopyrite near the dykes.

Gold mineralization of the Wasamac shear zone, Rouyn-Noranda, Québec

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AND RAYNALD VINCENT (RICHMONT MINES)

The Wasamac property is situated 15 km southeast of the city of Rouyn-Noranda. It is located along the Francoeur-Wasa Fault, a kilometre-scale satellite of the Cadillac-Larder Lake Fault, the southern structural boundary of the Abitibi Subprovince. The Cadillac-Larder Lake Fault hosts 72 deposits in Québec, many of which contain total resources of more than 100 tonnes of gold. The majority of the gold mineralization in these orogenic deposits is present in veins or in the cores of metasomatized shear zones.

The Wasamac Fault is a brittle-ductile fault oriented east-west and with a moderate 55° dip to the north. This structure marks the boundary between two lithologies: andesites in the footwall of the shear zone and rhyolite in the hanging wall, with preferential deformation of the more ductile andesites. These host units belong to the felsic to mafic metavolcanic sequences of the Blake-River Group (Noranda Subgroup). The width of the deformation zone locally exceeds 100 metres and is characterized by strong hydrothermal alteration in a mylonitized unit. The Wasamac shear zone is marked by a S1 schistosity, locally very intense, which is overprinted by a crenulation (S2) cleavage and associated slightly overturned Z-shaped centimetre-scale folds and microfolds.

The alteration documented in the shear zone comprises an assemblage of albite-sericite-carbonates-microcline-chlorite-hematite. This alteration, observed as successive centimetre- to millimetre-scale bands in drill core with an overall property-scale longitudinal zonality (with respect to the east-west axis), correlates with two distinct types of mineralization. The first zone is potassic in nature and associated with gold mineralization mostly in the form of tellurides. A second zone, observed in places adjacent to the first, is propylitic with a dominantly albite-sericite-chlorite-carbonate composition in which gold is almost always present as native gold. The potassic alteration is younger than the albitic alteration based on cross-cutting relationships.

The spatial arrangement of the transverse zonality and the timing of the alteration types suggest that Wasamac mineralization was the result of two hydrothermal phases: the first was alkaline in nature and possibly magmatic, with similarities to Kirkland Lake-type mineralization, whereas the second was the result of a lower-temperature process.

Plutonic suites in the Northeastern Superior Province (NESP), Québec Canada: A preliminary metallogenic approach

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AND ANDRÉA AMORTEGUI (MRN)

The Far North mapping program completed by the *Ministère des Ressources Naturelles du Québec* (MRN) from 1997 to 2003 namely resulted in the compilation of a vast amount of analytical data. The study area, covering about 350,000 km², corresponds to the Northeastern Superior Province (NESP) or the Minto Subprovince. The NESP is essentially composed of Archean plutonic rocks of the TTG (tonalite-trondhjemite-granodiorite) suite. Felsic plutonic rocks are by far the most widespread, with 40% tonalites, 20% granites, 15% granodiorites, 15% charnockites, and less than 1% monzonites and syenites (Simard *et al.*, 2008).

It is possible to assess the mineral potential of granitic suites in the NESP by defining their typology, analyzing their distribution, comparing them using regional data, and targeting areas of interest.

Numerous authors (Chapell and White (1974, 2001); Ishihara (1977, 1981); Blevin (1995, 2004); Černý (2005)) have shown that geochemical characterization of granitic suites and tracking magmatic processes can provide insights into their metalliferous potential. Based on its regional mapping programs and in collaboration with the mining industry, the Australian government studied the spatial relationship and the genetic link between intrusives, mineral occurrences observed in the field, and surrounding country rocks. The oxidation state and the degree of fractionation of granitic intrusives appear to be the main factors controlling the genesis of ore deposits. Overall, Cu-Au and Cu-Mo deposits tend to be spatially associated with oxidized and weakly fractionated intrusives (magnetite series). On the other hand, Sn and Sn-W mineralization tends to be associated with reduced and fractionated intrusives (ilmenite series).

Using new unpublished FeO data obtained by the MRN, it is now possible to apply this methodology to the NESP. According to the diagram showing Fe₂O₃/FeO (oxidation state) versus Rb/Sr ratios (degree of fractionation) (modified after Blevin *et al.*, 1995, 2003), analytical data for fresh intermediate to felsic intrusives appear to suggest a stronger metalliferous potential for Cu-Au and Cu-Mo mineralization in this region. Most of the analyzed intrusives belong to the magnetite series defined by Ishihara (1977, 1981). However, a certain heterogeneity in terms of oxidation state and degree of fractionation also appears to indicate local potential for Mo, W and Sn-W occurrences (ilmenite series). A regional assessment of these parameters (oxidation and fractionation) will make it possible to outline new areas of metallogenic interest within the NESP.

Magnetite-bearing parageneses of hydrothermal alterations in iron oxide-copper-gold systems

ANTHONY F. DE TONI (INRS-ETE), LOUISE CORRIVEAU (GSC-Q) AND JEAN-FRANÇOIS MONTREUIL (INRS-ETE)

Magnetite is a minor constituent in veins, breccias and replacements of the iron-oxide alkali-altered (IOAA) systems in the Great Bear Lake magmatic zone of the Northwest Territories. The predominance of magnetite in most iron oxide-copper-gold systems makes it a key mineral for understanding and tracking the evolution and development of such systems. Several magnetite-bearing parageneses associated with particular textures have been observed in these magmatic/hydrothermal systems. Macroscopic and microscopic observations were used to understand the processes that gave rise to the spectrum of documented textures. Mineralogical assemblages and textures can be used as exploration vectors for mineralization, whereas distinguishing between the different parageneses is a key element in understanding IOAA systems. We have established a protocol for the macroscopic and microscopic description of mineralization (replacement, breccia or vein types) to facilitate the description of these rocks in the field.

The main parageneses are: 1) magnetite (Fe alteration); 2) amphibole-magnetite $\pm$ apatite $\pm$ albite (high-temperature Ca-Fe $\pm$ Na alteration); and 3) K-feldspar-magnetite $\pm$ biotite or biotite-magnetite (high-temperature K-Fe alteration). Replacement by magnetite is preferentially concentrated around phenocrysts, in vesicles, in the matrix, or on fragments in the breccias. In layered rocks, the replacement is selective and stratabound along specific horizons. In porphyritic volcanic rocks, K-feldspar first replaces the matrix, followed by phenocrysts as the intensity of alteration increases, whereas biotite selectively replaces the mafic minerals. Replacement and vein-style high-temperature Ca-K-Fe and ultimately K-Fe alteration is generally followed by the formation of mineralized zones in which a wide range of elements may be concentrated (Cu, Au, Ag, Bi, Co, rare earths, etc.). Electron microprobe analyses measured the concentrations of Si, K, Ca, Al, Sn, Cu, Mn, Mg, Ti, Zn, V, Ni and Cr in magnetite grains associated with each paragenesis. The results indicate that magnetite chemistry varies according to: 1) paragenesis type; 2) whether the magnetite is of hydrothermal or magmatic origin; and 3) the presence or absence of mineralization. Ultimately, an atlas of iron-oxide alkali alterations and a chemical discrimination diagram of magnetite chemistry could be developed for use as exploration tools in underexplored areas.

Geophysical signatures of late Archean alkaline intrusions in the Abitibi, Québec-Ontario, Canada

CHARLOTTE CAPPÉ-KERBART, NOÉMIE FAYOL, CHRISTOPHE AZEVEDO, MICHEL JÉBRAC (UQAM) AND MICHEL CHOUTEAU (ÉCOLE POLYTECHNIQUE)

The Abitibi Subprovince contains late Archean alkaline intrusions with associated gold deposits. Formed between 2688 and 2672 Ma, these intrusions are often hosted within or adjacent to Timiskaming-type late Archean volcano-sedimentary basins. A geophysical study was carried out in Québec and Ontario to better understand the relationships between intrusions, host rocks and mineralization.

The alkaline intrusions and particularly the syenitic intrusions contain mineralization in the form of disseminated gold-bearing sulphides, with local concentrations of gold in quartz veins. In most cases, the mineralization is accompanied by alteration enriched in iron carbonates and iron oxides (magnetite-hematite). These minerals generate magnetic signatures around the intrusions.

Magnetic profiles were studied using a vertical derivative magnetic map. It was possible to distinguish different signatures based on the intrusions: (1) non-magnetic intrusions in strongly magnetic country rocks, as in the case of O'Brien (Lac Bachelor), Douay and Golden Arrow; (2) magnetic intrusions with more magnetic margins in less magnetic country rocks, as in the case of the Kirkland Lake district; and (3) magnetic intrusions with non-magnetic margins in more magnetic country rocks, as in the case of Holt Mc Dermott.

When interpreting the geophysical signatures of syenitic intrusions, it is therefore important to take into account the lithological nature of the country rocks and the effects of metasomatic processes along the margins of the intrusions. Furthermore, an analysis of the Otto pluton (Kirkland Lake) demonstrates that an intrusion's magnetism increases with depth, suggesting that iron-bearing minerals may accumulate at depth. Magnetic susceptibility measurements taken in the field should prove useful for determining correlations between lithologies, mineralization, and magnetic signatures.

Quaternary sediment mapping in the Chaudière-Appalaches region: Results and prospects

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In March 2012, the *Ministère du Développement Durable, de l'Environnement, de la Faune et des Parcs du Québec* provided financial assistance for the realization of a groundwater knowledge acquisition project (GKAP) in the Chaudière-Appalaches region. This GKAP namely includes a mapping component focusing on surficial sediments in this region. A team from the Geography and Earth Science departments at UQAM was assembled to carry out the Quaternary mapping program divided into two phases. The first phase of mapping was undertaken in the summer of 2013 and covers a surface area of 11,385 km² in 12 NTS map sheets at a scale of 1/50,000. The objective of this mapping campaign is to define the spatial distribution of the main lithostratigraphic units in this area. This work involved a preliminary assessment using aerial photographs at a scale of 1/40,000, to locate areas of interest such as sand and gravel pits, stratigraphic sections, and to trace the main geomorphological features. Subsequently, these observations were verified during a field campaign aiming to characterize the nature of deposits and thus complete the preliminary assessment. Preliminary data indicate that areas in the heart of the Appalachians are mainly dominated by sediments of the last glaciation (thin or continuous till cover, Tm or Tc), with more restricted areas characterized by sediments associated with the last deglaciation (glaciofluvial deposits, Gx and Gs). The area adjacent to the St. Lawrence River is distinctive with its abundant glaciomarine coastal (MGb) and deep-water (MGa) sediments. Overall, the results of this work will help refine the Quaternary history of this region and will provide the data required for the groundwater component of the project. Mapped features will be processed using digital mapping methods (GIS) to produce maps with a standardized legend. Preparation of maps for the first phase of the project and of an accompanying report is expected to be completed on May 20, 2014. Subsequently, the acquired data will be transferred to the primary users of the resource, namely those responsible for land management.

An overview of Quaternary mapping work in the Vaudreuil-Soulanges region

PIERRE-MARC GODBOUT AND MARTIN ROY (UQAM)

Mapping of the Quaternary deposits in the Vaudreuil-Soulanges region began in the summer of 2013. The work was carried out as part of a municipal groundwater knowledge acquisition program (PACES: *Projet d'acquisition de connaissances sur les eaux souterraines*). The area covers 814 km² and extends over four map sheets at 1:50,000 scale (31G01, 31G08, 31G09 and 31H05). The high quality of the previous mapping work (Richard, 1976, 1977, 1982) became evident while the field surveys were being carried out last summer. However, some differences were noted, particularly in the Saint-Lazare area where some of the thick sand units that were previously interpreted at surface as glacial outwash sediment (Richard, 1982) have now been reinterpreted as reworked deltaic sediments deposited in the estuary formed by the Ottawa River and the St. Lawrence in the Champlain Sea. This reinterpretation is based primarily on the distribution of fossiliferous sites and on sedimentary data obtained from the largest sand pits in the area, thereby confirming the results of the aggregate resource inventory conducted by Brazeau (1997a and 1997b). The work indicates that sedimentation in this area was strongly influenced by the presence of the Mont Rigaud massif, which is surrounded by sedimentary rocks of the St. Lawrence Platform and served as an anchor point for glacial ice retreating to the north. The conclusion that the sediments were deposited at the contact with waters of the Champlain Sea is supported by the presence of subaquatic outwash sand near the partially buried Saint-Télésphore esker and numerous generally east-west moraine ridges made of till. Overall, the mapped sediments are primarily coastal, deltaic and deep glaciomarine sediments, respectively constituting the lithostratigraphic units MGb, MGd and MGa. The units are directly juxtaposed with sediments from the last glaciation (till, Tc) and those associated with deglaciation (glaciofluvial deposits Gx and Gs). The alluvium of the proto-St. Lawrence and the proto-Ottawa River, often deposited as staggered alluvial terraces and as paleochannels, along with Holocene sediments (O and Ot), complete the general portrait of the mapped features. Only one site, Pointe-Fortune (Veillette and Nixon, 1984; Anderson *et al.*, 1990), exhibits cross-bedded sandy sediments of fluvial origin that predate the last glaciation. The mapping work will continue in winter 2013 using SUMMIT EVOLUTION photo-interpretation software, followed by a geological report and the publication of the final map in late March 2014.

G23

Rare earth mobility and sedimentary record in sediments from a northern lake

JADE BERGERON, CHARLES GOBEIL AND
ANDRÉ TESSIER (INRS-ETE)

Profiles for the pH level and rare earth element concentrations (Y, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb and Lu) as well as Fe, Mn, sulphate, sulphide, organic C, and major ion concentrations were determined for interstitial waters from sediments in an oligotrophic lake in the Canadian Shield. The vertical distribution of rare earth elements (REE), Fe, Al, total S, and organic C was also determined for dated (^{210}Pb , ^{137}Cs) sediment cores from the same lake. REE profiles in interstitial waters exhibit concentration gradients indicating these elements are reactive during the early stages of sediment diagenesis. The profiles were modeled based on a unidimensional transport-reaction equation, revealing net reaction speeds likely to result in only minor redistribution of elements following deposition in the sediment column. In the worst case, redistributed elements represented 3% of measured grades, indicating that sedimentary records are an accurate reflection of the chronological variations of REE contents in particles deposited at the water-sediment interface. The historical reconstruction of REE streams suggests the latter have increased throughout the 20th century. We interpret this trend in atmospheric REE emissions as the result of poorly defined anthropogenic sources, for example household waste incinerators or oil refineries.

G24

Quantifying the reliability of discontinuity orientation measurements in oriented drill core and the impact on mine slope stability assessments

JOSEPH KABUYA MUKENDI AND MARTIN GRENON (ULAAVAL)

During the initial phases of a mining project, rock slope design relies on data collected from oriented drill holes. The reliability of fracture orientation measurements can vary considerably along the drill core. A simple procedure was used to assess the reliability of such orientation measurements. The procedure was based on observations and drill core measurements taken during field surveys. As part of the project, a program was carried out in autumn 2011 at the site of the Meliadine mine project. Fracture orientation measurements were analyzed as a function of the degree of reliability. Similarities and differences were statistically quantified. Results indicate that the orientation of a family of discontinuities (average and dispersion) varies according to the degree of reliability. It was demonstrated that the variation in orientation values can have a significant impact on slope stability. The approach we developed constitutes a decision-support tool in terms of which fractures should be taken into account when designing a mine pit after conducting an oriented drilling program.

G25

Geomechanical analyses at the Meliadine mine project

JOSEPH KABUYA MUKENDI AND MARTIN GRENON (ULAAVAL)

This project addresses three aspects of the geomechanical design of mine pits using a case study carried out at the Tiriganiaq pit of the Meliadine mine project. First, a methodology was set up to quantify the reliability of fracture orientation measurements taken during programs of geomechanical characterization using oriented drill holes. We then investigated the impact of orientation measurement reliability on the results of a kinematic analysis of pit slope stability. Second, we studied an approach to quantify the contribution of successive structural data acquisition programs at a mine site on the characterization of fracture orientation. Finally, we assessed the stability of mine benches in the pit using software tools developed during the author's research work. We propose a systematic multicriteria approach using susceptibility maps to assess mine bench reliability.

G26

Geology of the Lac Okaopéo area, Côte-Nord (NTS 22K01, 22K02, 22K07, 22K08, 22K09 and 22K10)

ABDELALI MOUKHSIL, FABIEN SOLGADI (MRN), SAÏD BELKACIM, ABDELAZIZ ELBASBAS AND THOMAS CLARK (URSTM-UQAT)

The mapped area constitutes the third and final phase of a regional mapping project aiming to acquire new geological and metallogenic knowledge in the Côte-Nord region (NTS sheet 22K). Located south of Manic 5 Reservoir, the study area lies in the central Grenville geological Province.

Geological mapping was carried out at a scale of 1/50,000 in areas accessible by logging roads, and at a scale of 1/125,000 in areas with no land access. Several geological units were identified as a result of field mapping combined with a recent aeromagnetic survey. The oldest rocks in this area are metasedimentary rocks of the Plus-Value Complex (plv, <1765 Ma, >1487.6 Ma); the latter are intruded by the Bardoux plutonic Suite (bar, 1488 Ma) composed of garnet-bearing granite with porphyritic and porphyroclastic to augen textures. The Hulot Complex (ulo, 1434-1373 Ma) occupies the southwest part of the area and consists of porphyritic plutonic rocks (granite, charnockite, enderbite) and tonalitic to granitic gneisses associated with diorites and quartz diorites. The Renwick Mangerite (1402 Ma), strongly deformed and intruded by the Berté Anorthosite, was mapped in the NNE part of the area. The eastern and central parts of the area are underlain by rocks of the Castoreum plutonic Suite (not dated), consisting of porphyritic to porphyroclastic granites, charnockites, monzonites, and granitic gneisses. Another assemblage of strongly deformed tonalitic to granitic gneisses is exposed in the eastern part of the area (Baie-Comeau Complex, 1103 Ma). Mafic to ultramafic dykes (1228-1046 Ma) cross-cut all of these lithologies. Younger intrusions composed of porphyritic mangerite, oxide-bearing gabbro-norite (Fe-Ti ± P) and granite were also mapped within the study area (for example the Sabot Mangerite; 1016-1017 Ma). The latter were followed by the emplacement of mafic and ultrapotassic biotite-bearing dykes.

Two major phases of folding and a migmatization event affected the older units in the area (plv, ulo, bar). The first phase is represented by isoclinal F2 folds with NE-SW-trending axial planes, parallel to the planar fabric and the regional structural grain. The second phase mainly consists of open F3 folds with axial planes at a 20 to 30° angle relative to F2 axial planes. Wide mylonite zones several kilometres long cut across the study area along a NNE-SSW to NE-SW orientation. Rocks in the area are metamorphosed to the granulite facies (moderate pressure).

In terms of economic potential, the mapped area contains mineral exploration targets for REE, Fe-Ti oxides, Ni-Cu mineralization, and architectural stone.

Apatite potential in Québec

N'GOLO TOGOLA (MRN)

Québec offers good potential for apatite deposits. Two mining projects (Lac à Paul and Arnaud) focusing on the production of an apatite concentrate are currently in the development phase.

Apatite constitutes one of the main minerals found in phosphate rocks. This mineral is a source of phosphorus oxide (P_2O_5), which is namely used to produce mineral fertilizer.

The main apatite occurrences in Québec are located, for the most part, in the Grenville geological Province. The latter contains phosphate resources associated with anorthositic suites, layered igneous complexes, and carbonatites associated with alkalic igneous complexes.

Anorthositic suites in the Grenville Province locally contain apatite associated with iron-titanium mineralization hosted in ferrodiorite, gabbro, norite, monzonite, jotunite, leuconorite, leucotroctolite, and troctolite units within anorthositic complexes.

In the north part of the Saguenay-Lac-Saint-Jean region, the Lac-Saint-Jean Anorthositic Suite hosts the Lac à Paul deposit, one of the largest apatite deposits in Québec. This ore deposit is located in the Chute-des-Passes area north of Lac Saint-Jean. It contains several mineralized zones (Paul, Manouane, Zone 2). The Lac à Paul mining project is based on the Paul zone. In March 2013, measured and indicated resources in the Paul zone were estimated at about 590,240,000 tonnes grading 7.13% P_2O_5 .

The Sept-Îles igneous Complex, a layered mafic complex, also hosts a significant apatite deposit: the Rivière des Rapides deposit located near the town of Sept-Îles in the Côte-Nord region. In this ore deposit, apatite mineralization is hosted in nelsonite or titanium magnetite layers. The Arnaud mining project is based on the Rivière des Rapides deposit. Indicated resources are estimated at 110,870,000 tonnes grading 4.16% P_2O_5 , whereas measured resources stand at 370,870,000 tonnes grading 4.24% P_2O_5 .

Carbonatites in alkalic igneous complexes in the Grenville Province also offer interesting potential for apatite. Some apatite occurrences are associated with niobium-tantalum-rare earth deposits hosted in these carbonatites (Saint-Honoré, Oka, Crevier).

There are also minor apatite concentrations locally reported in alkalic intrusions (Sainte-Véronique, Mont Saint-Hilaire) or in hyperalkaline intrusions (near Parent in Haute-Mauricie).

Geology and mineral potential of the Lac des Vœux region (James Bay)

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A geological survey at 1:50,000 scale was carried out during the summer of 2013 in the Lac des Vœux region of James Bay, covering map sheets 33H10, 33H15 and 33H16. The mapped region lies within the La Grande Subprovince. This work is supported by new high-resolution airborne magnetic and spectrometric surveys.

The region is mostly underlain by Archean rocks. A large part of the area is occupied by the Polaris Batholith, of which the central part exposes potassic porphyritic rocks of intermediate to felsic composition.

Other voluminous felsic intrusions were mapped, mainly in the eastern and southern parts of the study area. They represent late Archean magmatism, principally syn- to post-tectonic. They belong to the Coates Suite (2743 to 2716 Ma, tonalitic), the Tramont Suite (2707 to 2686 Ma, granitic), the Savonnière Suite (2685 Ma, felsic to mixed) and the Sauvolles Granite (2708 Ma). The basement rock, represented by the Langelier Complex (3360 to 2788 Ma, foliated gneiss and tonalites), crops out slightly in the southwest part.

Remnants of dismembered volcanic belts are present in the southern part of the study area. These represent extensions of the Guyer Group (2820 to 2806 Ma), which was recognized further west during previous work, and the Escale Formation, which was mapped further east in 1996. We also found the extension of the Aquilon Belt, a NW-SE band in the northeast corner of the study area. Volcanics are intercalated with some sedimentary horizons and were metamorphosed to amphibolite facies.

Ultramafic rocks are present in the northeast corner of the study area in the form of sills within metavolcanic rocks of the Aquilon Belt. Their magnetic signatures form bands up to 200 m wide and 10 km long.

Dykes of gabbro and gabbro-norite cut the Archean rocks and display a strongly magnetic signature. The age of these dykes ranges from Neoproterozoic to Proterozoic.

The structural grain is variable. In the southern part, the arrangement is generally E-W to NE-SW, whereas in the east it becomes NW-SE, similar to the Minto orientation. Ductile shear zones separate the ancient volcanic belts and felsic intrusions. Metamorphism generally attained amphibolite facies.

Several rusty horizons were observed within the metavolcanics. In some cases, these horizons are associated with sulphide zones, containing an assemblage of PY-PO. The region also displays significant potential for the following types of mineralization:

- ▶ gold and base metal mineralization associated with iron formations;
- ▶ base and precious metal volcanogenic mineralization, including sulphide layers and sulphide disseminations (PY-PO ± CP) in alteration zones;
- ▶ Cu-Ni-PGE mineralization in ultramafic rocks.

Geology of the Lac Richardie area, Baie-James: The boundary between the Opinaca and La Grande subprovinces

JEAN GOUTIER (MRN), JOSÉPHINE GIGON (UQAT-URSTM)
AND WILLIAM CHARTIER-MONTREUIL (MRN)

The Lac Richardie area is located about 100 kilometres south of the La Grande 4 Reservoir. NTS sheets covered by this geological survey at a scale of 1/50,000 are: 33H02, 33H03 and 33H07. Previous geological surveys dating back to the 1950s and 1970s consisted in reconnaissance geological mapping (1/506,880) by the Geological Survey of Canada and regional mapping (1/100,000) by the MRN. Recent gold prospecting work has been carried out by industry. This area is located in the northeastern Superior Province and straddles the La Grande and Opinaca subprovinces. It is underlain by Archean rocks and Archean (Mistassini) and Proterozoic (Senneterre and Lac Esprit) gabbro-gabbro-norite dyke swarms. Archean metamorphism ranges from the amphibolite facies in the north to the granulite facies further south. Rocks of the Opinaca Subprovince mainly consist of biotite paragneisses and migmatites. They are intruded by significant volumes of centimetre-scale to decametre-scale granitic injections. Rocks of the La Grande Subprovince occupy the north part of the study area. They include: an early tonalite and tonalitic gneisses (2.84 Ga); mafic and intermediate volcanic rocks (2.7 Ga), transformed into banded amphibolites; silicate and magnetite iron formations and paragneisses. Certain volcano-sedimentary bands represent the extensions of the Escale and Trieste sequences. One of these contains an alteration zone with cordierite and anthophyllite associated with felsic volcanoclastic rocks and a leucocratic metagabbro-anorthosite. These rocks are intruded by large granitic bodies. Small ultramafic intrusions are injected in rocks in both subprovinces; they are much less deformed than their respective country rocks but show the same metamorphic grade. As a result of this work, the boundary between the La Grande and Opinaca subprovinces is now more clearly defined. This boundary is an important gold metallogenic in the Baie-James region. It is partly shaped by syntectonic plutons that were emplaced between the two subprovinces. The geology of the Quentin gold showing located at the contact between the two subprovinces, regional metamorphism, and ultramafic intrusions are the focus of undergraduate projects.

Ultramafic to mafic magmatism of the La Grande and Eastmain domains in the Superior Province, James Bay, Québec

MICHEL G. HOULÉ (GSC-Q) AND JEAN GOUTIER (MRN)

The James Bay region is dominantly underlain by Archean rocks belonging to the Superior Province, which is mainly composed of alternating sequences of predominantly sedimentary, volcano-plutonic and plutonic rocks. The distribution of mafic to ultramafic intrusions and ultramafic volcanism reveals a general abundance at the scale of the region, with the greatest volume in the La Grande and Eastmain domains in the central-east part of the Superior Province between the Opinaca Subprovince to the south, the Ashuanipi Subprovince to the east, and the Minto Subprovince to the north.

Although not yet well studied, it is thought that the ultramafic-mafic magmatism extended over a period of more than 200 Ma, from approximately -2.88 Ga to 2.66 Ga. Various types of ultramafic to mafic magmatism have been documented in the La Grande and Eastmain domains and their vicinity: 1) ultramafic lavas and ultramafic intrusions of komatiitic affinity; 2) dominantly ultramafic intrusions; 3) dominantly mafic intrusions; 4) ultramafic to mafic intrusions of alkaline affinity; and 5) lesser volumes of ultramafic lamprophyres. Several of these ultramafic to mafic magmatic types also contain Cr-PGE, Ni-Cu-PGE or Fe-Ti-V mineralization. The most important examples of these types of mineralization are the Menarik Complex (Cr- PGE), the Lac des Montagnes intrusion (Cr- PGE), the Lac Gayot intrusions (Ni-Cu-PGE), the Nisk intrusion (Ni-Cu- PGE), and the Baie Chapus Pyroxenite (Fe-Ti-V).

As part of the Targeted Geoscience Initiative – Phase 4 (TGI-4), the Geological Survey of Canada and the Ministère des Ressources naturelles du Québec have undertaken reconnaissance work to better characterize these types of intrusions in terms of their distribution, geochemical character, and prospectivity for the above-mentioned mineralization types. Studies are ongoing for intrusions in the Yasinski, Des Montagnes, De Fed and Pelletan areas, in addition to a more regional study underway in the area south of the La Grande 4 Reservoir. New geochronological work is also underway, which will allow us to better understand the temporal distribution of the ultramafic to mafic magmatism of this region in the Superior Province. A better understanding of these ultramafic to mafic intrusions will also reveal whether they demonstrate similar characteristics to ultramafic to mafic intrusions recently discovered in the McFaulds Lake area of Ontario (“Ring of Fire”), which contains major Cr-(PGE) and Ni-Cu-PGE deposits.

Geology and economic potential of the Lac Henrietta region, southeast Churchill (NTS 24H)

ISABELLE LAFRANCE, DANIEL BANDYAYERA
AND CARL BILODEAU (MRN)

This new geological survey at a scale of 1:250,000 was carried out in the summer of 2013 in the Lac Henrietta area, located 200 km southeast of Kuujuaq. The mapped area is part of the Core Zone of the southeast Churchill Province, which corresponds to an ancient Archean craton that was deformed and remobilized in the Proterozoic during the formation of the New Québec Orogen to the west and the Torngat Orogen to the east.

In this region, the Core Zone comprises two distinct domains separated by the Blumath Fault, generally oriented N-S to NNW-SSE. The rocks on the west side of the fault are Archean gneisses, migmatized to various degrees and injected by various Proterozoic potassic intrusions. The majority of these intrusions are part of the De Pas Batholith, which crosses the entire Core Zone over a distance of more than 600 km along a NNW-SSE axis. A roughly 50-km magnetic dome of orthopyroxene-bearing rocks was also observed within the gneissic rocks. On the east side of the Blumath Fault, the rocks were affected by the Torngat Orogen and constitute a sequence of enderbite and orthopyroxene diorite, commonly enclosing a diffuse charnockitic phase. These rocks are currently assigned to the Core Zone and considered to be the equivalents of the granulite-facies Archean gneiss sequences. Multi-kilometre slices of metavolcanic rocks were also observed throughout the Core Zone.

In the western part of the mapped area, the NNW-SSE-trending George River Shear Zone affected the Archean and Paleoproterozoic units over a width of more than 25 km. The regional structural grain of the Core Zone is essentially NNW-SSE with a dip to the northeast. East of the Blumath Fault, the structural grain displays a more regular orientation and a steep dip. The rocks east of the fault are also characterized by the development of a strong subhorizontal stretching lineation.

Our work revealed a well-preserved volcano-sedimentary belt measuring 4 to 8 km wide and more than 25 km long in the west part of the region. Several mineralized zones were also observed within a folded sequence of quartzite and paragneiss injected by layered ultramafic intrusions. Finally, sulphide veins (chalcopyrite $\pm$ pyrite) are associated with secondary shears cutting the De Pas Batholith.

Presentation of geophysical data published in 2013

RACHID INTISSAR, ISABELLE D'AMOURS
AND SIHAM BENAHEM (MRN)

Géologie Québec continued its large-scale airborne geophysical surveying of several geological provinces in 2012 and 2013. The number of linear kilometres flown over the past year is on the order of 296,000 km and covers a surface area of about 75,161 km². The ultimate goal of these high-resolution surveys is to provide a tool to support geological mapping, not only for Géologie Québec projects but for private company projects as well, and to encourage mining exploration in general. These data also stimulate private investment in exploration by generating targets of interest.

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

- ▶ **DP 2013-01:** Airborne magnetic survey covering 42 map sheets at 1:50,000 in the Lac Vallard area, southwest of Fermont. A large part of this survey was flown over the Grenville Province, whereas the rest was flown over the Superior Province. The company Geo Data Solutions conducted the survey.
- ▶ **DP 2013-02:** Magnetic and spectrometric survey covering 33 map sheets at 1:50,000 in the Lac Romanet area, Labrador Trough (Churchill Province). It was conducted by the company Geo Data Solutions. This survey, along with those conducted in 2011, complete the coverage of the Labrador Trough in terms of high-resolution magnetic and spectrometric data.
- ▶ **DP 2013-03:** Magnetic and spectrometric survey covering 17 map sheets at 1:50,000 scale in the Rivière de la Baleine region, Churchill Province. This survey was conducted by the company Eon Geosciences.

The processing and preliminary interpretation of the spectrometric data from these latter two surveys identified several exploration targets that were published in a promotional document (PRO 2013-01) available at www.mrn.gouv.qc.ca/produits-services/mines.jsp, via the tab E-Siggeom (Examine).

Geology of the La Motte area (NTS 32D08-SE)

PIERRE PILOTE, PIERRE LACOSTE, JAMES MOORHEAD (MRN), RÉAL DAIGNEAULT (UQAC), VICKI McNICOLL (GSC-O) AND JEAN DAVID (MRN)

The La Motte area is located in the southern Abitibi Subprovince. This three-year mapping project (2012-2014) covered during the summer of 2013 the southeast quadrant of NTS sheet 32D08 at a scale of 1/20,000. This work will provide a link between mapping carried out in the western Malartic Group (2006-2009) and previous work in the Val-d'Or area.

The La Motte area is underlain by Archean volcanic rocks (the Malartic and Louvicourt groups) and sedimentary rocks (Kewagama Group). This area represents the extension of volcanic units found in the Val-d'Or area, which is renowned for its wealth of volcanogenic massive sulphide and gold deposits. The Malartic and Louvicourt groups in this area encompass the La Motte-Vassan (2714 ± 2 Ma; which includes Spinifex Ridge), Dubuisson (2708 ± 2 Ma), Jacola (2706 ± 2 Ma), and Héva (2702 ± 2 Ma) formations. The lateral extent and thickness of each formation is quite variable in the area. The general orientation of S0 stratigraphic surfaces is also quite variable, ranging from WNW-ESE in the southeast corner of the map area, to NW-SE and N-S in the central part, to E-W in the north part. An S1 schistosity is moderately to intensely developed and appears to be subparallel to S0. This area is affected by the La Motte-Vassan Anticline, an F1 fold trending NW-SE to N-S. An E-W-trending S2 cleavage intersects the S1 fabric, mainly in areas where the stratigraphy is N-S or NW-SE. Stretching lineations are strongly developed in the central part of the area; they are moderately east-plunging in the west part but moderately west-plunging in the east part. The study area is transected by important shear zones and longitudinal faults, including the La Pause, Rivière Héva and Manneville South faults, all trending NNW to NW and steeply dipping to the north. Three extensive late- to post-tectonic intrusions, the Preissac (2680-2660 Ma), La Motte (2642 Ma), and La Corne (2680-2642 Ma) plutons, along with a series of isolated satellite bodies, cross-cut and deeply disturb the original volcanic and structural architecture. Regional metamorphism commonly reaches the amphibolite facies.

The La Motte area is distinguished by the fact that it contains the only nickel deposit ever mined in the Abitibi, at the former Marbridge mine. This mine was in production from 1962 to 1968 (703,000 metric tonnes of ore at 2.28% Ni and 0.17% Cu). The geology of the Marbridge area is characterized by ultramafic volcanic rocks (komatiites and peridotites), basalts, and massive to fragmental felsic volcanic rocks that are strongly foliated and rich in biotite-pyrite. The latter are commonly misinterpreted as sedimentary units. There are also legitimate sedimentary and volcanoclastic units, enriched in Py-Po-Mg. Nickel mineralization commonly occurs in the form of veins cross-cutting structural fabrics, suggesting significant remobilization in certain locations. Two other nickel occurrences are also reported in the area: the Cubric and Attaman zones. This area also hosts a molybdenum occurrence, dubbed Moly Hill, hosted in quartz-rich pegmatites and veins associated with the Preissac Pluton.

The results of this work will help improve our understanding and lead to a better definition of the mineral potential of this area. They will also help guide the search for comparable types of deposits elsewhere in the Superior Province.

Aggregate resource inventory in the Quaqtaq and Kangiqsujaq regions

ANDRÉ BRAZEAU AND GUILLAUME ALLARD (MRN)

In the summer of 2013, an inventory was made of aggregate resources in the vicinity of the northern villages of Quaqtaq and Kangiqsujaq.

The village of Quaqtaq is situated at latitude $61^{\circ}02'$ north and longitude $69^{\circ}37'$ west, on a peninsula that extends into the Hudson Strait. Its population is approximately 350 inhabitants. The village of Kangiqsujaq is situated on the southeast shore of Wakeham Bay, 10 km from the Hudson Strait, at latitude $61^{\circ}35'$ north and longitude $71^{\circ}57'$ west. The village has approximately 700 inhabitants. Both areas lie within the continuous permafrost zone.

The number of people living in northern villages is generally on the rise. Lodging and municipal infrastructure needs are very high. Permafrost coupled with global warming renders construction more difficult. The demand for aggregate material is greater than ever for the construction of road and building foundations.

The inventory results provide the locations and characteristics of aggregate material as well as their quantities. Field work mainly consisted of digging numerous test pits by shovel and visiting natural cuts and some sandpits. Eight samples of sand or gravel were collected from each region and sent to a laboratory to determine their physico-mechanical properties.

The main sources of aggregate are coarse glacio-marine sediments and coarse deltaic sediments. These were deposited during the last glacial retreat, which began around 7,900 years ago. The majority of these deposits were laid down along the edge of marine waters belonging to the postglacial Iberville Sea, which rapidly flooded the land surface still depressed from the passage of the ice sheet. The sea completely submerged the land to an altitude of 138 metres.

The sand and gravel sources close to the villages are nearly exhausted. Significant new sources were identified, approximately 9 kilometres from the villages and near access roads.

Drift prospecting in the southeast part of the Churchill Province: combined glacial and fluvioglacial sediment sampling

HUGO DUBÉ-LOUBERT (MRN), MARTIN ROY
AND OLIVIER LAMARCHE (UQAM)

Regions affected by major Quaternary glaciations continue to present difficulties for bedrock mapping projects and mineral exploration. The search for mineral resources in such regions is often complicated by several metres of glacial sediment cover that masks most of the underlying rock. In this type of terrain, many exploration programs have focused on collecting samples of glacial deposits to overcome this problem and target areas with the highest potential for mineral resources.

In the summer of 2012, the *Bureau de l'exploration géologique du Québec* initiated a large-scale Quaternary mapping program and glacial sediment (till) and fluvioglacial (esker) sampling program in the southern region of Ungava Bay. The project pursues two parallel objectives: first, the Ungava Quaternary project will assess the mining potential of the region using drift prospecting tools; second, the data collected from the Quaternary sediment samples will be supported by detailed mapping at 1:250,000 scale.

The Ungava region is particularly interesting for drift prospecting. Glacial flow directions and esker patterns converge toward the Ungava lowlands. A systematic sampling of eskers in this region should be able to detect evidence of kimberlites (kimberlite indicator minerals: KIMs) associated with the Mistassini-Lemoyne corridor further south (Moorhead *et al.*, 2000). In addition, the combination of till and esker sampling will respectively provide local- and regional-scale overviews of the region.

More than 800 till and esker samples were collected during the 2012 and 2013 programs. These were used to characterize grain size distribution and geochemistry of the matrix material. Heavy mineral concentrates were also extracted to test for the presence of kimberlite indicator minerals in the region. We will present the results for the samples collected during the 2012 program.

Geology of the Lac Lamarck (northern half of NTS map sheet 32G14) and Lac Thomelet region (southwest quarter of NTS map sheet 32J03)

FRANÇOIS LECLERC (MRN), YANNICK DAOUDENE
AND CHRISTINE VÉZINA (UQAM)

The mapping revision of the Lac Lamarck (southern half of NTS map sheet 32G14) and Lac Thomelet region (southwest quarter of NTS map sheet 32J03) constitutes the second phase of a survey conducted west of Chapais (Abitibi Subprovince, Québec). The objectives of the project are to: a) confirm the stratigraphic position of some of the volcanic units attributed to the Obatogamau and Waconichi formations; b) better define the trace of the contact between the Abitibi and Opatica subprovinces in the northern part of the region; c) investigate the potential for VMS and lode gold mineralization. The oldest rocks in the area are found north of Rivière Chibougamau and correspond to the mafic volcanic rocks of the Obatogamau Formation. Within this formation, the Pichamobi Member (felsic lapilli tuffs, rhyolite porphyries) forms an F1 syncline with a N-S axial trace refolded by a P2 anticline with an E-W axial trace. A sample of lapilli tuff will be analyzed to determine its age and to confirm the stratigraphic position of the Pichamobi Member. To the west of the Pichamobi, the axial planar S2 schistosity intensifies in the shear zones developed at the contact between the massive to pillowed volcanic rocks and the volcanic flow breccias and felsic intrusions. These strongly ankeritized zones host gold-bearing shear veins and tensions veins (quartz, carbonate, tourmaline, chlorite, epidote, fuchsite, pyrite, chalcopyrite, arsenopyrite). East of the NE-SW Lamarck shear zone, alternating units observed in the northern part of Lac Lamarck consist of: a) arenites and mudrocks; and b) volcanoclastic rocks of intermediate to felsic composition (lapilli tuff, crystal tuff and cherty tuff). The mudrocks locally contain graphitic horizons with Py-Po and lapilli tuffs representing chlorite-silica alteration zones containing disseminated sulphides. A sample of felsic lapilli tuff was collected for dating purposes, to determine whether these rocks belong to the Waconichi Formation. The northern part of the region corresponds to the boundary between the Abitibi and Opatica subprovinces. The intensity of metamorphism increases from greenschist to amphibolite facies and the tonalite dykes increase in number until they form a foliated tonalite intrusion with amphibolite enclaves. In the northeast part, the boundary between the Abitibi and Opatica subprovinces is marked by a shear zone between the mafic volcanic rocks of the Obatogamau Formation and the sedimentary rocks of the Opemisca Group (Py-Po ± Cp mineralized polygenic conglomerate with an amphibolitized matrix). The core of the deformation zone was injected by the syenitic Moraine Stock and the granodioritic Lac à l'Eau Noire Stock. In the Lac Clévis and Lac Sunset areas, the mafic volcanic rocks (Bruneau Formation) contain interbeds of mafic to felsic volcanoclastics. Gold-bearing quartz-carbonate-tourmaline veins cut the gabbro and quartz diorite intrusions.

Structural analysis of the Rivière France shear zone and gold mineralization, Chapais-Chibougamau region, Québec

CHRISTINE VÉZINA, ALAIN TREMBLAY (UQAM),
FRANÇOIS LECLERC (MRN) AND YANNICK DAOUDENE (UQAM)

The Chapais-Chibougamau mining camp, in the northeast part of the Archean Abitibi Subprovince, was the second most important mining area in Québec from 1953 to 2008 (84.26 Mt of ore yielding 1,525,962 t Cu, 176 t Au and 109 t Ag). Renowned for its Cu-Au vein-type deposits, this mining camp is also host to gold veins in volcanic rocks metamorphosed to greenschist facies, cut by shear zones oriented E-W and NE-SW. The Monexco gold-vein showing is located about 30 km northeast of the town of Chibougamau, in volcanic and sedimentary sequences of the Bruneau and Blondeau formations. These rocks are cut by QFP-type felsic intrusions, as well as by gabbro sills, and they were affected by the Rivière France E-W shear zone (150 to 250 m wide). This shear zone is oriented parallel to the regional E-W schistosity and cut by NE-SW faults. The mineralization is mainly concentrated in tension veins and veinlets composed of quartz-ankerite-tourmaline and gold-bearing sulphides. These veins and veinlets belong to a family with a dominantly N-S orientation. Mineralization is also found as disseminations in the wall rocks. The dominant alteration minerals are chlorite, ankerite and sericite. The main objective of the Master's project, undertaken at UQAM, is to carry out a detailed structural study of the Monexco showing to assess the relative chronology of the deformation and gold-vein mineralization. The summer 2013 work focused on the acquisition of field data, the identification of cross-cutting relationships, and detailed mapping (1:200) of three distinct zones on two stripped areas. The analysis and interpretation of the data, in addition to a regional-scale study (to follow), will establish the characteristics of the Rivière France shear zone that are common to other gold-mineralized zones in the Chapais-Chibougamau region or even elsewhere in the Abitibi. The results should generate exploration guides and hypotheses about the emplacement of gold mineralization in similar types of deformation corridors.

Tectonic and metamorphic evolution of the northern limit of the Abitibi Subprovince (Québec, Canada) – Phase 2

YANNICK DAOUDENE, ALAIN TREMBLAY (UQAM),
JEAN GOUTIER, FRANÇOIS LECLERC (MRN) AND GILLES RUFFET (UNIVERSITÉ DE RENNES 1 AND CNRS, FRANCE)

The Superior Province comprises tectono-stratigraphic units that were amalgamated during the Kenoran orogeny, between ~2.8 and ~2.65 Ga. Among these units, the Abitibi Greenstone Belt shows a dominantly east-west structural fabric and metamorphic conditions ranging from the greenschist to the amphibolite facies. Although this regional metamorphism is commonly attributed to an accretion period, its spatial variability, its age and its duration remain uncertain. This information is vital however to reconstruct the tectonic and thermal history of the region and to inform the debate concerning Earth's geodynamics during the Archean. The main objective of this study is therefore to clarify the metamorphic history of the Abitibi Subprovince.

Based on a structural and metamorphic study focusing on the area between Chibougamau and Lac au Goéland, located 90 km east of Matagami, we will show that volcanic and sedimentary sequences in the Abitibi structurally overlie rocks in the Opatika plutonic belt exposed further north, the entire assemblage being marked by the presence of an east-west-trending regional schistosity/foliation and cut by major strike-slip and oblique late shear zones. To the north, nearing the contact with the Opatika plutonic belt, Abitibi rocks exhibit metamorphic conditions gradually increasing from the greenschist to the amphibolite facies. Although rarely observed, the contact between the two units does not appear to correspond to a major deformation zone. Based on these field observations, we therefore postulate that rocks of the Opatika plutonic belt form the basement rocks for Abitibi sequences. Micas and amphiboles derived from a wide variety of metamorphic and igneous rocks were sampled in the Lac au Goéland area and dated using the $^{40}\text{Ar}/^{39}\text{Ar}$ method. The results were compared with ages obtained in the southern Abitibi Subprovince, to shed some light on the tectonic and thermal history of the entire Abitibi during the Archean.

To improve our understanding of the tectonic and metamorphic history of the Abitibi, it will be necessary to pursue this type of study elsewhere in the Abitibi, particularly in the central part of the subprovince, where we suspect the presence of geological windows exposing rocks that may be comparable and even correlatable with those observed in the Opatika Subprovince.

Assessment of the gold potential of alkaline intrusions in the Abitibi and Pontiac subprovinces, Québec

MARC LEGAULT (CÉGEP DE L'ABITIBI-TÉMISCAMINGUE)
AND JEAN GOUTIER (MRN)

Recent work by Legault and Lalonde (2009), Lafrance (2012) and Legault and Goutier (2012) have demonstrated that it is possible to distinguish, in the Abitibi and Pontiac subprovinces, syenites bearing gold mineralization (fertile intrusions) from those that are devoid of mineralization (barren). This distinction is even more important when we consider that the altered part of a fertile intrusion only represents, in many cases, a fraction of the total volume of the intrusion. It is therefore of great interest to establish the characteristics of fertile and sterile intrusions using fresh samples. The ability to classify intrusions would allow us to better target gold exploration in little known areas where syenites have been identified but not well studied. The area west of Rouyn-Noranda is well documented and will therefore serve as a control sector for this study. The characteristics of fresh samples ($< 2.25\% \text{CO}_2$) from alkaline intrusions in the region will be used to distinguish fertile intrusions from barren. Mineralogically, fertile intrusions generally display more intense sericite, chlorite and/or carbonate alteration than do barren intrusions. The coexistence of pyroxene, amphibole and biotite in the same sample is a feature unique to barren intrusions. Chemical analyses provide an even better distinction between fertile and barren. The best diagrams for displaying the contrasts are $\text{MgO} + \text{CaO}$ versus $\frac{1}{2}\text{SiO}_2 + \text{Al}_2\text{O}_3$, Sc versus Co , Cr versus Ga and normative quartz/normative serpentine. Within a fertile intrusion, the degree of alteration is highly variable, particularly if it is a large intrusion. The ratio $\text{K}_2\text{O}/\text{Na}_2\text{O}$ as well as the IFRAIS and muscovite-paragonite indexes, and normative quartz, are all useful in identifying known mineralized zones and would therefore be useful in targeting new areas for exploration. The same conclusions were applied to several alkaline intrusions distributed throughout different parts of the Abitibi and Pontiac subprovinces, and it was generally possible to clearly distinguish between fertile and barren intrusions. A compilation of assessment work on some of the better documented intrusions demonstrated the effectiveness of this classification.

Geological compilation of the Bas-Saint-Laurent: regional county municipalities of Kamouraska, Témiscouata and Rivière-du-Loup

MORGANN PERROT AND ALAIN TREMBLAY (UQAM)

In order to harmonize and update the geological map of the Québec Appalachians produced by the *Ministère des Ressources naturelles* (MRN) du Québec, we compiled and interpreted the geological maps for the Bas-Saint-Laurent region in the regional county municipalities (RCMs) of Kamouraska, Témiscouata and Rivière-du-Loup (map sheets 21 E 06 to 21E16). This work was carried out using new field data and mapping compilations produced by Daniel Brisebois (MRN) in the late 1990s and in early 2000.

Outcrops in the west part of the region are Cambro-Ordovician rocks belonging to the Caldwell, St-Rock, Rosaire, Trois-Pistoles and Trinité groups. These formations represent remnants of the Laurentian continental margin and were affected by a series of northwest-directed imbricated thrusts which, to the southeast, were overprinted by southeast-verging folds that have been correlated with backthrust structures discovered in the Appalachians of southern Québec (Tremblay and Castonguay, 2002). The Richardson Fault constitutes a major thrust in the region, emphasized by the juxtaposition of rocks of the Rosaire and Saint-Roch groups, in the hanging wall of the thrust over various lithological units of the Trois-Pistoles Group and the Rivière-Ouelle and Tourelle formations. In the Cabano area in the southeast part of the region is the Saint-Joseph Fault, a major normal fault recognized in the Beauce and Estrie regions (Pinet *et al.*, 1996; Perrot, 2013) for which the presumed age is late Silurian-early Devonian (Perrot, 2013). In the Bas-Saint-Laurent region, this fault juxtaposes rocks with a strong structural and metamorphic contrast: slates and green sandstones of the Caldwell Group displaying relatively little deformation in the hanging wall (to the southeast), and quartzites, black schists, mudslates and metasandstones of the Rosaire and Saint-Roch groups in its footwall (to the northwest). It is cut by the Lac Témiscouata-Petit Lac Biencourt Fault, a reverse fault attributed to the Acadian Orogeny. Siluro-Devonian rocks of the Gaspé Belt, belonging to the Chaleurs Group, mainly crop out in the hanging wall of this latter fault. They unconformably overlie an assemblage of Ordovician-Silurian rocks constituting an Ordovician "base-ment" (Trinité Group), which is unconformably overlain by the Cabano Group and the Pointe-aux-Trembles and Lac Raymond formations. Finally, Siluro-Devonian rocks of the Témiscouata and York River formations crop out at the eastern extremity of the region, east of the Causapsal Fault.

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Mapping of Quaternary deposits in the Charlevoix and Haute-Côte-Nord regions (Québec, Canada)

BRIGITTE POIRIER, PIERRE COUSINEAU (UQAC), ETIENNE BROUARD (ULaval), MOHAMED EL AMRANI (MRN), JOËLLE BRAULT AND PATRICK LAJEUNESSE (ULaval)

The geology of surficial deposits provides essential data for understanding the hydrogeological environment of a region. UQAC, in partnership with the *Ministère des Ressources naturelles* (MRN), has carried out a Quaternary deposit mapping project in the Charlevoix and Haute-Côte-Nord regions as part of the municipal groundwater knowledge acquisition program (PACES: *Projet d'acquisition de connaissances sur les eaux souterraines*) of the *Ministère du Développement durable du Québec*. The total area covered by the mapping work is 4,600 km². The work comprises four phases spread over two years: 1) the preliminary phase; 2) photo-interpretation and generation of maps at a scale of 1:50,000; 3) systematic field surveys; and 4) production of final maps and a synthesis report. In the summer of 2013, we visited 939 stations to validate and describe the main lithostratigraphic units. This activity revealed several distinctive traits between the Haute-Côte-Nord and Charlevoix regions. The stratigraphic framework of the Haute-Côte-Nord region is less complex, with a clear distinction between highlands, generally dominated by glacial and fluvial deposits, and lowlands dominated by thick units of well-stratified sand of deltaic origin. These are commonly overlain by large peat bogs that formed in response to an underlying impermeable iron-rich crust. Four main levels of terraces reflect the relative levels of the Goldthwait Sea: 10 m (associated with the Laurentian transgression), 60 m, 90 m and 130 m (the level of the main deltaic systems). In Charlevoix, the assemblage of sedimentary facies is more complex, influenced by the astrobleme topography and rugged shoreline. Coupled with strong seismicity, this renders the area prone to major landslides, making it more difficult to understand the facies. Glaciomarine sediments dominate the shoreline and some parts of the main valley floors (Malbaie and Gouffre). The numerous moraine ridges present in the area led to the formation of periglacial lakes (glaciolacustrine deposits) along the floors of some valleys. Several deltaic systems were observed at the mouth of Rivière du Gouffre, indicating a notable variation in the glaciofluvial flow directions. Deltas found higher up in the valleys, to an altitude of 200 m, are remnants from the gradual retreat of the Goldthwait Sea and thus provide a record of the highest sea level attained in the region. A veneer of melt-out till (dead-ice moraine) was observed to the west of Baie-St-Paul and is characterized by hummocky topography and numerous kettles.

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Quaternary deposit mapping program in the Rivière Nicolet watershed

RICARDO CAICEDO, MICHEL LAMOTHE, GUILLAUME ST-JACQUES, MARILI VINCENT-COUTURE, FLORENCE GAGNON, FRÉDÉRIC ROBERGE AND SIMON HÉBERT (UQAM)

The entire Rivière Nicolet watershed, as well as the downstream portion of Rivière Saint-François are the focus of a hydrogeology study under the Groundwater Knowledge Acquisition Program (PACES; *Programme d'acquisition de connaissances sur les eaux souterraines*) headed by the *Ministère du Développement durable, de l'Environnement, de la Faune et des Parcs* (MDDEFP). The map of Quaternary deposits in the upstream portion of Rivière Nicolet has not been revisited since the 1980s, whereas the downstream portion of the watershed was mapped by Nelson Gadd in the 1950s and 1960s within the scope of a systematic mapping effort by the Geological Survey of Canada (GSC).

The objective of this ongoing project is to update Quaternary mapping of unconsolidated deposits in the Rivière Nicolet and Rivière Saint-François watersheds, and to integrate the results with recent work carried out by teams from the Université du Québec à Montréal (UQAM) in surrounding watersheds (Rivière Bécancour and the upstream portion of Rivière Saint-François) and by the GSC in the Rivière Yamaska and Rivière Richelieu watersheds.

This mapping project was deemed necessary in light of the heterogeneity in terms of cartographic techniques and rendering, problems with the continuity of geological contacts along map edges, the lack of available geomorphology data, and the need to integrate the stratigraphy of this watershed with the more modern and more complete stratigraphy of the Saint Lawrence Lowlands (SLL).

The first component of this project consisted in a compilation of available data and integration into a Geographic Information System (GIS). In parallel, natural stratigraphic sections observed in the study area and inventoried in the literature are used to support hydrostratigraphic studies in the ongoing PACES project.

Field investigations carried out during the 2012 and 2013 summer campaigns served, firstly, to correct contacts between lithostratigraphic units occurring along the edges of map sheets. Secondly, known stratigraphic sections were reinterpreted, newly identified sections were described, and all sections were integrated in the conceptual stratigraphic framework for the southern SLL. All passable roads and accessible excavations (ditches, sand and gravel pits, quarries) were systematically investigated, which generated a substantial amount of field data.

G45

Highlights of advanced exploration and mine development in Abitibi-Témiscamingue in 2013

PIERRE DOUCET AND JAMES MOORHEAD (MRN)

In March, IAMGOLD announced it has commenced processing its stockpiled ore at the Westwood mine. In 2013, the company expects to produce 60,000 ounces of gold from Mouska and 80,000 ounces from Westwood. In April, Typhoon Exploration and Aurizon Mines announced the positive results of a preliminary economic assessment for the Fayolle project. The study examined an open pit mine scenario with a production of 568,941 tonnes of ore at a grade of 4.35 g/t Au over a 3-year mine life. Clifton Star Resources announced that a prefeasibility study on the Duparquet project should be completed in early 2014. Abcourt Mines pursued its production start-up work at the Elder mine. In July, four stopes were in production and two others in preparation or rehabilitation. An agreement was signed with Maudore Minerals to have the ore milled at the Sleeping Giant mine. On June 17, Royal Nickel Corporation announced positive results for its Dumont Nickel feasibility study.

In Val-d'Or, at the Goldex mine, Agnico Eagle Mines suspended production from the GEZ zone since October 2011. Production should start up again in late 2013 from the M and E zones, which contain proven and probable reserves of 6.529 Mt at 1.54 g/t Au. At the Beaufort mine, Richmond Mines announced its decision to proceed with commercial production from the W Zone that contains probable reserves of 132,251 t at 7.21 g/t Au. Richmond Mines also announced the decision to bring the Monique project into commercial production, with proven and probable reserves of 485,737 t at 2.29 g/t Au that could be mined from an open pit. At the Lac Herbin mine, QMX Gold Corporation suspended exploration and development. The mineralized lenses located above level 42 will be mined until the third quarter of 2014. The Kiena mine of Wesdome Gold Mines was closed in June 2013. In Malartic, Osisko Mining Corporation continues to optimize production at its Canadian Malartic mine. Proven and probable reserves of 298.6 Mt at 1.03 g/t Au were established for the Canadian Malartic and Barnat deposits. At the Québec Lithium mine, Canada Lithium Corporation has begun extracting spodumene ore. The first samples of high-purity lithium carbonate have been shipped to Asia. Commercial production is scheduled to start in the first quarter of 2014.

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New targets for mineral exploration – 2013 geoscience projects

MEHDI A. GUEMACHE (MRN)

Géologie Québec presents, again this year, targets of economic interest uncovered during its 2013 geoscience projects. New geoscience knowledge acquisition is one of the main missions of Géologie Québec. It contributes to the development of mineral resources across Québec and fosters the discovery of new deposits by the mineral industry.

During their fieldwork, geologists from the *Ministère des Ressources naturelles* identified areas with a favourable geological setting for mineral exploration. These areas of interest have not been studied in detail, but warrant further investigations by exploration companies.

This newly acquired information will be made public in November, during the Québec Mines 2013 Convention.

Geoparks: What they are and why we need them

PIERRE VERPAELST AND GODFREY NOWLAN (CANADIAN NATIONAL COMMITTEE FOR GEOPARKS)

A geopark is a geographic area containing geological heritage sites that are part of an integrated concept of conservation, education and sustainable socioeconomic development. The Global Network of National Geoparks, supported by UNESCO, was created in 1999. Geoparks showcase an area's geological heritage for the benefit of current and future generations. A geopark is not limited to its geological elements: it may include sites of archeological, historical, cultural or environmental interest (plants and wildlife). Geotourism and socioeconomic development are encouraged. In this way, a geopark becomes a tool for regional development. The development of a geopark is generally from the grassroots up through local initiatives.

The Global Network of National Geoparks currently has 92 geoparks in 28 countries. The only geopark in North America is Stonehammer in New Brunswick, which was created in 2009. Several projects are underway in Canada, three of which are in Québec: Charlevoix, Mont-Saint-Pierre and Percé.

Percé Geopark: A regional park project

O.P.R CONSULTANTS FOR THE PERCÉ GEOPARK
MULTI-STAKEHOLDER CO-OPERATIVE

Background

A regional park project, also known as a geopark, responds to the needs of tourism businesses in the area by creating a new source of attraction and new activities for visitors.

The site

The Percé cultural heritage site (recognized by the Québec Government) is the area targeted by the project.

The geosites we wish to showcase are located on private lands designated as conservation zones in the municipal zoning system. The majority of owners have already granted rights of way. The site already has a network of paths and spectacular attractions.

Infrastructure

The major attraction of the Geopark will be a welcome pavilion situated halfway up the mountain, on the eastern slope of Mont Saint-Anne. This building will serve as an anchor point for a 25-metre footbridge and lookout that will extend over a precipice to provide a spectacular panorama from Au Pic de l'Aurore to Cap Blanc, including views of Percé Rock, Bonaventure Island, and the heart of Percé village with its historical buildings.

Points of interest behind the structure and the summit of the mountain will also be suitably managed to avoid degradation.

The campground will be renovated and the "ready-to-camp" experience will be emphasized. A playground and recreation area will also be offered to enhance the family experience for campers, day-trippers and residents.

The experience

"Making the mountain accessible from the village" is the main goal. The project will make it easy and enjoyable to access one of the most spectacular lookouts in the Gaspésie region, organized and managed in a way that will promote and enhance the "general public experience".

A wide choice of hiking routes and guided services will provide close contact with the land and its heritage, appealing to those who enjoy a more profound experience.

The clientele

Customer loyalty will ensure good revenues right from the start. Cruise company clientele will be particularly attracted by the "mountain" experience, which will nicely complement the essentially maritime nature of their cruise trip.

Financial aspect

The project requires an investment of \$7.7 million. Once in operation, the Geopark will be profitable through parking, camping and entrance fees collected at the welcome pavilion on the mountain.

The promoter

A multi-stakeholder co-operative was created for the project. It brings together the biggest tourist businesses in the area, as well as organization and associations as supporting members. Each co-operant will invest \$10,000.

The Charlevoix geopark project

PIERRE VERPAELST (OBSERVATOIRE DE LA GÉOSPHERE DE CHARLEVOIX)

Charlevoix is a prime tourist destination, in large part due to its topographic relief, its climate, and above all, its cultural heritage. Many people are unaware, however, that the Charlevoix region also boasts geological features that are unique in Québec and even the rest of Canada in terms of its geological history and the tectonic and catastrophic events that shaped the land surface in the past and still to this day.

The Charlevoix region occurs in a geological zone where three large North American geological provinces meet:

- ▶ Precambrian rocks of the Canadian Shield north of the St. Lawrence River;
- ▶ Paleozoic rocks of the St. Lawrence Platform, just south of the Shield and dominantly present near the north shore of the St. Lawrence River;
- ▶ Appalachian rocks, traces of which are found on Île-aux-Coudres.

All these rocks were affected by a meteorite impact that disturbed the geology from Petite-Rivière-Saint-François to Saint-Siméon. The study of the Charlevoix astrophile, discovered in 1966, identified structures and rocks typical of meteorite impact. The central peak and ring-shaped trenches are among the most visible and most accessible features of their kind in the world.

The goal of the Charlevoix geopark project is to highlight Charlevoix's geological heritage, particularly the impact structure and the relationship between the three geological provinces found in the region. It also aims to raise public awareness about the deposits and landforms left behind by the glaciers, as well as modern geological phenomena that constitute natural risks, such as shoreline erosion, landslides and earthquakes.

The geopark project is not only about drawing attention to Charlevoix's geological heritage. It could also integrate the rich prehistoric, historical and cultural heritage of the region as well. That is why the project will partner with Charlevoix's biosphere reserve, its observatory, and its business community.

Hydrothermal deposits in iron oxide alkalic alteration systems: Colosses with feet of clay?

LOUISE CORRIVEAU (GSC-Q), JEAN-FRANÇOIS MONTREUIL (INRS) AND ERIC G. POTTER (GSC)

The extreme redistribution of chemical elements and metals in hydrothermal systems characterized by iron oxides and alkalic alteration can lead to the penconemporaneous formation of:

- ▶ iron oxide $\pm$ apatite (IOA) deposits (Fe, V, P, Th, REE, other high-technology metals, $\pm$ U);
- ▶ iron oxide-copper-gold (IOCG) deposits (Cu, Au, Ag, $\pm$ U, REE, etc.);
- ▶ certain types of albitite-hosted uranium deposits;
- ▶ certain skarn deposits (Pb, Zn).

Each type of deposit is associated with the systemic development of chemically distinct alteration facies, following a prograde (Na, Ca-Fe, K-Fe) and retrograde alteration sequence, with or without facies permutations and repetitions, which may be related to various tectonic and magmatic processes. In the end, the release of silica and acidic fluids leads to the formation of epithermal systems. These metasomatic systems individually extend over tens of kilometres and typically follow major lithospheric discontinuities. This results in large-scale metallogenic belts where a variety of sometimes colossal deposits with base metals, precious metals, high-technology metals (including those needed for green energy alternatives) and uranium are clustered: the Olympic Dam Province, the Cloncurry, Kiruna, and Carajas districts, Valhalla, Candelaria, Aitik, etc. Uranium ($\pm$ thorium), if present in altered sequences, is also remobilized (for example during albitization) and may precipitate in each type of deposit associated with these systems. High-temperature K-Fe alteration (with magnetite) precipitates uraninite with relative flat rare earth profiles, but at lower temperatures (with hematite), these profiles become enriched in light REE, and when the fluid becomes more siliceous, uraninite is replaced by coffinite. As for albitites and calcic alteration zones with magnetite, they may trap uranium given their propensity for brecciation, or via redox reactions. In Québec, Kwyjibo, the Bondy Complex, the Mistamisk-Romanet Horst, the Rex Lineament, and the Otish Basin all contain polymetallic or uranium mineralization within multi-kilometre halos of alkalic alteration ($\pm$ iron oxides) that represent regional-scale targets in the search for this spectrum of deposits. These crossovers involving multiple metals within colossal systems significantly increase the mineral potential of extensive geological terrains in Québec and Canada. On the other hand, the possible enrichment in uranium, if the latter is viewed as a deleterious element, and the opaque nature of potential links within the wide spectrum of deposits may in fact transform these systems into colosses with feet of clay.

Applicability of mineral carbonation in the mining sector

EMMANUELLE CECCHI, GUY MERCIER, JEAN-FRANÇOIS BLAIS, LOUIS-CÉSAR PASQUIER, SANOOPKUMAR PUTHYIA VEETIL, ALIA BEN GHACHAM AND NASSIMA KEMACHE (INRS-ETE)

In light of the current climate warming and regulatory framework for greenhouse gas (GHG) emissions, and with the industrial sector in Canada being responsible for 40% of CO₂ emissions, finding economic methods to control or to use CO₂ constitutes a major challenge. Among the various CO₂ capture and storage technologies, mineral carbonation has both the technical and commercial potential to succeed.

Mineral carbonation is a natural reaction that namely occurs during the weathering process. As it reacts with divalent cations (mainly Ca and Mg) contained in silicates, atmospheric CO₂ is trapped in solid form, as carbonate, which is a stable, inert and non toxic mineral: a perfect form to sequester CO₂ permanently and safely.

Although the kinetics of the process is slow, it is possible to speed up the reaction sufficiently to make it economically attractive.

The goal of this project is to optimise the mineral carbonation process to make it a viable option for many different industries. To reach this objective, various methods will be assessed, in particular a direct aqueous process. The process will be tested on various materials to guarantee a viable, robust and economic application for the largest possible number of industries.

Calcium- and magnesium-rich rocks and minerals (the Thetford Mines Ophiolite for example), mine tailings and industrial waste are all materials of interest and are often available nearby major GHG emitters such as steelmakers or the iron, aluminium, cement and oil industries.

To make the process more profitable, the production of a marketable end-product represents an important step ahead in developing an economic mineral carbonation technology. Calcium and magnesium carbonates are useful minerals that can find their way into various aspects of our daily life and that have commercial value. Other by-products such as silica and alumina may also be produced, which would improve the profitability of the mineral carbonation process. The transformation of two waste products, industrial CO₂ and industrial waste or mine tailings, via the mineral carbonation process, into environment-friendly value-added products not only reduces the environmental impact of the industrial sector but also has a positive impact on the industry's public image.

Examples of copper mineralization in the Eastern Anti-Atlas (Maroc): Geological context and mode of emplacement

ABDEL-ALI KHARIS, DAOUD ELAZMI, MOHAMED AISSA, HASSANE OUGUIR AND MOULAY LAHCEN ELMEDDOUDI (UNIVERSITÉ MOULAY ISMAÏL, MAROC)

The Eastern Anti-Atlas of Morocco lies to the northeast of the Anti-Atlas Major Fault, which separates it from the West African Craton. It constitutes, at its base, Pan-African basement of Neoproterozoic age, overlain by Paleozoic formations. The region contains numerous metal concentrations hosted in the basement (Bou Skour) and cover rocks (Oumjrane).

The copper mineralization of Bou Skour and Oumjrane are the focus of our work, with the aim of developing a model of emplacement and establishing whether a genetic link exists between the metal concentrations in the basement and those in the cover rocks.

The Bou Skour deposit is located 56 km east of Ouarzazate. It consists of porphyritic mineralization related to a granodioritic intrusion (680 Ma) of calc-alkaline affinity that cuts the andesites and was emplaced during the West African island arc collision at the end of the lower Cryogenian. The emplacement of the intrusion caused intense fracturing, thereby promoting the circulation of hydrothermal fluids that produced copper mineralization in the form of disseminations and stockworks in andesite. This mineralization is associated with potassic alteration, silicification, and argillic and propylitic alteration. Hercynian-age (Atlasic?) late remobilization of the NW-SE vein structures affected the mineralization.

The Oumjrane mineralized district is located 90 km northeast of Zagora. It consists of epithermal (high-sulphidation) copper mineralization related to an intracontinental extensional phase that has been recognized at the scale of the Eastern Anti-Atlas during Visean time. This mineralization is the result of remobilization of earlier mineralization via hydrothermal fluids, giving rise to lenticular vein-type mineralization in Ordovician quartz sandstones. Hydrothermal circulation produced vertical and lateral zonation of the metallic minerals (pyrite, arsenopyrite, chalcopyrite, galena and sphalerite) in E-W and NE-SW Hercynian mineralized structures. This was accompanied by strong silicification. Copper enrichment following supergene alteration, likely related to the lower Jurassic-Cretaceous emergence, affected the mineralized structures of Oumjrane.

By combining the geological and metallogenic characteristics of the two deposits described above, we can conclude that copper mineralization in the Eastern Anti-Atlas was likely related to two major events:

- ▶ a Pan-African (Neoproterozoic) event responsible for the emplacement of copper concentrations in the basement rocks;
- ▶ a Hercynian-Atlasic event that caused the remobilization and reconcentration of copper in NW-SE, NE-SW and E-W structures.

Copper mineralization of the Western Anti-Atlas (Anti-Atlas, Maroc): paragenetic succession and depositional context

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The western Anti-Atlas is in southern Morocco. It is formed of Proterozoic basement with a buttonhole morphology overlain by an Audoudounian cover (Infracambrian). This cover is represented by the Tarta-Taroudant Group, which begins with the Jbel Kerkar tholeiitic basalts of anorogenic continental origin. These flows are overlain by a detrital series known as "the basal series" (siltstone and sandstone) that progresses into increasingly carbonate-rich rocks, the Tamjout dolomite and the lower limestones. This domain constitutes a copper metallogenic province due to the presence of many copper showings, deposits and orebodies hosted by the Infracambrian cover rocks. The goal is to study three deposits: Tazalaght, Agoujgal and Ouansimi.

Copper mineralization in the Tazalaght deposit is represented by a paragenesis of chalcopyrite, bornite, siegenite and sphalerite. It is present as two types: 1) in veins and lenses 2 to 15 m thick, hosted by fractured quartzose basement rock; and 2) as stratiform disseminations or laminations in the basal series. In the Agoujgal deposit, mineralization is composed of chalcopyrite, bornite, tennantite, galena and sphalerite. It is disseminated in the basal series and in the Tamjout dolomite. It is also present as geode fillings and as veins in the Tamjout dolomite. In the Ouansimi deposit, mineralization is presents in veins and consists of chalcopyrite, bornite, pyrite, galena and sphalerite. It is controlled by NW-SE faults affecting the lower limestones on the north flank of the Ouansmi Anticline.

Field observations and microscopy studies of the three deposits suggest that both the disseminated and laminated mineralization are syngenetic and related to Eocambrian extension at the end of the Proterozoic.

Discordant mineralization (geodes, veinlets and veins) may be related to hydrothermal activity during the Hercynian Orogeny or to magmatic activity at the end of the Triassic, which manifested in western Anti-Atlas as a NE-SW dolerite dyke (50 to 100 m thick).

Both types of mineralization were then subjected to supergene alteration, which gave rise to new and more copper-rich mineral phases, such as covellite, chalcocite, copper carbonates, cuprite and native copper.

Geochemistry and Sr-Nd isotopes of the Ediacaran volcanic series of the Tifnoute Valley (Siroua Massif, central Anti-Atlas, Morocco)

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Part of the Ouarzazate Supergroup (575- 545 Ma), the rocks of the Ediacaran volcanic series of the Tifnoute Valley region (Ouzellagh-Siroua Promontory, Anti-Atlas, Morocco) cover a wide petrographic range, including basalts, basic andesites, andesites, rhyodacites and rhyolites, with the dominant elements being acid and intermediate pyroclastics. The entire sequence is cut by dolerite dykes oriented NE-SE and N-S.

The secondary transformations affecting these rocks produced a greenschist facies paragenesis (albite, chlorite, epidote, sericite, calcite, hematite and quartz), composed of a primary mineralogy of plagioclase, clinopyroxene, olivine, opaque minerals and apatite.

Despite the wide variety of rock types, these volcanics belong to the same calc-alkaline suite characterized by elevated Al_2O_3 (up to 18%) and TiO_2 contents (0.3-1.7%) and an enrichment in both transition and incompatible elements (Cr: 21.2-64.8; Zr: 97-310). Their major and trace element compositional evolution reflects the cogenetic relationships between different facies and a common link related to a process of magmatic differentiation. The dolerite dykes appear to represent feeder conduits for the summital basalts of lower Cambrian age that have been documented to the northwest of our study area (Poucllet *et al.*, 2007); these are distinguished from our series by their tholeiitic affinity. This basic activity constitutes the final magmatic episode of the Precambrian-Cambrian transition period. The basic rocks are characterized by enrichment in FeO_t and lithophile elements (Sr, K, Rb, Ba) and by elevated Zr/Y ratios between 4.5 and 6.5.

The rocks of the calc-alkaline group were issued from a source with a signature similar to a plate convergence zone, in particular with regards to the ratios Th/La (0.11-1.12), Ce_N/Yb_N (1.79-11), Eu/Eu* (0.38-1.03) and La_N/Yb_N (1.76 to 12), and the elevated LILE contents and strongly fractionated REE spectrum. The geochemistry of the dolerites, on the other hand, reflects an intraplate domain.

The sequence thus represents an evolution from a post-collisional context to an intraplate environment following the Pan-African orogenic events, and marks the Precambrian-Cambrian transition period.

Petrogenetic analyses undertaken as part of this study have linked the genesis of these rocks to a process in which the initial magma of mantle origin underwent fractional crystallization with a small crustal contribution.

This hypothesis is supported by isotopic data. The rocks yielded positive ϵ_{Nd} (570) values of 1.7 to 4.5 and small initial Sr ratios (Sri: 0.696 to 0.706), with Nd-TDM model ages between 810 and 1138 Ma. The rocks also have a depleted signature and appear to be derived from a juvenile mantle source with a small contribution from overlying crustal material.

The dolerite dykes are clearly juvenile with positive ϵ_{Nd} (570) values (4.12-5.03) (Sri= 0.705) and Nd-TDM model ages between 797 and 852 Ma.

These characteristics are examined in the context of the post-Pan-African magmatism of the Anti-Atlas chain.

Knowledge acquisition project on granites, mineral deposits and geochemistry of the Saint-Félicien area, Saguenay–Lac-Saint-Jean region (NTS 32A08, 32A09, 32A10)

CHRISTIAN TREMBLAY (CONSOREM),
SAMUEL MORFIN, LUCAS BRIAO KOTH (UQAC)
AND RÉAL DAIGNEAULT (UQAC-CONSOREM)

The study area constitutes the first phase of a knowledge acquisition project in the Saguenay–Lac-Saint-Jean region. It is located in the southwest area of Lac-Saint-Jean and is part of the central Grenville Province. The study will address, in particular, the geochemistry of the felsic intrusive suites that dominate the area. The geological reinterpretation of the geology of these map sheets will allow us to better understand the emplacement sequences for these intrusives and their inter-relationships.

The basement in the region comprises gneisses of various compositions injected by generally porphyritic intrusive rocks of felsic to intermediate composition. The northwest part of the region is dominated by porphyritic mangerites surrounded by tonalitic to dioritic gneiss. These gneisses contain slices of mafic rocks measuring metres to decametres. All the units are cut by granite-monzogranite intrusions forming large magmatic systems. In the far west part is a kilometre-scale band of graphitic paragneiss. In the southeast part (32A08), intrusions of granitic rock with variable charnockitic components dominate the map sheet area. Large volumes of mangerite and charnockite with some granitic facies constitute part of an AMCG suite. The northeast part of the map is occupied by Lac-Saint-Jean and a cover of Trenton limestone of Ordovician age. With the exception of the limestones, the ages of the basement rocks remain unknown. We propose a chronological order of emplacement based on crosscutting relationships.

The structural grain of the region is mainly N-S, but is disrupted by the emplacement of several intrusions. Regional faults produced mylonitized zones that can be recognized over several kilometres. The graben structure imposes a NW-SE morphology that produces numerous lineaments with similar directions. Metamorphism attained upper amphibolite and granulite facies. The mapped region contains several exploration targets for graphite, silica and iron-titanium oxides. The granite-mangerite intrusions form sizeable massifs with little fracturing that would be favourable for quarrying dimension stone. This is particularly the case south of Roberval where new logging roads provide easy access. The Lac-Bouchette–Chambord corridor is known for its large hydrothermal system that generated the Lac-Bouchette silica deposit and the silica deposit along the edge of Rivière Métabetchouan.

Reassessment of the Selbaie volcanic complex paleoenvironment and metallogenic potential, northwest Abitibi

STÉPHANE FAURE (CONSOREM-UQAM)

The base metal potential of the ancient Selbaie mine region in northwest Abitibi was reassessed (production from 1981 to 2004 of 56.9 Mt @ 0.87% Cu, 1.85% Zn, 39 g/t Ag and 0.55 g/t Au). This area, which covers more than 700 km², has been the subject of only one regional-scale mapping program (Lacroix, 1990 and 1994a) since the discovery of polymetallic mineralization in 1974, and all scientific publications focus on the geology of the mine and its vicinity. The geology of the Selbaie camp has now been completely reinterpreted using recent public geological and geophysical data, in addition to new unreleased drill data from companies, some of which are members of CONSOREM. This study examines, at the regional scale, synvolcanic structures, rock and alteration geochemistry, and magnetic and gravimetric signatures. Innovative data processing methods were used to characterize synvolcanic structures and hydrothermal alteration.

The principal results indicate that: 1) the Brouillan Group volcanics are calc-alkaline and comagmatic, and include intermediate and felsic phases of the Brouillan intrusive complex; 2) the mafic phase of the Brouillan complex is comagmatic with the Enjalran tholeiitic basalts surrounding the Brouillan volcano-plutonic complex, implying that the mafic feeder intrusions and basalts are younger than the Brouillan intrusive complex; 3) the lithogeochemical signature of the 8-Mt barren volcanogenic massive sulphide horizon at Selbaie, the WAT unit, was geochemically defined and recognized further south (the Carheil and B-26 mineralized zones); and 4) two families of synvolcanic faults can be distinguished: a NNW-SSE set in the northern part of the complex, and an E-W set that cuts across the NNW-SSE faults and is associated with the more felsic phases of the Brouillan pluton. Structures inferred based on geophysical signatures were interpreted as graben faults, and some circular patterns may correspond to the footprints of small calderas. Hydrothermal alteration was characterized using Norm SV350 in LithoModeleur. The alteration is typically volcanogenic and concentrated along structures bordering some of the volcanic basins. The interpreted synvolcanic faults are considered important exploration targets, particularly those located near the Brouillan pluton (heat source). Several of these faults have seen little exploration and are therefore zones of high potential.

Optimization of soil geochemistry data using strong acids applied to mineral exploration

SILVAIN RAFINI (CONSOREM)

The objective of this project is to verify the effectiveness of soil geochemistry in mineral exploration and to propose qualitative and quantitative optimizations.

Abrupt physico-chemical variations in successive horizons of a differentiated soil produce complex profiles of metal concentrations. The first component of this work was to address the state of knowledge on the following aspects: metal segregation during pedogenesis; concentration profiles for substances of economic interest; the distinction between primary and secondary metals; and methods to extract the metals from each horizon.

This first step identified problematic issues and sources of uncertainty during exploration surveys. The second step, more quantitative, addressed the following questions:

- ▶ For each substance, what is the nature of the metal signature in each horizon? Particular emphasis was placed on distinguishing *enrichment due to the presence of mineralization* and *independent enrichment*, produced by an accumulation that reflects the stability of each substance and the physico-chemical conditions of the horizon.
- ▶ What are the baseline levels observed in each horizon, for each substance? Knowing these levels is necessary for detecting anomalies.
- ▶ For each substance, which is the best horizon in terms of performance in mineral exploration?

Clear answers to these questions were provided by a statistical analysis of 2,900 stations from eight regional surveys carried out by the Ontario Geological Survey in the Superior Province.

We demonstrated that the Pb, Zn and Au have baseline levels that are systematically elevated in the organic horizon (humus-Ah), indicating a certain stability in organic acid environments, whereas Cu and Ni are more concentrated in the C horizon, indicating a behaviour dominated by pedogenetic leaching. The elevated signal for Pb, Zn and Au in humus is only weakly correlated with mineralization and demonstrates an extreme sensitivity to surface conditions. The use of this horizon is not recommended for exploration. The contrasts, which are standard, objective and reliable statistical indicators of performance, clearly demonstrate that:

- ▶ The C horizon displays the overall best performance in detecting deposits, followed by the B horizon;
- ▶ Anomalies can be detected in the C horizon at distances of less than 1 km;
- ▶ Gold analyses in all three horizons are not very effective in detecting gold deposits, whereas arsenic in the C horizon demonstrates more satisfactory performance.

Geochemistry of the Otish Gabbro Dykes and Sills

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AND MIKE HAMILTON (UNIVERSITY OF TORONTO)

Mantle-derived mafic dyke swarms contain potential information as to the tectonic and metallogenic evolution of the Earth's crust. The intracratonic Otish basin in central Quebec, post-dates the northwest-trending Mistassini dykes and pre-dates the Otish gabbros. Multiple ages have been proposed for the Otish Group: (1465 Ma (Wanless et al. 1965), 1730 ± 10 Ma (Hohndorf et al., 1987), 1750 Ma (Chown and Archambault, 1987), 1721 ± 20 Ma (Beyer et al., 2012)) and each with implications for the depositional age of the uraniferous Otish Basin that they cross-cut. Recent, preliminary U-Pb dates (ca. 2169 Ma), suggest a significantly older age for the Otish basin.

Northeast-trending dykes and sills have been sampled for the first detailed study of petrology, paleomagnetism and geochronology of the Otish gabbros. The Otish gabbroic suite consists of stratigraphically distinct sills and dykes that belong to two distinct geochemical suites. Field relationships show that the more evolved suite cross-cuts the less evolved suite. The early suite is geochemically more primitive, with comparatively Mg-rich olivine (Fo63), fewer oxides and sulphides. The later, more evolved, suite contains a higher proportion of oxides, sulphides, less magnesian olivine (Fo54) and up to 2% apatite. The two suites also have different immobile trace element profiles. Both suites are moderately enriched in LREEs, relative to the weakly fractionated HREEs and have a negative Nb anomaly. The later suite displays absolute enrichment in all trace elements relative to the more primitive and has a small positive Ti anomaly. Both suites occur in the sills and feeder dykes, thus it seems that these geochemical differences reflect either two distinct igneous pulses or in-situ magma differentiation.

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Underground mines and the hydrogeologic characterization of regional aquifers in bedrock

EMMANUELLE B. GAGNÉ, ALAIN ROULEAU, ROMAIN CHESNAUX, DENIS W. ROY (UGAC), VINCENT CLOUTIER (UGAT) AND RÉAL DAIGNEAULT (UGAC)

Underground mines facilitate the task of assessing the roles of fracture systems and major geologic structures on the hydrogeologic behaviour of aquifers in bedrock. The mine workings offer easy access for the collection of samples and data. Such access is particularly useful in areas where there is little outcropping bedrock. Furthermore, data collected during normal mine operations may be very helpful in understanding the regional hydrogeology of the fractured bedrock. These aspects will be illustrated using examples from the Beaufor, CANMET and Lac Herbin mines, located in the Abitibi region of Québec.

We have documented the characteristics of fracture networks by conducting surveys in mine drifts and by making observations at outcrop sites near the mines. These new data were combined with existing data and corrected for orientation bias. The results were used to characterize families of fractures and determine structural domains.

Analytical models of groundwater flow have already been designed for mines, tunnels and collector wells to predict quantities of infiltration water. These models were developed for drainage conditions similar to those observed in mines, but they do not take into account the heterogeneity of the fracture systems. Using the data collected from mines, they can, however, be used to estimate the hydraulic conductivity of a regional bedrock aquifer. The majority of the models specifically developed for mine drainage conditions are based on the assumption of a single vertical shaft. Even if the solutions designed for tunnels are simple and the necessary data available, the underpinning assumptions of these models generally do not correspond to the conditions observed in a mine. The models for radial wells are based on geometry similar to that of a mine and they take into account the length and number of lateral drains. The use of several models results in a higher level of confidence for the estimates of hydrogeological properties.

Hydrogeochemistry varies as a function of depth. In the Canadian Shield, for example, water near the surface is commonly charged with calcium bicarbonates, whereas at depths of more than 200 m, the water is richer in sodium and potassium, and below 500 m, it is typically chloride-rich.

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Preliminary analysis of active slope failure in the wall of the LAB Chrysotile mine: LiDAR monitoring and numerical modelling

PHILIPPE CAUDAL AND MARTIN GRENON (ULAAVAL)

Maximum pit slope angles are a compromise between stability and profitability. In other words, the goal of extracting the maximum amount of ore possible without engendering excessive risks in terms of slope stability produces steep angles. The initial design proposal is never definitive; mining operations supply new information that must be taken into account to refine, improve and fortify the geometry of the pit. Throughout the mining process, the technique of retro-analysis is employed to optimize the design by calibrating models using ruptures observed in the field. The consequences of a slope rupture can impact the economic, social and environmental aspects of a mining operation. These consequences can be exacerbated if the slope failures occur in an urbanized environment.

In 2011, mining operations ceased at the LAB Chrysotile open pit mine near the town of Black Lake in the Chaudière-Appalaches region. Pumping was stopped and the pit has since filled with water. In July 2012, slope failure occurred on the east wall of the pit, taking with it a portion of highway 112. The first objective of the current study was to use laser technology (LiDAR) to monitor and understand the evolution of the slide. As part of this preliminary analysis, the movements were documented and quantified. The second objective was to carry out a retro-analysis of the failure using 3D modelling software in order to determine a range of values for the geomechanical properties of the bedrock constituting the rock mass.

Toward a “green” mining industry in Québec: Québec’s mine tailings, a serious regional alternative to capture CO₂ emissions

GNUYARO PALLA ASSIMA, FAÏÇAL LARACHI,
GEORGES BEAUDOIN AND JOHN MOLSON (ULAAVAL)

In an effort to mitigate the eventual impact of CO₂ emissions, a search for CO₂ sequestration methods eventually gave rise to more or less efficient CO₂ capture technologies in the past decade. Methods designed to capture CO₂ emitted by discrete sources (for example industrial smokestacks, incinerators, etc.) are relatively advanced from a technical standpoint. However, methods focusing on CO₂ that is already present in the atmosphere or CO₂ that is continually added by diffuse sources (vehicles, agriculture, forest fires, etc.) are still in their infancy.

Even if, all of a sudden, all CO₂ emissions stopped, global warming would continue simply as a result of the Earth’s thermal inertia. Consequently, it remains necessary to reduce the amount of CO₂ currently present in the atmosphere and to reduce, as much as possible, current emissions.

In Québec, about 60% of all CO₂ emissions are in diffuse form, such that they cannot be captured by currently developed technologies. Extraction of CO₂ from the atmosphere requires a medium- to long-term and ideally low-cost process, given its diffuse nature and low concentration (~395.15 ppm).

We propose to take advantage of the abundant ultra-mafic mine tailings (UMT) available in Québec (tens of billions of tonnes) and to use them in ambient conditions to directly capture atmospheric CO₂. This would not only result in mine tailings becoming a valuable resource, but it would also reduce CO₂ emissions and simultaneously mitigate atmospheric CO₂ concentrations.

Preliminary results obtained by our research group in laboratory and field tests indicate that UMT sequester CO₂ when in direct contact with air. By controlling the water saturation of UMT, carbonation may be improved by up to 750%. By optimizing watering conditions and using chelates, we were able to achieve an 18% conversion rate (i.e. 1800% improvement) after four days.

Social impacts of the Raglan mine in the communities of Salluit and Kangiqsujuaq in Nunavik

JONATHAN BLAIS AND THIERRY RODON (ULAAVAL)

This research project is part of a Masters study done by Jonathan Blais and supervised by Thierry Rodon from the Department of Political Science at Université Laval. This research is an attempt to document and analyze the social impacts of the Raglan Mine on the communities of Salluit and Kangiqsujuaq in order to further understand the consequences of such projects on the Inuit populations of Nunavik. The goal of this project is to understand how to maximize positive and minimize negative impacts of mining development in Nunavik.

Nunavik is facing an unprecedented mining boom. Extractive companies are attracted by its considerable mineral resources in nickel, gold, iron, and platinum. Following the promotion of mining development through Le Plan Nord by the Quebec Government, the level of exploration and exploitation is unprecedented North of the 49th parallel. Major players such as Anglo-American mining, Jien, AREVA as well as world nickel extraction leader Xstrata-Glencore International are investing heavily in exploration or exploitation. However, the large-scale development of the mining industry is not without consequences for the Inuit people of Nunavik that will be the first to feel the impacts of these mining projects.

This development will certainly lead its own set of social changes in Nunavik, which is occupied by 10,000 Inuit. For example, Quebec argues that the implementation of Le Plan Nord will drive the development of ten new mines in Nunavik which will result in the creation of over 4,000 jobs. Already, we know that large mining projects require a skilled workforce which is usually imported from the South. What social impacts will this massive influx of labor have in Nunavik? Will communities adapt themselves to this new situation? How will their social dynamics be affected? Will it be transformed? Also, the social impacts of economic benefits raise many questions concerning the well-being of individuals and the community. What are the impacts of mining royalties paid to Inuit communities and individuals? Culture and language might also be impacted. How will mineral development affect land based activities, cultures, language usage?

However, we know little about the social impacts of mining projects taking place in Nunavik. Unlike the environmental and economic impacts, both of which have been the object of many studies, rare are the research that deal comprehensively with social impacts. By studying and comparing the social impacts of Raglan on the communities of Salluit and Kangiqsujuaq, this research aims to help bridge these gaps and bring on new light on the impact of mining development in Nunavik.

G85

Municipal groundwater knowledge acquisition program, northeast Bas-Saint-Laurent region (PACES-NEBSL) – Quaternary features in the Trois-Pistoles region

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The first year of the municipal groundwater knowledge acquisition program in the northeast Bas-Saint-Laurent region was focused on assembling any relevant documentation for the project (geology, pedology and hydrology reports, etc.) and laying the foundation for direct collaboration with all regional stakeholders concerned with groundwater resources. Meetings were organized with the main stakeholders (OBV, MRC, CRÉ-BSL, Comité ZIP, municipalities, etc.) to present the project's objectives and to encourage their participation, particularly by sharing any problems encountered in the region and their expectations in terms of project results. Field work got underway in the summer of 2013, and the products of that work include: 115 water quality analyses, 21 boreholes in surficial deposits (in collaboration with INRS), the installation of 6 piezometers, 10 permeability tests, 16 kilometres of seismic reflection (MBMS Solution), 5 drill holes in bedrock, 7 pumping tests, and 100 surveys using a Guelph permeameter. The mapping of unconsolidated deposits, currently in the process of being validated, was done by Jean Veillette (GSC). The mapping work will be supplemented by field work to be carried out in the summer of 2014. Some preliminary results from the Trois-Pistoles region will be presented as examples. The Trois-Pistoles fluvioglacial delta is currently the subject of a specific study led by Denys Dubuc (a Master's thesis as part of the PACES-NEBSL project). In addition to providing new data on the Quaternary geology and geomorphology of Trois-Pistoles, this study will refine the regional stratigraphic framework, thereby obtaining a clearer picture of the area's aquifer environment.

G86

Mapping of landslide-prone areas in sensitive clays, Québec, Canada

(JANELLE POTVIN, RÉMI MOMPIN AND DENIS DEMERS (MTQ))

Since 2003, the Ministère des Transports du Québec has been mapping landslide-prone areas in sensitive clays in the southern part of the province of Québec. The area covered by this mapping program comprises the post-glacial seas of Champlain, Laflamme and Goldthwait, where approximately 90% of the population of Quebec is settled. The maps are produced on a scale of 1/5000 and are also available in electronic vector format. Municipalities must then apply regulations based on the maps and geotechnical studies are required before any work is carried out in identified areas. Therefore, the way the information is displayed on the maps has to be adapted to its various users.

ACRONYMS

ACPE : Association canadienne des prospecteurs et entrepreneurs

AEM: Agnico Eagle Mines

AMQ : Association minière du Québec

BAPE : Bureau d'audiences publiques sur l'environnement (Gouvernement du Québec)

CCIM-Ottawa : Conseil canadien de l'innovation minière

CCSN: The Canadian Nuclear Safety Commission

CERM-UQAC : Centre d'études sur les ressources minérales de l'Université du Québec à Chicoutimi

CGC : Commission géologique du Canada

CGC-CB : Commission géologique du Canada – Colombie-Britannique

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

CGTNL : Commission géologique de Terre-Neuve-et-Labrador

CMIC: Canadian Mining Innovation Council

CNRC : Conseil national de Recherche Canada

CNRS : Centre national de la recherche scientifique

CNSC: Canadian Nuclear Safety Commission

CONSOREM : Consortium de recherche en exploration minérale

CPESI : Corporation de protection de l'environnement de Sept-Îles

CRC-MM-UQAC : Chaire de recherche du Canada en métallogénie magmatique, Université du Québec à Chicoutimi

CRÉ : Conférence régionale des élus

CRÉBJ : Conférence régionale des élus de la Baie-James

CREM : Centre de recherches en exploration minérale, Université Laurentienne

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

CSMO Mines : Comité sectoriel de main-d'œuvre de l'industrie des mines

CSST : Commission de la santé et de la sécurité du travail

DIVEX : Diversification de l'exploration minérale du Québec (Réseau de recherches géoscientifiques)

ENSG/CRPG : Université Nancy, École nationale supérieure de Géologie / Centre de recherches pétrographiques et géochimiques

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

GSNL: Geological Survey of Newfoundland and Labrador

INRS : Institut national de la recherche scientifique

INRS-ETE : Institut national de la recherche scientifique – Centre Eau, Terre et Environnement

IRME : Institut de recherche en mines et en environnement

LAGAGE : Laboratoire de Géologie appliquée et Géo-Environnement

LERME : Laboratoire d'études des ressources minérales et énergétiques

MDDEFP : Ministère du Développement durable, de l'Environnement, de la Faune et des Parcs

MERC: Mineral Exploration Research Centre

MISA : Mines, innovations, solutions et applications

MPMPS: Mineral potential maps production system

MRN : Ministère des Ressources naturelles

NRC: National Research Council Canada

NTS: National Topographic Series

OGS: Ontario Geological Survey

PDAC: Prospectors and Developers Association of Canada

SPCPM : Système de production des cartes de potentiel minéral (MRN)

ULaval : Université Laval

UQAC : Université du Québec à Chicoutimi

UQAM : Université du Québec à Montréal

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



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