



**QUÉBEC
MINES
2014**

CROSSROADS OF GEOSCIENCE
AND MINERAL RESOURCES

ABSTRACTS OF ORAL PRESENTATIONS AND POSTERS

**Mineral Resources to
Transform the World**

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TABLE OF CONTENTS

Québec Mines Team 6

Abstracts of oral presentations..... 7

Abstracts of posters.....46

Project location 49

Acronyms.....81



A WORD FROM THE MINISTER FOR MINES

It is a pleasure for me to welcome you to Québec Mines 2014, Crossroads of geoscience and mineral resources.

Québec Mines is a privileged time not only to share knowledge, but also to exchange information on the industry good practices. The social acceptability of mining projects is a major challenge of high concern to me, and Québec Mines is the right place to address this issue from several angles. Sharing expertise and geoscience information will be part of the program as well as an initiation to the mining world through the Québec Mines Discovery component.

This meeting is the occasion to demonstrate that Québec is a valued place for investment in responsible mining development. Québec Mines is a networking platform with its commercial exhibition and diverse networking activities. Numerous actors of northern development in Québec will also attend the meeting, so take advantage of this opportunity to enlarge your horizons.

Québec's mining community and the actors of northern development will be there. I hope to see you too!

A handwritten signature in black ink, appearing to read 'Luc B.', with a stylized flourish at the end.

Luc Blanchette

Minister for Mines

Ministère de l'Énergie et des Ressources naturelles



MESSAGE FROM THE ASSOCIATE DEPUTY MINISTER FOR MINES

It is a great pleasure for me to welcome you to Québec Mines 2014.

The Crossroads of Geoscience and Mineral Resources organized by the *Ministère de l'Énergie et des Ressources naturelles* is celebrating 35 years of meetings between all players involved in mining development in Québec. To mark the occasion, Québec Mines has put together a special program! All aspects of mining development will be covered, by speakers from a range of complementary backgrounds. Current topics such as the Plan Nord, sustainable mining development and the place of Aboriginal communities in mining development in Québec will, of course, be given pride of place. Activities with an international focus will open up new horizons. There will be numerous opportunities for discussion and networking. In short, Québec Mines 2014 will be an unmissable event for the mining sector.

I would like to highlight the fact that this major convention has received support once again this year from the Canadian Institute of Mining, Metallurgy and Petroleum, the Québec Mining Association, the Institut national des mines du Québec, the Comité sectoriel de main-d'œuvre de l'industrie des mines, Groupe MISA, 48^e Nord, Aboriginal Affairs and Northern Development Canada, Québec International, the Association des économistes québécois and the organizers of Les Entretiens Jacques-Cartier. The outstanding quality of the Québec Mines program reflects the quality of their input for the benefit of all convention participants.

The convention's component for young people and the general public, Québec Mines Découverte, will be visited by over 3,000 young people and adults. They will be able to learn more about, and appreciate, the key role played by mining development in their daily lives and, above all, to meet some of the passionate people who work in the industry.

I hope you enjoy the convention!

Line Drouin

Associate Deputy Minister, Mines Sector
Ministère de l'Énergie et des Ressources naturelles

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THE MINISTRY WANTS TO THANK THE FOLLOWING PERSONS FOR THEIR SPECIAL CONTRIBUTION TO THE ORGANIZATION OF THE EVENT

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ABSTRACTS OF ORAL PRESENTATIONS

SESSION 2 - MINING ENGINEERING CHALLENGES

The Renard diamond mining project: Development challenges	10
Mine development at the Raglan Mine Qakimajurq Project	10
Meadowbank: Engineering challenges in developing an integrated mining plan in an arctic environment.....	11
Bypassing diesel in northern mines and communities: Wind-LNG alternatives.....	11
Stability of large-scale underground mine openings, the CCCP concept	12
Electric equipment: the Atlas Copco green line	12
Process optimization in the mining value chain: opportunities and challenges.....	13

SESSION 3 - A BROADER VIEW OF QUÉBEC'S GEOLOGICAL DOMAINS AND NEW EXPLORATION HORIZONS

Overview of recent geological work by the MERN and new exploration targets in Québec	13
The Southern Appalachians in Québec: Present state of knowledge and implications for mineral exploration	14
Overview of chrome, nickel and vanadium occurrences in the Baie-James region in a "Ring of Fire"-type metallogenic setting	14
Supracrustal rocks of the Les Escoumins area: A well-preserved Pinwarian back-arc setting in Québec's central Grenville Province	15
The Labrador Trough: Present state of knowledge and outlook	15
Alkaline magmatism and REE resources: A European overview, and links to Canada	16

SESSION 4 - MINES AND NORTHERN ABORIGINAL COMMUNITIES: SOMETHING FOR EVERYONE

Nunavik Inuit mining policy.....	16
Cree Mineral Exploration Board: Mining development in Eeyou Istchee, Québec.....	17
Cree mining business in the Québec history, hopes and facts	17
The long relation of Aupaluk and mining development.....	18

SESSION 5 - MINING PROJECTS IN QUÉBEC: ORE PROCESSING CHALLENGES

Processing quality and cost challenges at the Lac à Paul phosphorus mining project.....	18
The Lac Knife development project: High-purity flake graphite for green technologies.....	19

Nemaska Lithium: Green and innovative.....	19
Extracting value from low grade ultramafic nickel deposits	20
Overview of the Crevier project: A new source of critical metals in Québec	20
Development of the Strange Lake Alkalic Complex: Addressing logistics, processing and environmental challenges	21

SESSION 6 - USE OF GEOPHYSICAL AND GEOLOGICAL DATA FROM DIFFERENT SOURCES IN MINERAL EXPLORATION

Observing Earth from space: An overview of more than 40 years of expertise.....	21
Remote Sensing for Mineral Exploration: A comparison of hyperspectral, ASTER & WorldView-3 data	22
Airborne hyperspectral remote sensing as an efficient exploration tool in northern territory	22
High-resolution satellite imagery to support mining operations: A user's opinion	23
Characteristics of drones and potential applications in the mining sector	23
Mine surveying and drones: A marriage of convenience.....	24

SESSION 7 - SUSTAINABLE DEVELOPMENT AND MINES: REAL-LIFE EXPERIENCE OF COMPANIES' SOCIAL RESPONSIBILITY

Mines and sustainable development: How do we square the circle?	24
Responsible development of Québec's mining industry: A lifecycle perspective.....	25
Arianne Phosphate: Developing a mine in Saguenay-Lac-Saint-Jean.....	25
Creating a monitoring committee in an evolving social setting.....	26
The social risk index: A new mining project evaluation tool accessible to all stakeholders.....	26

SESSION 8 - MINING GEOMECHANICS: FROM FEASIBILITY STUDY TO "POST-MINE"

Lapa Mine – Ground control practices in squeezing ground	27
Review of rock bursts to improve ground support effectiveness at the LaRonde mine.....	27
Interpretation of stresses adjacent to the Cadillac Fault (assuming marginal large-scale rock mass stability at great depth).....	28
Impact tests on anchor bolts: Results and interpretation.....	28
Use of paste backfill at the Goldex mine	29
Management of historical underground openings in an open pit mine.....	29

LIDAR monitoring and retro-analysis of an active slope failure: The case of the LAB Chrysotile mine	30
---	----

SESSION 9 - USE OF GEOPHYSICAL AND GEOLOGICAL DATA FROM DIFFERENT SOURCES IN MINERAL EXPLORATION

Geophysical expressions of ore systems: Our current understanding	30
Exploration for magmatic Ni-Cu deposits: Strengths and limitations of Mag and EM surveys.....	31
The importance of integrating geophysics and geology for successful exploration: the example of Raglan Mine.....	31
Integration and interpretation of geophysical data using structural geology: A case study of the Lalor volcanogenic massive sulphide deposit, Snow Lake, Canada.....	32
Integrating airborne geophysics with Landsat TM imagery and geology for assessing the mineral potential of the Iullemeden Basin, Niger	32
Defining a framework for the integration of geological and geophysical data	33

SESSION 10 - INDUSTRIAL EXPERIENCE OF SUSTAINABLE MINE DEVELOPMENT IN FRENCH-SPEAKING AFRICA

Sustainable mine development in French-speaking Africa: The case of the Essakane mine in Burkina Faso	33
Key scientific advances derived from 5 years of Canadian-Moroccan cooperation in the mining environment field	34

SESSION 11 - MINE SITE RESTORATION CHALLENGES

Single-layer cover with elevated water table to control AMD from tailings ponds: Design principles and methodology	34
Approach and studies for the rehabilitation of abandoned-mine sites	35
Tailings rehabilitation in northern climates: The case of Meadowbank mine, Nunavut	35
Study and overview of rehabilitation concepts at the Raglan Mine tailings pond	36

SESSION 12 - GOLD MINERALIZATIONS AND DEFORMATIONS ALONG THE CADILLAC FAULT IN ABITIBI

The Larder Lake-Cadillac Break: A historical overview	36
The Larder Lake-Cadillac Fault, an Ontarian perspective and a comparison with the Ridout Fault.....	37
Architecture of the Malartic, Piché and Cadillac groups and the Cadillac Fault, Abitibi: Geological revision, new dates and interpretations	37
Structural evolution of the Cadillac Fault, relationship with orogenic gold occurrences, and characterization of the Piché Group, Abitibi Subprovince, Québec.....	38

Typology of gold mineralization along the Cadillac Fault	38
---	----

SESSION 13 - SUSTAINABLE MINE DEVELOPMENT IN FRENCH-SPEAKING EUROPE

Sustainable management of mineral resources in Wallonia (Belgium): A few lines of thought to promote better integration.....	39
Environmental impacts and management of abandoned mines scattered in the French Alps	39
Occurrence of Rare Earth Elements in ecosystems and assessment of their ecological impacts: research approaches used in the French programme Labex Ressource 21.....	40
Strategy, tools and environmental policy of Variscan Mines in France: The sustainable mine	40

SESSION 14 - INNOVATION AT THE SERVICE OF WORKPLACE HEALTH AND SAFETY

The safety side effect: Things supervisors do that, coincidentally, improve employee safety	41
The contribution of morphology recognition technology in the prevention of machine-pedestrian collisions.....	41
Development of the Visi+ camera	42
TopVu™ eTag Board.....	42
Health and safety aspects to consider for drilling and blasting operations.....	43

SESSION 15 - NEW TARGETS FOR INTRUSION-RELATED MINERALIZATIONS

Elements of a porphyry Cu(Au-Mo) deposit: Formation and preservation	43
Reduced intrusion-related gold deposits (RIRG): A common Paleozoic perigranitic gold deposit model?.....	44
Searching for subalkaline Cu-Au porphyries in high-grade metamorphic terrains in Québec: Geochemical criteria and exploration targets	44
The Bachelor Lake gold mine: A new plutonic model for the Abitibi	45
Hydrothermal alteration at the Canadian Malartic mine: Distribution, mineralogy, and geochemistry of a complex multiphase Archean gold system	45

SESSION 2

The Renard diamond mining project: Development challenges

GHISLAIN POIRIER (STORNOWAY DIAMONDS)

There are many challenges associated with the development of a mining project; some are technical and some are social, environmental or financial, and these can occur at the exploration phase, during development, construction or during production. This is especially true when the project is located in an isolated area, and even more so if the company developing the project is not already a mining producer. Financing then becomes a critical issue! This presentation will focus on the numerous challenges that Stornoway Diamonds had to overcome during the development of its Renard project. It will also look at the remaining milestones to achieve before becoming not only the first diamond producer in Québec, but also a major diamond producer on the global stage.

SESSION 2

Mine development at the Raglan Mine Qakimajurq project

MARTIN VERREAU (GLENORE)

The development of new mines always entails increasingly stringent requirements concerning worker safety, respect of timelines, and cost control.

At the Qakimajurq project, Raglan Mine overcame these challenges by maintaining an exemplary health and safety performance while incorporating new ways of doing things in order to improve worker productivity.

A strong spirit of cooperation with the mining contractor, the implementation of an effective management system, and the use of jumbo drills for the installation of ground support, a method commonly used in Australia, made the Qakimajurq project a success.

This success is the result of a series of beneficial measures and this presentation will briefly review the succession of events.

SESSION 2

Meadowbank: Engineering challenges in developing an integrated mining plan in an arctic environment

**STÉPHANE FRÉCHETTE AND PIERRE MCMULLEN
(AGNICO EAGLE MINES)**

Located in Nunavut, about 300 kilometres from the Arctic circle, the Meadowbank mine is currently Agnico Eagle Mines (AEM)'s largest gold producer. From the first few days following its acquisition in 2007, the Meadowbank team had to overcome significant challenges to bring to production the first gold mine in Nunavut. The history of this mine can be divided into four pivotal stages, which were successfully achieved thanks to the know-how, ingenuity, and determination of AEM employees.

The first major stage was construction, which took place from 2008 to 2010. Problems with the weather, logistics, and the lack of infrastructure nearby, constituted major obstacles for the mining company. Commissioning of the mine in February 2010 was the second significant milestone. The challenges that came with trying to reach production objectives became a priority and required a collective and constant effort. This difficult learning process resulted in the implementation of action plans in which all departments were called upon to reach common objectives, to ensure operations ran smoothly.

The third stage occurred in 2012, when optimal cost management became top priority to ensure the mine's long-term sustainable development in a difficult context. The Meadowbank team at once implemented a plan to reduce the cost per ounce, to ensure the long-term development of AEM.

The fourth and final stage is the development of AEM in Nunavut. With the closure of the Meadowbank mine less than three years away on paper, the team is exploring interesting expansion opportunities. AEM is working to develop a plan that will maintain jobs and take advantage of its expertise gained over the past few years with regard to mining in an Arctic environment. Many options are currently on the table.

AEM has always stood out for the quality of its operations and its responsible behavior. A mining operation in such a fragile ecosystem as the Canadian Arctic requires the involvement of each and every employee. This presentation will review the achievements of the engineering department since the start of the Meadowbank project, as well as the challenges that lay ahead. Mine engineering required to operate an open pit mine in an Arctic environment will be discussed, as well as the geo-technical structures designed to enable operations to proceed. Tailings and water management issues will also be discussed.

SESSION 2

Bypassing diesel in northern mines and communities: Wind-LNG alternatives

PIERRE RIVARD (TUGLIQ)

Off-grid systems in the North, whether public or in the mining sector, run exclusively on diesel or heavy fuel oil. However, the price for crude oil has tripled over the past decade, while the price for certain commodities remained stable or declined during the same period. In light of such uncertainty and fluctuations, how can we ensure the sustainability and growth of the mining sector in the North, a key component of Québec's economy? The authors will discuss the need to diversify sources of energy and potential solutions, and will present a few innovative projects currently underway.

SESSION 2

Stability of large-scale underground mine openings, the CCCP concept

JEAN GARANT AND PHILIPPE BELZILE (GLENCORE)

Matagami Mine, a Glencore company, operates the Bracemac-McLeod underground mine near the town of Matagami in northwestern Québec.

Proven mineralization defined to date occurs in the form of three deposits physically separated from one another. Ore is brought to the surface using diesel-powered trucks, prior to crushing. The mine initially used 45-tonne trucks, but with the development of the McLeod deposit, located more than 3 km from the surface by ramp, the production department opted for 60-tonne trucks.

To enable the free circulation of 60-tonne trucks, it is necessary to excavate drifts with a nominal width of 6 m. In certain zones, the hanging wall is 8 m high. Since workers are constantly exposed to large-scale openings, ensuring their stability is paramount.

Issues

The need to provide appropriate support, from the onset and at minimum cost, is even more important given the fact that ground support problems are difficult to detect with the limited lighting provided by miner's lamps. Regular inspections are conducted by members of the field crew, however heavy equipment may also damage the support mesh in areas that remain accessible to pedestrians.

Ground support of large-scale openings is more costly and rehabilitation, where required, is more complex. The higher rocks can fall, the greater their destructive potential.

It is recognized that the quality of drilling and blasting in drifts has an impact on the profile and stability of openings. The Perimeter Control Compliance Index and its easily remembered acronym in French "CCCP" (cote de conformité du contrôle périmétrique) was created to determine what could be achieved using current procedures.

This index, expressed as a percentage, corresponds to the countable traces of holes of 1 m or more in length (in a single segment or in many small segments) over a pre-established maximum potential number of traces based on the size of the drift. Geologists in charge of structural and economic geology (mapping) help the engineering department by providing an index for each blast.

This presentation will focus on a tool being developed to quantify the impact of blasting on the rockmass and to improve drilling and blasting practices in an effort to guarantee its integrity. Better control of excavation profiles is also beneficial.

SESSION 2

Electric equipment: the Atlas Copco green line

JAMIE TOMPOROWSKI (ATLAS COPCO)

The types of equipment that are in the Green Line, Tethered Load Haul Dump units (having a cable and plug for power), Trolley Haul type units (powered by an overhead trolley system), Battery powered units and combination units that use diesel power for transport but function under electric power.

The advantages of using electric powered units, such as, better operating environment for operators, zero/reducing exhaust emissions, reduced energy requirement overall, higher productivity and lower operating costs.

The possible challenges that may be associated with each type of electrically powered unit.

Description of the various Atlas Copco electric units.

What does the future hold for non diesel powered units.

SESSION 2

Process optimization in the mining value chain: opportunities and challenges

MOHAMAD SABSAHI
(NATIONAL RESEARCH COUNCIL CANADA)

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. Furthermore, in order to be competitive the mining and metal-producing industry is striving to reduce costs, and maximize benefits from existing equipment. To remain competitive and to thrive in our current and future economy, companies must take steps to implement a technology infrastructure that optimizes the supply chain from “pit” to the point of export, import, or consumption. Mining companies that fail to optimize an end-to-end supply chain by integrating and automating operations, logistics, and process control subject themselves to significantly heightened risks that can erode profits, impede productivity, and compromise product quality. Understanding the challenges of optimizing an end-to-end mining supply chain and how to address them is critical to ensuring efficient, streamlined operations that maximize profit.

Canadian mining operators are traditionally secretive about their methods and processes and do not involve suppliers or OEMs for more profound process improvements and innovation. This approach tends to limit the ability of Canadian mining operators to improve the global competitiveness of their operations. Moving technology ideas to innovation then to business growth will both cause and require reinforcement of the value chain in a gradual fashion, including research and monitoring capacity that controls technical risks along the value chain.

One group of technologies that will contribute to meeting these challenges is related to reliable online measurements that provide key analysis information at all steps, from mine to metal. For example, in the pyrometallurgical process, metal making involves the basic steps of charging the furnace, melting the charge and refining. In mineral processing, elemental characterization is critical to monitor and optimize mine-site recovery and subsequent processing operations. In all these steps, 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. 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, mineral characterization etc. In particular, we will be focusing on the application of LIBS for analyzing gold ore samples.

SESSION 3

Overview of recent geological work by the MERN and new exploration targets in Québec

PATRICE ROY, GUILLAUME ALLARD, MEHDI AMINE GUEMACHE, DANIEL BANDYAYERA, PÉNÉLOPE BURNIAUX, JEAN GOUTIER, HANAFI HAMMOUCHE, ISABELLE LAFRANCE, FRANÇOIS LECLERC, ABDELALI MOUKHSIL, PIERRE PILOTE AND FABIEN SOLGADI (MERN)

The *Bureau de la connaissance géoscientifique du Québec* (BCGQ) conducts geological surveys to improve geoscientific understanding and showcase the mineral potential of Québec. In 2014, the 22 ongoing projects – 4 geophysics projects, 8 bedrock mapping projects and 8 Quaternary mapping projects, 1 inventory of stone and industrial minerals, and 1 mineral potential study – have already identified 53 exploration targets. This work is in addition to the many thematic studies carried out in collaboration with our institutional and university partners.

Some of the BCGQ's mapping surveys take longer than a year. Below is a summary of completed, ongoing and new projects.

The mapping program in the Manicouagan area, now finished, highlights the area's potential for Ni-Cu-PGE, Fe-Ti-P-V oxides, rare earths and graphite. In all, 46 new exploration targets were identified.

Several projects will wrap up over the next few months. In the southeast part of the Churchill Province, reconnaissance mapping has successfully differentiated major geological entities and defined settings that are favourable to exploration. In the James Bay region, a mapping program along the northern contact between the Opinaca and La Grande subprovinces has come to an end. In addition to elucidating the gold potential, several volcanosedimentary belts were refined or newly defined. In the Chibougamau-Chapais area, recent work improved the stratigraphy, uncovered the oldest volcanic rocks in the Abitibi, and better defined the area's base and precious metal potential. Mapping of the Malar-tic-Val-d'Or segment, once complete, will provide an updated map of the Rouyn-Val-d'Or segment. Both the stratigraphy and the gold and nickel potential have already been refined.

Finally, new mapping projects have started in the Gouin Reservoir area, in the Attic Complex of the Abitibi region, and to the south of Rimouski in the Appalachians. The Gouin project will detail the geology around the reservoir, a promising area for several commodities such as rare earths, graphite, copper, zinc, apatite and phlogopite. The mapping verification project to the south of Rimouski will complete the geological compilation of the Appalachians.

SESSION 3

The Southern Appalachians in Québec: Present state of knowledge and implications for mineral exploration

ALAIN TREMBLAY (UQAM)

In the Canadian Appalachians, the Humber and Dunnage zones, amalgamated during the Taconian Orogeny, represent the remains of Laurentia and adjacent oceanic terrains, which are overlain, in Québec, by a Silurian-Devonian sedimentary sequence, the Gaspé Belt. Over the past two decades, detailed structural analysis and the acquisition of U-Pb and $40\text{Ar}/^{39}\text{Ar}$ ages have played a key role in improving our understanding of the tectonic evolution of the Appalachians in Québec. These data were used to constrain structural and metamorphic events during the Ordovician, the late Silurian-early Devonian, and the middle Devonian. Ordovician ages (D1) are associated with NW-directed thrusts in the Humber zone, structures resulting from the obduction of ophiolites and the subsequent collision of Laurentia. Silurian-Devonian ages (D2) are derived from a series of SE-verging folds and faults and provide constraints compatible with the exhumation of Laurentia and the formation of the Gaspé Belt. The Dunnage zone is exposed in the hanging wall of the Baie Verte-Brompton Line, which was redefined as a major normal fault along the contact with the Humber zone. The Dunnage zone consists of ophiolites, the Saint-Daniel Melange, the Magog Group, and the Ascot Complex. Isotopic ages coeval with D1 suggest the emplacement of ophiolites onto Laurentia took place over a time span of about 15 Ma and that Humber nappes are contemporaneous with the “early” exhumation of the Taconian orogenic wedge. The Saint-Daniel Melange and the Magog Group form an unconformable basin overlying a “basement” of continental, ophiolitic, or volcanic rocks. “Exotic” lithologies in the Saint-Daniel Melange consist either of structural inliers exposing its base or its basement, or of stratiform volcanic sequences and their lateral facies variations. The Magog Group is a 300-km sedimentary basin that overlies the Saint-Daniel Melange in the NW and the Ascot Complex in the SE. The Gaspé Belt unconformably overlies the Dunnage zone or is in tectonic contact with the latter along the La Guadeloupe Fault. Metamorphism and locally polyphase structures associated with the Devonian (D3) Acadian Orogeny show variable intensity, but are commonly associated with overlapping folds that complicate the understanding of the deformed end-product, in both post-Ordovician rocks and the Humber and Dunnage zones.

The metallogenic implications of work carried out in the last few decades vary according to the lithological domain. For example, in the Humber zone, D2 is characterized by significant hydrothermal circulation, expressed as abundant quartz veins that offer potential for lode occurrences; in the Dunnage zone, ophiolite sequences are capped by a major erosion surface that suggests the likely recycling of PGE-bearing chromitites and the potential formation of paleoplacers in the Saint-Daniel Melange or the Magog Group; finally, the latter two units are contemporaneous with regional magmatism that may be related to the formation of SEDEX-type gold mineralization.

SESSION 3

Overview of chromium, nickel and vanadium mineralization in the James Bay area, in a Ring of Fire-type metallogenic setting

MICHEL HOULÉ (GSC-Q), JEAN GOUTIER (MERN), C. MICHAEL LESHER (LAURENTIAN UNIVERSITY), ANNE-AURÉLIE SAPPIN (GSC-Q), RIKU METSARANTA (OGS) AND VICKI MCNICOLL (GSC-O)

Chromium, nickel and vanadium mineralization in mafic-ultramafic intrusions of the Superior Province was considered to be of marginal significance until the discovery of world-class Cr and Ni-Cu-(PGE) mineralization and substantial Fe-Ti-V-(P) mineralization in the McFaulds Lake greenstone belt (Ring of Fire or RoF) in northern Ontario. Furthermore, recent work in this emerging mining region has greatly renewed interest for these types of mineralization throughout the Superior Province.

The RoF is a greenstone belt ranging from Meso- to Neoarchean age that extends more than 200 km in the central part of the Oxford-Stull domain (Ontario). This belt is characterized by a variety of mafic-ultramafic intrusions, host to world-class chromite deposits (Black Thor and Blackbird), a large Ni-Cu-(PGE) deposit (Eagle's Nest) and major Fe-Ti-V-(P) mineralization (Thunderbird). At least two generations of mafic-ultramafic intrusions (approx. 2810 and 2735 Ma) have been identified, and although either generation may host these types of mineralization, most of the occurrences appear to be associated with the Neoarchean intrusions. Chromium and Ni-Cu-(PGE) mineralization is found in predominantly ultramafic intrusions, whereas Fe-Ti-V-(P) mineralization is found mainly in predominantly mafic intrusions.

The La Grande and Eastmain domains of the James Bay region, which appear to correlate with the RoF, also contain numerous Mesoarchean or Neoarchean mafic-ultramafic intrusions. Many chromite showings have been identified over the years, the most important of which are associated with the Menarik Complex (Neoarchean) and the Lac des Montagnes intrusion (Mesoarchean). Each complex displays an ultramafic zone containing several centimetre- to metre-scale layers of chromite; the zones are laterally continuous and overlain by mafic zones. These chromite deposits are distinguished from those of the RoF by their uniquely Neoarchean age. Other intrusions (e.g., the Nisk intrusion) also contain Ni-Cu-(PGE) mineralization near their base. Although more limited in size, Fe-Ti-V mineralization is also found in mafic-ultramafic intrusions (Baie Chapus Pyroxenite). This mineralization is present as a massive to semi-massive accumulation of titanomagnetite near the upper part of the intrusion.

The aim of the ongoing work is to establish the geological framework and dominant characteristics of the orthomagmatic Cr-(PGE), Ni-Cu-(PGE), PGE and Fe-Ti-V deposits in these areas. A better understanding of these types of mineralization will improve the probability of discovering new resources, not only in the James Bay region but also in other areas of the Superior Province and Canadian Shield.

SESSION 3

Supracrustal rocks of the Les Escoumins area: A well-preserved Pinwarian back-arc setting in Québec's central Grenville Province

PIERRE-ARTHUR GROULIER, APHRODITE INDARES (MEMORIAL UNIVERSITY OF NEWFOUNDLAND), ABDELALI MOUKHSIL (MERN), GREG DUNNING AND STEPHEN J. PIERCEY (MEMORIAL UNIVERSITY OF NEWFOUNDLAND)

The Les Escoumins and Petit-Saguenay areas, located within the Grenville Province of Québec, are characterized by the presence of volcanic rocks metamorphosed to the amphibolite facies. Major units in the area, the Tadoussac Complex and the Saint-Siméon Group were defined during previous mapping campaigns. The Tadoussac Complex is composed of migmatites and tonalitic, granodioritic or granitic gneisses, whereas the Saint-Siméon Group is divided into three formations: Saint-Paul-du-Nord, Moulin à Baude, and Port-aux-Quilles. These formations consist of an assemblage of supracrustal metasedimentary rocks (quartzite, meta-arkose, conglomerate, calc-silicate rock, metagraywacke and a few rare layers of marble and paragneiss) and metavolcanic rocks (basalt, andesitic basalt, and andesite). The latter occur as relatively massive amphibolite layers interpreted as flows and volcaniclastic deposits (hyaloclastites, breccias, and ash, lapilli, pumice, fiamme, and bomb tuffs), all intruded by felsic to ultramafic dykes, sills, and plutons. A few felsic (dacitic to rhyolitic) units, probably volcaniclastic in origin, were locally observed in the amphibolites. These observations enable us to redefine the Saint-Siméon Group as the Les Escoumins volcano-sedimentary belt. From a structural standpoint, the supracrustal rocks occur within synforms, whereas migmatitic and plutonic rocks are characterized by positive topographic relief, outlining a dome-and-basin-type structural arrangement. The Les Escoumins volcano-sedimentary belt, which hosts many Au-PGE-Ni-Cu showings as well as Zn-Cu-Pb-Ag occurrences, offers significant economic potential for base and precious metals associated with lode, volcanic, and exhalative deposits.

A dacitic bomb tuff was dated at 1493 ± 3 Ma (TIMS U-Pb zircon analysis), confirming the Pinwarian origin of the supracrustal assemblage, with a metamorphic age at 1000 Ma. A TIMS U-Pb titanite analysis on the same tuff confirmed the late Grenvillian metamorphism, with two age groups at 1000 Ma and 985 Ma. Field observations of pillowed basalts, pumice-fiamme-bomb tuffs, cross-bedded quartzite, and conglomerate suggest the sequence was emplaced in a marine environment. The major and trace element geochemistry of the least-altered metavolcanic and intrusive rocks point to an arc/back-arc-type setting.

SESSION 3

Labrador Trough: Present state of knowledge and outlook

CARL BILODEAU (MERN) AND THOMAS CLARK (UQAT-MERN)

The Labrador Trough constitutes a roughly 800-km-long Paleoproterozoic segment of the New Quebec Orogen. Its mineral potential is among the best in Québec. A variety of commodities, notably iron, nickel and copper, have been the subject of exploration work since the 1950s. This work relied on a foundation of geoscientific knowledge, particularly geological maps produced by government geologists. Over the years, exploration tools and methods have become modernized and new players with innovative concepts have arrived on the scene to boost the effort to develop new commodities, in addition to those that have already made the Trough so well known.

The MERN recently completed a high-resolution airborne geophysical survey (magnetic and spectrometric) covering the entire Labrador Trough in Québec. The ongoing reinterpretation of geological maps demonstrates that by combining new geophysical data with modern imaging products (for example, RapidEye), it is possible to refine lithological contacts and redefine the structural architecture of many areas. Furthermore, since 2009, the MERN has been coordinating mapping work in the Southeastern Churchill Province, deepening our understanding of lesser known domains and defining new prospecting targets in the eastern part of the New Québec Orogen.

By proposing new field data acquisition programs, the MERN and the Geological Survey of Canada are collaborating to generate new exploration targets and review certain geological settings. The objectives of the planned work are to refine geological maps, acquire a new lithogeochemical and geochronological database, and carry out thematic metallogenic studies. The MERN will also lead a five-year program in priority areas, more specifically in strategic and lesser known parts of the Trough such as the region south of Baie aux Feuilles, the area between Payne Bay and Hopes Advance Bay, the Lac Roberts syncline at the northern end of the Trough, the Lac Le Moyne carbonatite area, and the Romanet horst and Wheeler dome area.

The new geological and geophysical data will be used to redefine the geodynamic model and mineral potential of the Labrador Trough and the internal domain of the orogen. On the eve of the Plan Nord, industry and local populations alike will benefit from the support of geoscientific data and improved exploration guides.

SESSION 3

Alkaline magmatism and REE resources: A European overview, and links to Canada

KATHRYN GOODENOUGH, EIMEAR DEADY (BRITISH GEOLOGICAL SURVEY), ADRIAN FINCH (ST ANDREWS UNIVERSITY), RICHARD SHAW, PAUL LUSTY (BRITISH GEOLOGICAL SURVEY) AND FRANCES WALL (UNIVERSITY OF EXETER)

In recent years, the European Union (EU) has prioritised the issue of critical raw materials – those materials which are important for the economy, but have risks to their supply. Of the materials identified as critical, the rare earth elements (REE) are considered to have the highest supply risks, since > 90% of global production comes from China. Several programmes are underway in Europe to investigate the supply chain for the REE and other critical materials. These include the EU-funded EURARE project^b, which aims to set the basis for the development of a European REE industry; and the Security of Supply of Mineral Resources (SoS Minerals) research programme in the UK.

As part of these projects, we have studied European REE resources, in particular primary resources associated with alkaline magmatism in continental rift zones. The most significant REE resources so far recognised in Europe are associated with Mesoproterozoic alkaline magmatism around the margins of Archaean cratons in Greenland and Sweden. Carbonatites in Greenland and Scandinavia, formed during Neoproterozoic, Devonian and Jurassic rift phases, also represent potential REE deposits that are typically enriched in the less valuable light REE (LREE). Cenozoic rifts associated with alkaline magmatism arc across central and southern Europe, including the Rhine Graben and the Massif Central. All these rift systems have the potential to host REE resources, but whereas the older provinces of northern Europe are deeply exposed, exposures in southern Europe are largely at the supracrustal level, and the plutonic rocks that may contain REE enrichments are not exposed at the surface.

Canada shares much of its tectonic history with parts of Europe, and thus there are many similarities in the primary REE resources. The Strange Lake pluton, on the Québec – Newfoundland border, is similar in age to intrusions in the Gardar Province of Greenland, and may represent part of the same Mesoproterozoic rift system. Both Strange Lake and the Ivigtut pluton (Gardar Province) are peralkaline granites in which rare metals have been mobilised and concentrated by late-magmatic hydrothermal fluids. The Thor Lake REE deposits in Canada lie within a Palaeoproterozoic alkaline to peralkaline layered intrusive complex that resembles Greenland's Ilímaussaq Complex. Carbonatites of the Neoproterozoic St Lawrence Rift system in Canada are similar in age to carbonatites with REE potential across Europe. There is thus much to be gained in studying these systems together to investigate the processes by which the REE are enriched.

SESSION 4

Nunavik Inuit mining policy

JOBIE TUKIAPIK (MAKIVIK)

In recent years, Nunavik has witnessed a significant increase in mineral resource exploration and mining projects. Two nickel-copper mines are in operation and several other projects are at advanced development stages. The region has significant, yet still-undefined, multi-element potential.

At Parnasimautik community consultations conducted in 2013 to identify a comprehensive vision for regional development, Nunavik Inuit called for the creation of their own mining policy. The new Nunavik Inuit Mining Policy clearly sets out the conditions for mineral resource development in Nunavik as follows:

- ▶ Maximize the short- and long-term social and economic benefits of mining for Nunavik Inuit.
- ▶ Minimize the negative environmental and social impacts of mining.
- ▶ Ensure open dialog and good communications between project developers and Nunavik Inuit.
- ▶ Ensure balance between conservation and mining development.

The *Nunavik Inuit Mining Policy* will support mining development in Nunavik that is responsible and equitable, i.e. provided that Nunavik Inuit derive significant benefits during the exploration, development, operation and restoration phases of mining activities and that these activities take into account the Nunavik Inuit way of life and are carried out in accordance with Nunavik Inuit rights and the James Bay and Northern Québec Agreement as well as with all applicable federal and provincial legislation respecting environmental and social protection.

SESSION 4

Cree Mineral Exploration Board: Mining development in Eeyou Istchee, Québec

JACK R. BLACKSMITH
(CREE MINERAL EXPLORATION BOARD)

The Cree Mineral Exploration Board is born after the agreement between the government of Quebec and the Crees of Quebec called “La Paix des Braves”.

Mining is not in the culture of the Cree nation as the environment and the nature respect are, and the mineral resources of Eeyou Istchee were all property of the mining industry. The Creation of the CMEB permits the participation of the Crees to the mining activity and regulation of environment impact in the territories.

The main purposes of the Mineral Exploration Board consist of (a) assist the Crees in accessing mineral exploration opportunities and evaluating the environment impact, (b) facilitate the development of mineral exploration activities by Cree Enterprises, (c) facilitate and encourage the access by the Crees and Cree Enterprises to regular Quebec program funding and other encouragements for mineral exploration activities, (d) act as an entry mechanism for offers of services by Crees and Cree Enterprises in the field mining.

Furthermore, the CMEB acts as an intermediate between the mining industry and the Crees to resolve matters concerning mineral resources and the land. The board has the mandate to develop the mining activity and answer to environmental needs of the Cree trapelines. It supports and funds also consistent projects for the all communities and specifically the Cree prospectors.

Concerned by the regional development, the CMEB collaborates with several entities, Cree and non Cree; and these collaborations are having a large success.

CMEB program and projects are managed by his board. This latest evaluates the administrative structure and also compares with what is known elsewhere in Canada and in the rest of the world in the trend to ameliorate and reach the excellence.

SESSION 4

Cree mining business in the Québec history, hopes and facts

SAM R. BOSUM
(NIMSKEN CORPORATION AND NATIVE EXPLORATION)

From *La paix des Braves* till now, the Crees involving in mining changed a lot their relationship with the mining industry.

Nimskén Corporation and Native Exploration are a result of this changes. They are Cree private organizations born because of the huge mining rush in Eeyou Istchee.

Mining is not in the culture of the Cree nation and the mineral resources of Eeyou Istchee were all property of the mining industry. The Creation of companies as Nimskén and Native permits the participation of the Crees to the mining activity in the territories. Joint ventures and collaborations concerning the exploration and environment projects in the James Bay Region are continually developed.

We built and develop different techniques for exploration such Geophysics and geochemistry of alterations. The main purposes of these companies are: access to mineral exploration opportunities, development of mineral exploration activities and environment interventions, access to regular Quebec program funding and other encouragements for mineral exploration activities, and training for youth Crees in the domain of exploration and environment.

Furthermore, all the Cree mining organizations act as an source of job for the trained for all the communities with the collaboration of the mining. We work close to the communities involved in mining and specifically the Cree prospectors.

Nimskén Corporation and Native Exploration program and projects are managed by different staff, where each group has his own expertise. We believe that the Crees as community or individuals have to thing to surf on the mining wave that happening these days in Eeyou Istchee.

SESSION 4

The long relation of Aupaluk and mining development

DAVID ANGUTINGUAK (MAYOR OF AUPALUK)

"Where the earth is red." The meaning of the name Aupaluk evokes the color of the rocks and the local geology observed in the immediate area of the community. Aupaluk is the smallest village in Nunavik with a population of about 200 people. It is located on the south shore of Hopes Advance Bay, an inlet in the western edge of the Ungava Bay. Unlike other communities in Nunavik, Aupaluk was not built around a trading post of the Hudson's Bay Company, but rather at the location representing an ancestral hunting and fishing site where accessibility and abundance of renewable natural resources were essential to the lifestyle of several generations of Inuit families. The development of the actual village of Aupaluk is thus anchored in the past and history, but was planned in conjunction with the Inuit community itself.

Even before the signing of the James Bay and Northern Quebec Agreement in 1975, the formal establishment of the Aupaluk village in 1981, and until today, the community has seen a lot of prospectors and numerous exploration campaigns that were successively interested in the northern part of the Labrador Trough, rich in iron-bearing deposits and other minerals. Since the first observations of Albert Peter Low in 1893 to the current advanced development projects, through the campaigns of the 50's and 60's, residents of the community have heard all kinds of promises and opportunities development without being materialized.

Currently, people of Aupaluk are again facing a potential mine development in their region and they have to think about the desired development for their community. In the current context, important discussions are underway within the population and decisions will be taken to reach a balance between preserving the right to subsistence and traditional activities and the deployment of mining operations that could, if promises are kept, contribute to improving the living standards of Aupalummiut, composed mostly of a young Inuit community, as it is for all the villages of Nunavik.

SESSION 5

Processing quality and cost challenges at the Lac à Paul phosphorus mining project

GHISLAIN GOYETTE (ARIANNE PHOSPHATE)

Founded in 1997 under the name Arianne Resources and listed on the TSX Venture Exchange in 2003, Arianne Phosphate is a Canadian company with a world-class phosphorous deposit, one of the largest in the country. The company is dedicated to the development of this deposit, the Lac à Paul project, located roughly 200 km north of the town of Saguenay.

The first phosphorous showings at Lac à Paul were discovered more than fifteen years ago. Following the increase in demand for fertilizers and the rise in the price of phosphorous over the course of the last decade, the company has made every effort to develop the project.

This presentation provides an overview of the project and presents the last five years of work to develop a concentration process. Phosphate concentrates are used in the production of fertilizers for vegetable crops destined for human and animal consumption. The quality aspect of the final product has been the main preoccupation during process development. Volatility in raw material prices over the last few years makes it essential that production be at the lowest possible cost to ensure project sustainability. Metallurgical testing was also carried out with the same goal of reducing process costs.

SESSION 5

The Lac Knife development project: High-purity flake graphite for green technologies

DON BAXTER (FOCUS GRAPHITE)

The Lac Knife project, held 100% by Focus Graphite, is located 27 km south of Fermont. The metamorphosed mineralization of the Lac Knife deposit is massive to disseminated and ranks among the best in the world in terms of grade and the size of its flake graphite crystals. These parameters are important when evaluating graphite mineralization. The exceptional quality of this deposit is related to the intense regional metamorphism (from upper amphibolite facies to granulite facies).

The flake graphite deposit contains proven and probable reserves of 7.86 million tonnes at a grade of 15.13% graphitic carbon (Cg). The feasibility study, based on a 25-year mine life, projects an internal rate of return of 30.1% (24.1% after tax), a net present value of \$383 million (\$224 million after tax) calculated at 8%, and a capital payback period of 3 years (3.2 after tax).

Metallurgical studies have shown it is possible to produce a high-grade graphite concentrate (98% C) above 200 mesh by flotation only (no purification process). This initial concentrate grade of 98% C significantly lowers the costs related to the thermal or hydrometallurgical purification processes used to attain an end-product above 99.95% C, the required grade for manufacturing Li-ion batteries for electric cars. This is Lac Knife's big advantage over other deposits.

Focus Graphite aims to become one of the lowest cost producers of graphite concentrate and is well positioned to become a green technology mining company with a "mine-to-technology market" business strategy. Thanks to a historic offtake agreement for its concentrate, exceptional results from lithium-ion battery performance testing on its concentrate, and the completion of a feasibility study, Focus Graphite is poised to compete with the synthetic graphite market.

SESSION 5

Nemaska Lithium: Green and innovative

**JEAN-FRANÇOIS MAGNAN AND GARY PEARSE
(NEMASKA LITHIUM)**

The Whabouchi lithium deposit held by Nemaska Lithium is located in Eeyou Istchee/Baie-James, Québec. It is the second-largest spodumene deposit in the world both in terms of grade (averaging 1.53% Li_2O) and volume (27 Mt of proven and probable reserves), and exhibits features indicating that mining the deposit will be both environmentally and economically interesting. Due to its width and inclination, the Whabouchi ore deposit is indeed exceptional. The recently released feasibility study demonstrates it will be possible to develop an open pit mine with a stripping ratio of 2.2:1 and a low dilution rate (10%). A concentrate at 6% Li_2O will be produced, two thirds by way of dense media separation (DMS), a robust process that uses less chemicals, and one third by way of an optimized flotation process. Process water will be entirely recycled and the waste rock, a granitic ore with a very low leachable mineral content, will be disposed of in such a way as to minimize its impacts on the environment and the community. The Whabouchi orebody is homogeneous and has low concentrations in sodium, potassium, and mica. These impurities, when present, are known to cause problems and entail additional costs, both during the production of spodumene concentrate and its transformation into lithium compounds. However, given the nature of its orebody, Nemaska Lithium will not have to deal with these issues. After a significant amount of rigorous development work carried out on a representative 50-tonne sample, and given its close collaboration and respectful approach with the community, Nemaska Lithium is in a good position to face the challenges that will come with mining the Whabouchi ore deposit. Downstream, the company has developed a unique process to transform lithium extracted from the concentrated ore into high-quality, low-cost lithium compounds: battery-grade lithium hydroxide and battery-grade lithium carbonate. These raw materials are needed to make batteries used in electric vehicles (namely the Tesla S and the Prius Plug-in Hybrid) and renewable energy storage. Compared to the conventional transformation process, Enviro-Accès estimates that Nemaska's process could help reduce GHG emissions on the order of 191,000 t of CO_2 eq./yr, the equivalent of 47,000 cars, not to mention indirect reductions attributable to the users of electric vehicles. This process also eliminates an environmentally hazardous by-product (Na_2SO_4) and drastically reduces the consumption of fuel and chemicals.

SESSION 5

Extracting value from low grade ultramafic nickel deposits

JOHNNA MUINONEN, MICHELLE SCIORTINO, JOHN KORCZAK
AND ALGER ST-JEAN (ROYAL NICKEL CORPORATION)

The Dumont deposit is a large (1,179 Mt proven and probable reserve) low grade (0.27% nickel), nickel sulphide project located in the Abitibi region 25km west of Amos, Quebec. Royal Nickel Corporation acquired the project in 2007 and has since taken the deposit through to feasibility (2013) and into detailed design.

The disseminated nickel sulphide and alloy mineralization is hosted within the serpentinized dunite subzone of the Dumont Sill; a differentiated, pervasively serpentinized, ultramafic sill of komatitic affinity. Pentlandite, heazlewoodite and awaruite are the dominant nickel-bearing, metallic phases and can be recovered by conventional methods (flotation, mag separation). Non-recoverable nickel is also present within the silicate matrix of the serpentinized dunite and is locked in serpentine (Fe and Mg-rich variants) and minor olivine.

A detailed mineralogical program including 1420 QEMSCAN® samples and 3295 electron microprobe points were undertaken to increase the understanding of the nickel deportment in the various recoverable and non-recoverable phases in a spatial context across the deposit. One hundred and five (105) metallurgical tests performed under a standard procedure have linked the mineralogy to metallurgical performance. This has allowed the creation and modelling of geometalurgical domains on a block by block basis to understand the recovery variation and metallurgical performance throughout the deposit.

In addition to understanding the detailed mineralogy and nickel recovery of the deposit, the ultramafic nature of the deposit causes rheology challenges when the ore is mixed with water. Removing the fine portion (slimes) from the primary grinding circuit is key to achieving nickel recovery and concentrate grades from the Dumont deposit. This presentation will review the flowsheet development of the Dumont deposit from pre-feasibility through to detailed engineering.

SESSION 5

Overview of the Crevier project: A new source of critical metals in Québec

CLAUDE DUFRESNE (MDN)

The Crevier deposit is situated northwest of the municipality of Dolbeau-Mistassini, in the Lac-Saint-Jean region. Following an NI 43-101 compliant preliminary economic assessment, it was determined that the deposit contains a world-class resource of two critical metals: niobium and tantalum.

This presentation on the Crevier project covers the work to date and reviews the markets and applications for these metals, which are not well known to the general public. The mined niobium will be destined mainly for the aerospace sector, a rapidly growing and well-established field in Québec, whereas the tantalum will be used in the manufacture of electronic parts for high-end technologies.

The economic development opportunities associated with the Crevier project are very attractive to all the stakeholders. Moreover, recent internal studies have shown that the project is technically and financially viable. The company is also studying the downstream processing of niobium in Québec, through research carried out by strategic partners. With its Crevier project, MDN will become the sole producer of niobium and tantalum oxides in North America.

SESSION 5

Development of the Strange Lake Alkalic Complex: Addressing logistics, processing and environmental challenges

**DIRK NAUMANN, YEMI OYEDIRAN, AND MIKE ROBERT
(QUEST RARE MINERALS)**

This paper describes the development of the Strange Lake Alkalic Complex (SLAC), from a metallurgical and processing point of view in the context of logistics, processing and environmental issues and presents work completed by Quest Rare Minerals Ltd on options developed to address the challenges. The SLAC, originally discovered by the Iron Ore Company of Canada (IOC) in the northeastern Canadian Shield of Québec and Labrador, is one of the world's largest deposits of yttrium, heavy rare earths and zirconium. It is part of a Precambrian, post-tectonic complex of peralkaline granites which intruded along the contact between gneisses and monzonites of the Churchill Province of the Canadian Shield. Mineralization of interest at Strange Lake occurs within peralkaline granite-hosted pegmatites and aplites and, to a lesser degree, within the host granites, particularly in intra-pegmatitic granites. The highest grade and metallurgically most favorable mineralization is in the upper, open pit mineable parts of the SLAC. Due to the remote location of the mineral deposit, the project envisions two main operating sites including the mine site and beneficiation plant in the north at Strange Lake and the processing plant in the south at Becancour. This arrangement requires key logistics infrastructure including a road linking the mine site to a port and marine transportation from the port to Becancour process plant. SLAC contains mostly unique minerals that requires tailor made process design to unlock the value. A significant amount of work has been completed to develop a robust process flow sheet for the production of a high purity rare earth mixed oxide. Uranium and thorium are key environmental concerns for rare earth projects, strategies for management of streams containing radioactive elements are provided.

SESSION 6

Observing Earth from space: An overview of more than 40 years of expertise

ROBERT SAINT-JEAN (CANADIAN SPACE AGENCY)

It was the advent of aerial photography that first prompted researchers to take a step back in order to obtain a broader view of Earth's surface. It nonetheless took the launch of Landsat-1 in 1972 for the era of space-based observations of Earth to really take off. Sensors first used the visible portion of the electromagnetic spectrum, then moved to the near-infrared range, and finally to the thermal infrared and microwave spectrums; the spatial and spectral resolutions of sensors have never stopped improving. For several years now, the trend has been towards smaller, less costly satellites that are both more efficient and more specific, with an acquisition frequency that is faster than ever before. Research is also focusing on super- and hyper-spectral sensors, lidars, gravimeters, new GPS systems, mono- and bi-static radars that acquire the signal phase and polarization, as well as other space-based systems that pave the way for new techniques.

This presentation will provide an overview of how technologies have evolved since the advent of Landsat-1, with particular emphasis on applications in the fields of geological mapping and mineral exploration.

SESSION 6

Remote Sensing for Mineral Exploration: A comparison of hyperspectral, ASTER & WorldView-3 data

LORI WICKERT (CONSULTANT), JAN M. PETER,
J.R. HARRIS (GSC), BILL BAUGH (DIGITALGLOBE),
AND DAVID COULTER (GEOSPECTRAL ANALYTICS)

Remotely sensed data have been used to assist in mineral exploration for decades, with applications in bedrock and surficial geological and alteration mineral mapping, which can be integrated with other data for remote predictive mapping or prospectivity analyses. Here, we present remotely sensed data for the Hope Bay orogenic Au deposit and the Hackett River Ag-bearing VMS deposit, both in Nunavut, Canada. Data from three different sensors types will be examined: airborne hyperspectral imagery from the Geological Survey of Canada's SINED survey in 2009, commercially available Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) data, and WorldView-3 from DigitalGlobe's satellite launched 13 August, 2014. The objective is to demonstrate how remotely sensed data can provide exploration targets for deposits in Canada's north, as well as compare and contrast results from the different sensors. ASTER is a 14 band multispectral sensor launched by NASA and Japan's METI (Japan Space Systems) in December 1999. ASTER has bands in the visible to near infrared, short-wave infrared and thermal (with spatial resolutions of 15, 30 and 90 m, respectively), and has been widely used world-wide to generate regional-scale mineral exploration targets. WorldView-3 is a 17 band multispectral sensor with a 31 cm resolution panchromatic band, 8 bands in the visible to short-wave infrared and 8 bands in the short-wave infrared, with native or collected spatial resolution of 1.2 and 3.7 m, respectively. Current US regulations will limit the spatial resolution of the SWIR sensor to 7.5 m when released.

SESSION 6

Airborne hyperspectral remote sensing as an efficient exploration tool in northern territory

BENOIT RIVARD (UNIVERSITY OF ALBERTA)
AND DEREK ROGGE (GERMAN REMOTE SENSING
DATA CENTER)

Hyperspectral imaging is a promising avenue to facilitate detailed continuous regional mapping in sub-Arctic regions. This presentation focuses on the use of AISA optical airborne hyperspectral and simulated EnMAP satellite imagery (2 m and 30 m spatial resolution, respectively) to demonstrate the capability of producing detailed maps to highlight ultramafic rock units associated with Ni-Cu-(PGE) mineralization in the presence of lichen coatings. A total of 20 AISA flight-lines were flown over part of the Proterozoic fold and thrust Cape Smith Belt (Nunavik, Canada) in 2008. These lines have been radiometrically leveled and merged to form a single mosaic approximately 10x20 km in size. This mosaic was subsequently used to generate a simulated EnMAP satellite scene.

An endmember extraction tool was used on both the AISA and EnMAP simulation data to find image end-member spectra that represent lithological units in the study area. Image endmember spectra were compared with spectral measurements taken from field samples to establish the index mineral controls behind the perceived lithological discrimination in imagery. The derived endmembers were also used to map the distribution of various geological units in imagery. Results indicate that the airborne data, as expected, allow for better detailed regional mapping compared with the EnMAP simulated data. However, results also showed that even at the 30 m spatial resolution of the EnMAP data, broad scale lithological units could be discriminated and mapped. With the launch of the EnMAP hyperspectral satellite it should be possible to pursue regional scale reconnaissance mapping of mafic-ultramafic terranes in sub-arctic regions of the globe.

SESSION 6

High-resolution satellite imagery to support mining operations: A user's opinion

MARC DESCHÊNES (LAFARGE)

At Lafarge, with more than 500 active sites, it is a constant challenge to keep track of all our quarry operations. Quarry sites are generally small compared to metal mines, and consequently have limited personnel and means. Regular topographic monitoring is not systematic. An annual or semiannual land survey is the preferred method of tracking quarry faces and whether their progression is consistent with the mining plan. The most commonly used method is aerial photography, although this approach can be very costly, prohibitively so in some developing countries. The development of high-resolution satellite imagery has provided a lower-cost global alternative, unhampered by local constraints. For 10 years now, Lafarge has used this method to produce numerous topographic surveys. The accuracy, on the order of a metre, has proven adequate for operational monitoring. When greater precision is required, for example in geochemical monitoring, field surveys are performed. The delays in acquiring data in regions with thick cloud cover are unavoidable and represent a drawback of the method. The low cost of the surveys on a per-surface-area basis allows more land to be covered, which provides ideal support for planning and monitoring rehabilitation work, and for exploration programs. In some cases, different spectral frequencies have been used to follow the progression of revegetation efforts and even assess plant health. Moreover, satellite images provide valuable tools for external communication.

The highly competitive rates for drones, the better resolution, and the ability to circumvent problems related to cloud cover make them an interesting alternative to satellite imagery technology. The ways in which quarrying methods are evolving require increasingly frequent survey updates as machinery becomes more integrated and automated. Whether a particular technology is part of a satellite, affixed to a drone, or stationed on the ground, if it can provide more frequent monitoring with greater accuracy and at lower cost, with a minimum of human intervention, it will always be the method of choice.

SESSION 6

Characteristics of drones and potential applications in the mining sector

YACINE BOUROUBI AND MICHEL RHEAULT
(EFFIGIS GEO-SOLUTIONS)

Remote sensing has evolved from the use of hot air balloons to that of airborne and subsequently spatial platforms, but is now coming back to Earth, so to speak, with the recent development of unmanned aerial vehicles (UAV), which are becoming increasingly popular for civilian applications. As their name suggests, UAVs are aerial vehicles that fly without pilots: they are remotely controlled either manually or automatically thanks to an accurate on-board GPS. In the mini-UAV category, several types are currently being used: paragliders, fixed-wing planes and single or multi-propeller helicopters. Their flying autonomy varies from 20 to 120 minutes, depending on vehicle type and payload. Operational flying speed can exceed 70 km/h and radio line of sight reach 10 km. Depending on flight altitude, digital images can be acquired with centimeter or decimeter spatial resolutions. Wide spatial coverage is usually achieved by flying back and forth over a site and automatically producing image mosaics using the on-board GPS. Sensor manufacturers have adapted their products to the UAV's limitations by offering multispectral, thermal and hyperspectral cameras that are lighter as well as more compact.

Remote sensing has been used by the mining industry to meet its information needs ever since the early twentieth century when aerial photography first appeared. It provides essential spatial and spectral information that is useful at all stages of a mining project. During the exploration stage, Earth Observation images and digital elevation models (DEM) that can be derived from them are used to study site geomorphology as well as its mineral and structural properties. During the exploitation stage, remote sensing is used to produce maps of land cover and surficial deposits, which help in planning the development of infrastructures and the storage of tailings or in supporting environmental impact studies. Finally, at the mine closure and rehabilitation stages, remote sensing is used to monitor the overall site conditions and the stability of the restored and the re-vegetated areas. For some of these information needs, UAVs can bring benefits particularly with respect to improved spatial resolution, easier deployment logistics and the possibility of getting imagery regardless of cloud conditions.

SESSION 6

Mine surveying and drones: A marriage of convenience

MARCEL LABERGE (GEOMATECH)

From aviation regulations to accurate topographic maps, this presentation will provide information on how aerial imagery is acquired using airborne drones and how it can be applied.

What are the benefits to the mining sector of acquiring aerial imagery using drone technologies? Is it a dream or reality? Are topographic surveys using such acquisition technologies possible, practical and accurate? How are aviation regulations evolving to adapt to these new acquisition tools?

SESSION 7

Mines and sustainable development: How do we square the circle?

CLAUDE VILLENEUVE, OLIVIER RIFFON
AND DAVID TREMBLAY (UGAC)

Is it possible to qualify an activity that exploits non-renewable resources as “sustainable”? Reconciling development in the mining industry with the requirements of sustainable development presents a major challenge.

In a globalized economy, the ever-growing consumption by an expanding world population exercises increasing pressure on resources, land and energy, often to the detriment of local populations. When it comes to mine development, economic indicators remain the principal factor justifying the exploitation of a deposit.

The predominance of the economic aspect, to the detriment of other key indicators, is the heart of many socio-environmental controversies that have had a negative impact on this industry over the last few decades, leading to greater mobilization of all stakeholders and a growing opposition to mining development in general.

Within the sector, we do acknowledge certain inadequacies in practicing the sustainable development concept. Sustainable development issues related to the mining industry are complex, and we believe it is crucial to address this problem at two levels of management: at the level of organizational management (**planning strategy**) and at the level of mine project management (**pragmatic strategy**).

At the organizational level, a sustainable development planning strategy should enable a company to implement a multidimensional, long-term global vision of its development, and to use suitable and adapted tools to provide a framework for this approach within a continuous improvement process. Sustainable development management systems allow a company to take into account all the economic, social, ecological and ethical considerations in the management and governance processes in order to analyze this complexity.

In terms of projects, a pragmatic sustainable development strategy aims to address problems arising from a mining project relating to its regional setting, and the issues raised by one or more stakeholders.

By virtue of the settings in which mining projects develop and operate, mining companies face certain constraints, and opportunities, in applying the principles of sustainable development. The availability of a number of sustainable development tools means that companies must reflect on their purpose and approach in order to choose the right tools (typology of sustainable development, analytical grids, CSR, etc.). This presentation will use examples of tools and concrete applications to illustrate these notions and shed light on the limitations, difficulties, and key factors for both strategies, within a mining industry context.

SESSION 7

Responsible development of Québec's mining industry: A lifecycle perspective

ÉDOUARD CLÉMENT (QUANTIS CANADA)
AND JEAN-MICHEL COUTURE (GROUPE AGÉCO)

In today's ever-changing business environment, the mining industry faces many new challenges such as the social acceptability of projects, the expectations of the general public and government for more environmentally friendly products and business practices, rising energy costs, and the growing demand for transparency and accountability. Companies that are willing to anticipate the risks inherent to this environment and continue to evolve in a cost-effective manner will reap the benefits if they adjust their operations to adopt sustainable development as their *modus operandi*.

This talk will present the results of a study carried out for the *Association minière du Québec* (AMQ) on sustainable development issues specific to the Québec mining industry and on best practices that would improve the sector's position. Before developing its action plan on sustainable development, the AMQ wanted to establish an overall portrait of the initial position of the sector and its members. The project was carried out by adopting a "lifecycle" approach that examines sustainable development issues in a comprehensive perspective (that is, taking into account the entire value chain, from the extraction of raw materials, through processing, transport and applications, to end-of-life), taking into account a multitude of environmental and social indicators (GHG emissions, water, waste, working conditions, health and safety, community engagement, etc.). We will also present the framework used to identify the most important sustainable development issues, as well as the guidelines and initiatives in place to support sustainable development management in the mining sector. Lastly, we will present an overview of the position of the AMQ in matters of best practice adoption, and its strategic recommendations for the development of a responsible mining industry in Québec.

SESSION 7

Arianne Phosphate: Developing a mine in Saguenay-Lac-Saint-Jean

JEAN-SÉBASTIEN DAVID (ARIANNE PHOSPHATE)

The development of the Saguenay-Lac-Saint-Jean area is largely attributable to the forestry and aluminum industries. For several years now, these sectors have faced a significant decline in the number of available jobs. The region, which is renowned for its dynamic nature and quality of its workforce, is looking to diversify its economy.

Along with the challenges faced by this region, the world's population continues to grow each year. Changing diets combined with global population growth have called into question the availability and quality of food resources. The very high quality of more than 26 years worth of resources at Arianne Phosphate's Lac à Paul Project allows the company to be part of the solution because these resources represent a source of long-term supply for the North American market.

As we do our part to help feed the world, Arianne Phosphate will also become a major economic driver for the Saguenay-Lac-Saint-Jean region. It is truly a project with promise for the future.

To achieve our goals, the company must overcome the major challenges facing many mining companies. Among them, the development of a mining project in an area with a non-mining background, the understanding and acceptance of technical issues related to transporting the finished product, managing human resources and the permitting process. In addition to gaining social acceptance, Arianne Phosphate must also attract strategic partners, and raise the capital needed to carry out the project.

The Lac à Paul project is about nourishing a region's future and growing tomorrow's food.

SESSION 7

Creating a monitoring committee in an evolving social setting

MICHEL GILBERT AND SYLVIANE LEGAULT
(OSISKO MONITORING COMMITTEE)

The new Mining Act recently adopted in Québec requires that the majority of mining projects set up a monitoring committee. The government is currently working out the details of these committees, which will be governed by the law.

But shouldn't monitoring committees be created to reflect their community?

The quest for social acceptability by companies is a commendable albeit utopian goal in the sense that social acceptability can never be truly attained. Rather, social acceptability is based on the perception of risks and the expectations of the community environment and society in general. The host community is part of a larger society in which other social groups exercise an influence on expectations and risk perception. These viewpoints inevitably evolve over time based on the information received and what people experience.

Given this social setting, how should mining projects be developed?

The emergence of monitoring committees is part of a broader and integrated management approach that promotes greater involvement from local and regional populations during the development of their territory. A good understanding of the community environment enables a company to know when citizen mobilization begins, and what issues drive them.

For these reasons, we believe no rules can be uniformly applied to all monitoring committees.

At Malartic, a number of citizen groups formed even before the mining lease was granted and before BAPE (*Bureau d'audiences publiques sur l'environnement*) public hearings were held.

In this context, how should the Malartic monitoring committee have been created?

What would be its place?

The creation of a functional monitoring committee that is both useful and legitimate in the eyes of the community must be done in a manner that respects existing committees. We chose to be the link — the "liaison agent" — between the mining company and the community, through continual dialogue that allowed us to learn everyone's expectations and how they perceived the associated risks.

To work effectively within a committee, one must first recognize that citizens have inherent knowledge of their environment and a capacity for action, and then support this with expertise. A monitoring committee thus becomes a vehicle from which we can learn about the knowledge held by each member.

SESSION 7

The social risk index: A new mining project evaluation tool accessible to all stakeholders

KRISTINA MAUD BERGERON AND MICHEL JÉBRAK
(UQAT-UQAM)

As a mining project takes shape, can we predict the reactions it will provoke from neighbouring communities? Can we identify whether a mining company will make productive use of suggestions and requests from residents and local authorities? Which elements draw the most attention to a mining project in the exploration phase, and which features are the most contested? Using these questions as a springboard, a multidisciplinary team was set up to identify the most influential factors on relations between communities and mining companies during project development. This relationship is more complex than is conveyed by the term "social acceptability," an expression used often in recent years, but one that remains poorly conceptualized.

Using a compilation of identified factors, the teams developed a practical evaluation tool for mining companies, investors, communities and all other stakeholders involved in mine development in Québec. Combining objective and subjective aspects with social, physical, communication and management characteristics, this tool can identify the issues on which the players share a similar point of view, and those for which they have diverging perspectives. It is also intended as an invitation to open a dialogue between the various stakeholders of a project at the exploration phase.

Benefiting from the input of multiple disciplines (geology, political science, sociology, economy, communication, project management, anthropology and management sciences), the social risk index for mining projects in Québec provides a concrete and pragmatic approach to an unavoidable issue in the mining world.

Our presentation will focus on the steps that led to the creation of the social risk index, on the challenges the team faced as it was developed, and on the possibility of extending its application to other domains.

SESSION 8

Lapa Mine – Ground control practices in squeezing ground

FRÉDÉRIC MERCIER-LANGEVIN AND DEVIN WILSON
(AGNICO EAGLE MINES)

Many underground mines operate under squeezing ground conditions. Depending on the severity of the convergence, considerable investments in ground support may be necessary to maintain the integrity of the affected tunnels. In the worst cases, the conditions may require major rehabilitation activities that could hinder production. To minimize any negative consequences on mining operations, it is essential to have a good understanding of the rock mass and mechanisms involved in order to develop a roof support system. The safety and operating conditions of the latter must be adequate for the life of the mine, and at the lowest possible cost.

The Lapa mine of Agnico Eagle in the Abitibi operates under extreme squeezing conditions. We propose a rupture mechanism that agrees with field observations. The resulting roof support strategy and its performance in the field will be presented.

SESSION 8

Review of rock bursts to improve ground support effectiveness at the LaRonde mine

PASCAL TURCOTTE (AGNICO EAGLE MINES)

The LaRonde mine of Agnico Eagle Mines is located in the Abitibi region of northwest Québec, about 650 km from Montreal. This world-class Au-Ag-Cu-Zn deposit forms a complex of massive sulphide lenses. With more than 4 million ounces of gold in proven and probable reserves, the LaRonde mine is one of the biggest actively mined gold deposits in Canada. Reserves extend from surface down to 3.1 km, and the deposit remains open at depth. Production is 6,300 tonnes per day, which includes the mining of a new horizon 2,930 metres below surface since 2013.

Seismicity has been recorded at the LaRonde mine since 2004. Some of the past seismic events have damaged infrastructure. This presentation provides a critical review of these damaging seismic events. We will describe the observations and the integration of information that served to adapt the mine's ground support design. This review improved seismic risk assessments for underground workings, and in so doing, yielded a proactive approach to updating ground support before significant seismic events occur.

SESSION 8

Interpretation of stresses adjacent to the Cadillac Fault (assuming marginal large-scale rock mass stability at great depth)

DENIS LABRIE (CANMETMINES) AND STEVE D. MCKINNON (QUEEN'S UNIVERSITY)

In situ stresses were measured near the Cadillac Fault in the Cadillac region of Québec (Canada). The depths of the four measurement sites ranged from 1,450 to 2,200 m. Measurements made at intermediate depth (ex., 1,460 and 1,500 m) generally conform to expected stress levels, but stress magnitudes determined at greater depth, around 2,200 m, were not only lower than those determined at shallower depth, but also lower than expected. An analysis of other stress measurements made in the vicinity of the Cadillac Fault has shown that the characteristics of the stress tensors determined near the fault differ from those of other regions in eastern Canada. We developed a method of analyzing the stress measurement data based on a state of marginal stability of the large-scale rock mass at great depth. The analysis provides a rational explanation for the low stress levels determined at greater depth in the vicinity of the Cadillac Fault and the changes in the orientation of the stress field.

SESSION 8

Impact tests on anchor bolts: Results and interpretation

FRANÇOIS CHARETTE (NORMET CANADA)

This presentation will review impact tests on anchor bolts. These tests are used to assess a bolt's potential for dynamic absorption when used in rock burst conditions. Several types of anchor bolts were compared based on impact energy and number of impacts, as well as their specific energy dissipation device. The discussion will relate the results and applicability of the dynamic tests to the energy requirements of different types of rupture observed during dynamic events in underground mines, in both hard and weak rocks. The importance of compatibility between bolts and accessories will also be discussed.

SESSION 8

Use of paste backfill at the Goldex mine

CHANTALE DOUCET (AGNICO EAGLE MINES)

The Goldex mine restarted operations in September 2013 with the exploitation of the M and E zones. These zones are mined using the long hole stoping method in a primary and secondary sequence, with paste backfill. The commissioning of a paste backfill plant was an essential prerequisite for commencing mining operations.

This presentation will focus on the original paste backfill design (amount of binder, barricades and backfilling sequence) and its optimization since operations commenced, which yielded substantial savings for the mine.

SESSION 8

Management of historical underground openings in an open pit mine

PATRICK FRENETTE (CANADIAN MALARTIC MINE)

The Canadian Malartic mine is the biggest gold mine in Canada. It is also one of the first large open pit mines along the Cadillac Fault in the Abitibi because the deposits in this region were historically mined underground. With the advent of new knowledge and technologies, low-grade deposits can now be mined in open pits, including some that had already been mined underground, but for which considerable resources had been left behind due to their subeconomic grade. This is the case for the Canadian Malartic mine where four underground mines that operated between 1935 and 1983 are present in the current footprint of the pit. These excavations pose significant security issues, particularly if they had not been effectively managed in the past. It is essential that the location and stability of these historical excavations are known. In the case of the Canadian Malartic mine, the archives of these former mines were available and a preliminary assessment was possible. However, the thoroughness and accuracy of these plans, coupled with stability changes over the years, means they cannot be completely relied upon. Field investigations have delineated areas of risk, and access is securely managed near these areas to ensure the safety of personnel. This presentation will detail the measures that have been implemented and how they have evolved since the start of open pit operations.

SESSION 8

LIDAR monitoring and retro-analysis of an active slope failure: The case of the LAB Chrysotile mine

MARTIN GRENON AND PHILIPPE CAUDAL
(UNIVERSITÉ LAVAL)

This talk will present our analysis of an active slope failure on the east wall of the LAB Chrysotile mine in Québec. The landslide had major consequences for road infrastructure near the pit, forcing the closure and diversion of highway 112. LIDAR monitoring provided a series of digital terrain models (DTM) of the mine slope before and after the east wall failure. The DTM were used to recreate and quantify displaced volumes. They were also used to perform a retro-analysis of the failure. Finally, the profiles were also used to perform a preliminary prospective analysis of the impact of the raised water table on the stability of the east wall.

SESSION 9

Geophysical expressions of ore systems: Our current understanding

KEN WITHERLY (CONDOR CONSULTING)

Mineral exploration is the primary means to define new mineral resources. Following the end of World War II, there was a global economic boom which required the identification and mining of vast numbers of new deposits in order to provide the needed raw materials to sustain the demand. By and large, shallow easy-to define ore bodies were recognized first and developed. In the past 20 years, the discovery performance across virtually all mineral sectors has fallen, resulting in growing concern that if unchecked, there could be shortfalls in a number of commodities within the next 20 years. The collective sense is that there are more deposits to be found, but these are expected to be at greater depths than those that have been typical targets in the past. To operate in this environment, new approaches for identifying deposits are required and the concept of a mineral systems approach, first suggested 20 years ago, has emerged as a powerful means going forward to build strategies and capabilities. In terms of geophysical exploration, the major change that will be required is a shift from a focus almost entirely on direct targeting with geophysical surveys of deposits, to a staged process where geophysical approaches are used initially to help define the pathways in the earth that carried the mineralizing solutions, which formed the target deposit. These pathways would provide a much larger target and if detected and mapped, should allow explorers to follow the pathway to the location of potential deposits.

This task is different from most geophysical studies, where the focus has typically been on improving the direct targeting capabilities and not the larger scale mapping problem that a mineral systems approach requires. A review of the current state-of-play for a number of major deposit styles shows how geophysical data are being used at present to explore for the larger scale mapping problem. The assessment overall is encouraging but major challenges remain outside of the technical issues of defining a mineral systems strategy that relate primarily to human resources and the commercial environment. With regard to the human resources issue, are there going to be a sufficient number of the right people to develop and implement the required programs? Universities play a critical role in producing new geoscientists but the industry then must take responsibility to train and mentor these people to become functioning professionals. In the commercial environment, at present there is little interest for long-term, strategic programs, either in terms of the needed fiscal support or commitment to undertake the implementation of outcomes. Although governments likely have a greater sense of urgency with regard to this problem, it may be difficult to unilaterally and successfully deal with this complex issue.

SESSION 9

Exploration for magmatic Ni-Cu deposits: Strengths and limitations of Mag and EM surveys

CIRCÉ MALO-LALANDE AND CLÉMENT DOMBROWSKI
(ANGLO AMERICAN EXPLORATION CANADA)

Some magmatic Ni-Cu deposits comprise a series of mineralized lenses that were deposited at the base (footwall) of an ultramafic rock horizon. In certain cases, the latter overlies a band of sedimentary rocks with variable amounts of graphite. The case we will present is that of Payne Bay, in Nunavik. Previous work led to the discovery of several mineralized showings in a band of ultramafic rocks in the Qarqasiaq area, with nickel grades ranging from 2.1 to 6.5%. In 2010, Anglo American, in partnership with Virginia Mines, carried out a high-resolution airborne magnetic survey. This survey was completed not only to support mapping efforts, but also to adequately delineate the ultramafic horizon. In the two years following the survey, ground-based TDEM surveys were carried out over the ultramafic horizon to detect conductive bodies possibly representing massive sulphide lenses. The surveys on the property are problematic due to the geological setting whereby mineralized zones overlie graphitic sediments that also generate an electromagnetic response. The challenge is to trace discrete conductors (massive sulphides) at the interface between the ultramafic rocks and the sedimentary sequence (formational conductor).

To establish drill targets, the magnetic data were inverted to generate a 3D magnetic susceptibility image that was used to interpret the volume and geometry of the ultramafic horizon. In the absence of drill data, the inversion was performed without any initial constraints. However, susceptibility values were collected from outcrops with the aim of correlating the results. TDEM anomalies defined during the surface surveys were modelled in order to establish, on the map, the geometry of the sediments and the potentially mineralized zones. Using the combined 3D model, we were able to distinguish discrete conductors located at the base of the magnetic envelope that coincide with mineralized zones at the surface.

The results of the 2013 drilling program underscored the strengths and limitations of the magnetic data inversion method and the numerical modelling of TEM anomalies.

SESSION 9

The importance of integrating geophysics and geology for successful exploration: the example of Raglan Mine

MATHIEU LANDRY (GLENCORE)

Geophysical methods play an important role in exploration strategies throughout the world. There is a fundamental link between geophysics and geology. First, it is of utmost importance to identify the physical properties of the rocks underlying an area to be investigated. Then, geophysical data can be combined with this information to refine geological models and even consider new alternatives. But to do this, it is necessary to have a process that can integrate different sources of data. Considering the relatively high conductivity of the nickel sulphide ore at the Raglan mine, electromagnetic techniques are the method of choice to directly detect the highly localized sulphide masses. The complete investigation of an exploration area also requires the exploration geologist to examine all sources of data in order to develop holistic geological models that explain all available information, with the ultimate goal of carrying out viable exploration programs. As an example, magnetism not only allows us to delineate the parent ultramafic formations to the Raglan deposits, but it can also be used to better understand the overall potential of this mining camp. As exploration continues ever deeper at the Raglan mine, the contextualization of new data, such as those from audio-magnetotelluric surveys, must take into account the existing geological and geophysical data as well. With a creative but reliable approach that takes into account all the compiled geological and geophysical data, the exploration geologist has a greater chance of success and can generate better interpretations with greater clarity to guide exploration drilling.

SESSION 9

Integration and interpretation of geophysical data using structural geology: A case study of the Lalor volcanogenic massive sulphide deposit, Snow Lake, Canada

PEJMAN SHAMSIPOUR, ERNST SCHETSELAAR
AND GILLES BELLEFLEUR (GSC-O)

Modelling the subsurface requires the integration of diverse sources of information into a single model. Two main problems are inherently associated with subsurface modelling.

First there is the scaling problem where the voxel size (volume support) of the model differs from the scale of information provided by other data sources. Secondly, integrating prior geological information into inversion models is a challenging task.

Generally, the integration of different sources of information into the final model calls for an iterative solution of an ill-posed inverse problem. In stochastic approaches, sampling solutions have been introduced, however applications of such methods are computationally demanding.

In this contribution two examples are provided to demonstrate how prior geological constraints support interpretation of geophysical data. In the first example we demonstrate how integrating prior geological information into inversion methods can effectively reduce ambiguity and improve inversion results. In most inversion applications, the problems are underdetermined and have non-unique solutions, i.e., there are an infinite number of models that can reproduce the geophysical observations. The purpose of any well-founded inversion method is to provide a model that is consistent with all the available geophysical, petrophysical and geological information.

We present a new method which includes structural orientation constraints into the linear inversion method using a stochastic framework. The method considers known geological interfaces and planar orientation data such as stratification estimated from seismic surveys or drillhole information. The method is applied to the inversion of gravity data collected over the Lalor volcanogenic massive sulphide deposit near Snow Lake, Central Manitoba, Canada.

In the second example we demonstrate how litho-geochemical data supports the geological interpretation of borehole gravity data recently acquired at Lalor mining camp. Apparent density logs were calculated from the borehole gravity data and compared with lithofacies and Zr/TiO₂ logs, the latter being a geochemical proxy for differentiating volcanic rocks of felsic to mafic composition. The apparent density anomalies predominantly reflect alternating mafic and felsic volcanic rock units in the footwall and hanging wall of the massive sulphide deposit. We demonstrate that when integrated with ancillary geological data, gravity borehole data can, in addition to the direct detection of mineralization, be employed as a subsurface geological mapping tool.

SESSION 9

Integrating airborne geophysics with Landsat TM imagery and geology for assessing the mineral potential of the Iullemeden Basin, Niger

NASREDDINE BOURNAS AND JEAN LEGAULT (GEOTECH),
DJIBO-MAÏGA ABDOUL-WAHAB (MINISTRY OF MINES AND
INDUSTRIAL DEVELOPMENT OF NIGER), KARL KWAN,
MARTA ORTA, GEOFF PLASTOW, ALEX PRIKHODKO,
SHAOLIN LU, AND KEEME MOKUBUNG (GEOTECH)

Airborne geophysical surveys, consisting of fixed-wing magnetic gradiometer and gamma-ray spectrometer and helicopter-borne full-waveform Versatile Time-Domain Electromagnetic (VTEM) surveys were carried out over the Iullemeden basin, in western Niger for mineral exploration and detailed geological mapping. The eastern portion of the basin is known to include substantial phosphate, lignite coal and iron ore deposits whereas, the western portion, which belongs to the Liptako Metallogenic Province, hosts several mineral occurrences including base and precious metals, precious stones and special metals in various deposit styles.

Geophysical data integration with other available types of information including Landsat ETM+ imagery and geological maps has been performed using innovative approaches based on Neural Networks (NN) and Enhanced Maximum Likelihood (EML) supervised classification techniques. Combined techniques have proven very useful during the analysis of multidisciplinary data resulting in better understanding of the distribution of mineralization and the results were used for targeting and selecting new favorable areas for the exploration of various mineralization styles within the study area.

Results of gamma-ray spectrometer, aeromagnetic and Landsat TM data interpretation and their integration with known geology suggest the existence of three metallogenic provinces within this area. The first two provinces are associated with tertiary sediments of the Iullemeden basin and include potential radioactive mineralization (uranium and thorium). The third province is associated with intrusive and metavolcanic sedimentary formations of the Birimian Liptako basement outcropping partly along the east side of the Niger River and hosting various styles of polymetallic mineralization (Cu, Pb, Zn, Ag), precious metals (gold and diamonds), special metals (Sn, W, Ta, Bi, Li, Ti), iron ore, REE and Ni-GE mineralization.

SESSION 9

Defining a framework for the integration of geological and geophysical data

GERVAIS PERRON, JOHN MCGAUGHEY, GLENN PEARS (MIRA GEOSCIENCE) AND PETER FULLAGAR (FULLAGAR GEOPHYSICS)

Geoscientists working in the mineral exploration sector face a number of new challenges. Exploration targets are deeper, geological settings more complex and host rocks may not be directly accessible. The context in which mineral exploration operates must evolve to adapt to these conditions. An emerging multidisciplinary approach that relies on understanding the signature of an ore deposit emplacement system in a 3D space, is gaining momentum. A framework, based on a single 3D model, is proposed in order to facilitate the implementation of multidisciplinary mineral exploration projects by emphasizing the link between geology and geophysics. In this context, it is important to understand the geological setting indicated by the physical properties of the rocks, and to use geophysical data inversion technologies in order to validate or refine the geological models underpinning the decision-making exploration process. The effectiveness and quality of such integrated interpretations rely on an iterative geological/geophysical modelling process carried out by a multidisciplinary team. We will present an example of how this framework was applied to copper exploration around the Sudbury Basin.

SESSION 10

Sustainable mine development in French-speaking Africa: The case of the Essakane mine in Burkina Faso

ANNIE BLIER (IAMGOLD)

IAMGOLD adopts a partnership approach when it comes to community relations. Through proactive communication, we promote direct discussion with our host communities so that they may reap the greatest possible benefit at the local scale from a mining project.

In May 2014, IAMGOLD received the Towards Sustainable Mining Award for Community Engagement from the Mining Association of Canada for its market garden project at the Essakane mine in Burkina Faso.

This presentation describes how a sustainable development approach and a strategy based on common values were implemented and integrated at the Essakane mine, which has been in operation since 2011. Essakane, a modern world-class mine, is not only the biggest employer in the region but in all of Burkina Faso. In compliance with national requirements, it is a model of stakeholder commitment and a leading example of social responsibility. We will also present our various projects and support programs for suppliers of local goods and services (Sahel), for training, and for community investments (water and sanitation, agriculture, education and vulnerable people).

SESSION 10

Key scientific advances derived from 5 years of Canadian-Moroccan cooperation in the mining environment field

RACHID HAKKOU (UNIVERSITÉ CADI AYAAD, MARRAKECH) AND MOSTAFA BENZAAZOUA (UQAT)

Morocco is believed to have around 200 abandoned mines of various sizes and different polluting potentials. No post-closure plan has been put in place to manage the decommissioning of these mines or control any negative impact they may have on their surrounding environment.

Since 2009, the IDRC (Canada) Research Chair in “Management and Stabilization of Mining and Industrial Wastes” has been carried out in partnership with UCA (University Cadi Ayyad, Morocco) and UQAT (University of Quebec in Abitibi-Temiscamingue, Canada). The IDRC Research project has been an important research opportunity to conduct laboratory and in the field studies for the development of cost-effective restoration methods adapted to semi-arid climate. The project also allowed to manage and stabilize harmful mine wastes in Morocco. The Canadian expertise and knowledge in the field of mining environment has helped a large number of persons to get a high quality training.

The Canada-Morocco partnership has allowed the realization of many research projects (practical trainings, masters, Ph.D.) on 10 major closed mines: Tiwine (Mn), Tiouit (Ag, Au, Cu), Zgounder (Ag), Erdouz (Pb, Zn), Azegour (Cu, Mo, W), Kettara (FeS), Zaïda et de Mibladen (Pb), Jerada (Anthracite) and Touissit (Zn, Pb). A GIS based environmental database was established for Kettara as an example.

When the tailings are non-acid generator, the possibility of their recycling in the construction sector might be an attractive option. A good example of this is the valorization of the Zeïda and Mibladen (Upper Moulouya) mining wastes and those of Touissit-Boubker (Zn, Pb) district mine (North-east of Morocco) for the production of rendering mortars. It is also possible to valorize phosphates tailings (OCP group) as industrial ceramics and calamine by-products (MANAGEM group) as raw materials for red clay bricks.

Furthermore, thanks to IDRC funds and the transfer of knowledge from UQAT/IRME in the field of mining environment, the Kettara mine (school site) will be the first mine site restored in North and West Africa in the near future, based on an efficient laboratory and field testing. Indeed, promising results provided by the Kettara field investigation validated the reclamation scenario of this site through the reuse of phosphate mine wastes as a store-and-release (SR) cover. The scientific pair review considered the resulting works as innovative because the restoration concept adapted to arid climates is efficient and cost effective.

SESSION 11

Single-layer cover with elevated water table to control AMD from tailings ponds: Design principles and methodology

BRUNO BUSSIÈRE (UQAT) AND MICHEL AUBERTIN (POLYTECHNIQUE DE MONTRÉAL)

The rehabilitation of tailings ponds is a major environmental challenge facing the mining industry, particularly when the tailings could potentially generate acid mine drainage (AMD). The latter occurs when mine tailings contain sulphide minerals that oxidize when exposed to oxygen and water and produce acidity thereby promoting the dissolution of metals and metalloids due to the low pH conditions. In temperate climates, oxygen barriers are often constructed on tailings ponds to prevent AMD. Among the techniques that can be used to control the flux of oxygen is a new approach known as single-layer cover with elevated water table. This approach relies on the very low effective diffusion coefficient of oxygen in water. In saturated (or near-saturated) conditions, the sulphide oxidation rate in mine tailings decreases significantly due to the low availability of oxygen, which will control AMD formation. With this technique, the tailings are only partly submerged (in contrast to the water cover method), which has a positive effect on the stability of the retention infrastructure. To ensure that losses due to evaporation are kept to a minimum and the water table remains high, the elevated water table technique requires that a protective layer be placed over the AMD-generating mine tailings.

This talk will address the basics behind the technique of single-layer cover with elevated water table, as well as the principal influencing factors. We will also summarize the methodology proposed by the authors for an optimal design of this technique. Finally, some examples, as well as the results obtained in both the laboratory and the field, will also be presented.

SESSION 11

Approach and studies for the rehabilitation of abandoned mine sites

MARTINE PARADIS, JEAN DIONNE
AND PHILIPPE-ANDRÉ LAFRANCE (MERN)

Over the years, mining activities have generated many tailings ponds in Québec. A number of these storage sites have no known or solvent responsible entities and have become the responsibility¹ of the State. These sites, often abandoned long ago and generally lacking waste containment measures, have a negative impact on the environment and sometimes on human health. The rehabilitation of these sites presents a significant challenge given the large surface areas and particular issues involved, not to mention the costs.

The mandate of the Mine Site Restoration Branch (DRSM: *Direction de la restauration des sites miniers*) of the MERN's Mines Sector is to oversee mine site rehabilitation, including the responsibility to advance, approve and monitor rehabilitation projects involving abandoned mines. Rehabilitation plans are developed with the help of consulting firms that compare methods of mine site rehabilitation and identify which one is best suited for a given setting and problem. Rehabilitation techniques are selected on the basis of the three spheres of sustainable development — social, environmental and economic — in addition to expected short-, medium- and long-term effectiveness and performance. Maintenance and post-rehabilitation monitoring requirements must be reduced to a minimum.

Several rehabilitation techniques can be divided into two main categories: water covers and dry covers. An in-depth understanding of the environment is required to confirm the feasibility of a proposed technique. This is particularly true of the single-layer cover technique with elevated water table, the multi-layer cover with capillary barrier, and passive treatment. These techniques, which are often the top choices during the scenario selection process, require data on the physical, geochemical, hydrological and hydrogeological properties of the site, in addition to the geotechnical and chemical characterization of the materials. Some abandoned sites have an additional level of complexity because the initial site design, which often dates back several decades, did not account for mine site closure. It is also important to consider any past contamination of the site when selecting a rehabilitation scenario. Different scenarios are presented, either at the stage of analyzing the rehabilitation techniques proposed by the DRSM, or at the stage where supplementary studies are needed once the technical design has been established. These studies may include column tests, modelling and specific laboratory or field-based tests on traditional or innovative cover materials.

1 - Government responsibility is at the level of assuming the costs of rehabilitation. It does not acknowledge legal responsibility for any contamination.

SESSION 11

Tailings rehabilitation in northern climates: The case of Meadowbank mine, Nunavut

THOMAS LÉPINE AND ERIKA VOYER
(AGNICO EAGLE MINES)

With an average daily temperature of -35.4 degrees Celsius in the coldest months of the year, the Meadowbank gold mine of Agnico Eagle Mines (AEM) was named the coldest operating mine by Mining.com in January 2014. The Meadowbank mine is located 10 km north of the community of Baker Lake, in the Kivallik region of Nunavut. In operation since early 2010, the mine currently consists of three pits, with more than 100,000 tonnes of material moved each day.

Mining operations are scheduled to end in late 2017. The mine closure plan is already underway with, among other things, the progressive reclamation of tailings during the mining phase, and this work will intensify over the next few years. One of the main factors in rehabilitating Meadowbank tailings is to encapsulate the potentially acid-generating tailings and waste rock in permafrost using a cover of non-acid generating material. A program has been initiated that combines the operational challenges with research work in order to determine the optimum design for a tailings cover, in terms of both cost and long-term performance. Many technical and logistical constraints will have to be incorporated into the design of the cover, and it will require significant financial investment. It is essential for AEM to develop a design that ensures adequate long-term performance at the lowest possible cost and with the simplest logistics.

The case of mine waste rehabilitation at the Meadowbank mine will be presented, with details about ongoing work and scheduled activities over the next few years. An instrumentation and monitoring program has already been set up to corroborate the predicted conditions and proposed closure plan. A research program involving experimental cells constructed on the tailings will also play a key role in designing the cover and achieving the needed level of performance. The challenges that can be expected when constructing a mine tailings cover in Arctic conditions will also be addressed, particularly those specific to the Meadowbank mine.

SESSION 11

Study and overview of rehabilitation concepts at the Raglan Mine tailings pond

LOUIS MARCOUX AND MÉLANIE CÔTÉ (RAGLAN MINE)

The Raglan mining complex is located at the 62nd parallel in Nunavik. By virtue of its geographic location, Raglan Mine faces several specific challenges in the rehabilitation of its open pits, ore and waste rock piles, and tailings pond. Moreover, the changing climate conditions observed during recent years has raised concerns in nearby communities, prompting Raglan Mine to review its rehabilitation design concepts that were adopted in 2001. More specifically, the original concept for rehabilitating the tailings pond had been developed on the premise that tailings could be stored in permafrost and would remain permanently frozen once mining activities ceased. Now that we expect climate change to cause a rise in future ambient temperatures, there are doubts about the long-term performance of the current storage process. Acid-generating tailings could thaw at surface during the summer months and produce acid-mine drainage.

For these reasons, Raglan Mine set up a committee of experts in 2005 to support the company's management team in conducting a short-, medium- and long-term analysis of tailings management issues. Based on the committee's recommendations, Raglan Mine constructed experimental cells on top of the tailings pile in autumn 2011 to test four different types of tailings covers: Base Case Cover, Thermal Capillary Barrier Cover, Geomembrane Cover, and Modified Base Case – Convective Air Flow Cover. A prefeasibility study on these concepts was completed in 2014 using, among other data, the monitoring results from the experimental cells. Based on the results of this study, Raglan Mine will choose two scenarios that will be studied in greater detail, and will select only one final scenario, which will then be the subject of a feasibility study. Following that stage, the selected tailings cover scenario will be presented to Raglan Mine's communities of interest and the relevant ministries.

SESSION 12

The Larder Lake-Cadillac Break: A historical overview

HOWARD POULSEN (ATIAT)

C.W. Knight recognized two "gold lines" in the western part of the Southern Abitibi belt in 1922 and argued that their defining geological characteristic is the presence of conglomerate. L.V. Bell later described "a zone of chloritized and talcose schist" at Cadillac and postulated that it is closely related to mineralization "from a genetic standpoint": H.C. Gunning subsequently introduced the term "Cadillac Break" for this southern structure and extended it eastward to Malartic and westward toward Rouyn-Noranda where a similar feature was known variously as the Thompson River Fault or the Bouzan Lake Break. J.E. Thomson mapped a comparable segment in the Kirkland Lake and Larder Lake so that by the late 1940's the existence of a single persistent structure and gold metallogenic belt, the Larder Lake-Cadillac Break, was well-established.

From Matachewan to Val-d'Or, this regional structure displays six unifying geological characteristics:

- ▶ spatial association with ultramafic rocks (mainly the Piché Group of Latulippe);
- ▶ spatial association with conglomeratic sedimentary rocks (mainly the Timiskaming);
- ▶ locus for intermediate to felsic intrusions, particularly "albitite" and "porphyry";
- ▶ locus for carbonate alteration;
- ▶ locus for phyllonitic rocks, shear zones and minor folds;
- ▶ site of deposition for numerous gold deposits and occurrences.

Despite differences in approach and detail, many workers have argued the Larder Lake – Cadillac Break is a long-lived geological feature. This possibly included volcanic construction of the Blake River Group at which time it may have been syn-volcanic basin-bounding fault. Many authors have also argued that it later became a growth fault along which conglomerate and age-equivalent intrusions of the Timiskaming Group were emplaced. Reactivation of the structure resulted in south to north reverse faulting which juxtaposed deeper, older rocks of the Malartic and Pontiac groups onto upper levels of the Timiskaming Group, as preserved best today at Kirkland Lake: carbonate alteration and gold were likely introduced in and around the break at that time. Subsequent orogenic contraction led to variable folding and overturning of both the break and the unconformity at the base of the Timiskaming Group. The effects of this overprinting deformation increase in intensity from Larder Lake eastward and extend well beyond the bounds of the break itself: it may have resulted in a late increment of dextral oblique slip at some locations along it, particularly in rheologically weak, altered lithologies: auriferous zones within the break would have been deformed depending on their relative competence.

SESSION 12

The Larder Lake-Cadillac Fault, an Ontarian perspective and a comparison with the Ridout Fault

BRUNO LAFRANCE (LAURENTIAN UNIVERSITY)

Many gold deposits are associated with the Larder Lake-Cadillac Fault in Ontario. The geology along the fault comprises tholeiitic and komatiitic rocks of the Tisdale Assemblage (2710-2704 Ma), unconformably overlying sandstones, conglomerates, lavas and alkaline intrusions of the Timiskaming Assemblage (2676-2670 Ma). Several styles of gold mineralization are present: (1) disseminated pyrite associated with iron-rich tholeiitic volcanic rocks (flow ore); (2) quartz-carbonate veins hosted by carbonate- and fuchsite-altered komatiitic rocks (green carbonate ore); and (3) quartz-carbonate veins in sericite, carbonate, arsenopyrite and pyrite alteration zones within sandstones, lavas and alkaline intrusions. These three styles of mineralization have different host rocks, but all were emplaced during either the formation or reactivation of the Larder Lake-Cadillac Fault. The latter has been interpreted as (1) a dextral and sinistral transpression zone; (2) a normal fault contemporaneous with Timiskaming sedimentation, subsequently reactivated as a south-verging thrust fault and reactivated again as a sinistral then dextral fault; and (3) a north-verging thrust fault reactivated as a dextral strike-slip fault. The latter interpretation is preferred because it is compatible with the interpretations proposed for several mines along the fault, including the Young-Davidson mine in the western segment.

The Ridout Fault is located in the Swayze Belt, west of the Young-Davidson mine. This fault, a major structure, is parallel to the Larder Lake-Cadillac Fault. Several gold deposits are found along this fault, which is interpreted as the western extension of the Larder Lake-Cadillac Fault in the Swayze Belt. Its kinematic history differs, however, from that of the Larder Lake-Cadillac Fault. The Ridout Fault is a south-verging thrust fault reactivated as a sinistral then dextral strike-slip fault. It constitutes a new deformation corridor to the south of the Larder Lake-Cadillac Fault, which is also associated with a number of gold deposits.

SESSION 12

Architecture of the Malartic, Piché and Cadillac groups and the Cadillac Fault, Abitibi: Geological revision, new dates and interpretations

PIERRE PILOTE (MERN), RÉAL DAIGNEAULT (CERM-UQAC), JEAN DAVID (MERN) AND VICKI MCNICOLL (GSC-O)

The Cadillac-Larder Lake Fault is one of the most prolific structures in terms of gold mineralization. In the Québec portion of the Abitibi Subprovince, it juxtaposes sedimentary and volcanic rocks of different natures and ages. Geochronological determinations have constrained the ages of some of enclosing rock units. The youngest of these, the Timiskaming Group, is well exposed to the south of Rouyn-Noranda as the Granada Formation, and formed between 2680 and 2670 Ma. The Cadillac Group, a sedimentary basin comprising turbidite sequences (wacke, siltstone and shale), lies immediately adjacent to the fault on its north side. This group is interpreted to have formed between 2690 and 2680 Ma, although two ages recently obtained from a sandstone-conglomerate facies in the Rivière-Héva and Malartic areas (< 2678 and < 2676 Ma) correspond to the age of the Timiskaming Group. Consequently, Timiskaming-type rocks extend much farther east than was previously known. The ages indicate that this same type of facies may be found among lithologies assigned to the Cadillac Group, thus demonstrating the complexity of the basins and the episodic character of sedimentation.

The Rivière Héva Fault is a regional-scale (>60 km) subsidiary structure of the Cadillac Fault, characterized by considerable ductile deformation. It transects the entire length of the Malartic Group. It separates the mafic rocks of the Dubuisson Formation (2708-2712 Ma) from those of the Jacola Formation. An age of 2700 Ma was recently obtained for the felsic volcanoclastic rocks on the north side of the fault, south of Lac Malartic. The Rivière Héva Fault is comparable in extent and importance to the Parfouru and La Pause faults.

The Cadillac Fault has long been known to be associated with talc-chlorite-serpentine schists that have now been assigned to the Piché Group. This group, which is not well known, expresses the extension of the Cadillac Fault. Consisting of variably deformed and carbonatized ultramafic and mafic volcanics, it is a band of rocks ranging from less than 100 m thick to more than 1,500 m. The Piché Group extends nearly continuously from Louvicourt to Rouyn-Noranda, over a distance of more than 150 km. Its origin remains obscure; it may be a single stratigraphic unit or a composite assemblage. A U-Pb date recently obtained from a felsic dyke cutting ultramafic rocks in the Buckshot pit, to the northeast of the Canadian Malartic deposit, revealed an age of 2710 Ma, correlating the Piché Group with the base of the Malartic Group.

Numerous intrusions of various shapes, sizes, compositions and ages are also found along the Cadillac Fault. Calc-alkaline intrusions were injected between 2690 and 2680 Ma, whereas younger alkaline intrusions were emplaced between 2680 and 2670 Ma. These features reveal the role of the fault as a conduit for both magmas and hydrothermal fluids, and also demonstrate its long-lived deep crustal nature.

The Cadillac Fault is important not only for its metallogenic wealth, but also for its geodynamic models and juxtaposition of varied lithologic assemblages along its subsidiary faults. The E-W and WNW sections of the fault reflect a deep asymmetry in the Abitibi Subprovince, a feature that influenced the styles and episodes of gold mineralization.

SESSION 12

Structural evolution of the Cadillac Fault, relationship with orogenic gold occurrences, and characterization of the Piché Group, Abitibi Subprovince, Québec

PIERRE BEDEAUX (UQAC), PIERRE PILOTE (MERN),
SILVAIN RAFINI AND RÉAL DAIGNEAULT
(UQAC-CONSOREM)

The Cadillac Fault (CF) is a major fault in the Abitibi Subprovince for which several deformation events have been documented: shortening, extension and strike-slip. To date, there has not been consensus in terms of chronological relationships or integration into a single tectonic model. Important occurrences of gold mineralization are spatially associated with the CF, but their temporal relationships to deformation are still not well understood. Moreover, there has been insufficient research on the Piché Group, which constitutes the physical manifestation of the CF. This project, which is supported by the MERN, aims to (1) synthesize the structural styles observed along the fault and integrate them into a model of structural evolution; (2) attempt to integrate gold mineralization into this model; and (3) characterize the Piché litho-tectonic unit.

In Québec, the CF can be divided into segments according to orientation: the western and eastern segments are oriented east-west, whereas the central segment is oriented southeast. A regionally developed east-west schistosity dips steeply to the north. It is related to isoclinal F1 folds and reverse shear zones, indicating a shortening regime. The associated stretching lineation has an overall vertical component. In the central segment, the regional schistosity tends to run parallel to southeast faults. In the western segment, a late subhorizontal cleavage indicates that shortening was followed by an extensional regime. Near the CF and second-order faults, evidence for a late strike-slip movement includes minor Z-folds, sigmoidal features, CS relationships, and variations in the plunge of the stretching lineations. A north-east-trending secondary cleavage is associated with this phase and constitutes the axial plane of the flexure in the CF, between the western and central segments.

The thickness of the Piché Group is variable at the regional scale. Ultramafic lithologies are dominant, although basaltic rocks and even andesitic rocks are locally present. Ductile deformation is generally very well developed, particularly near contacts, although in places it may be absent or only weakly developed, specifically in the core of the unit.

In the eastern segment, crosscutting relationships between quartz-tourmaline veins and some of the structural features indicate that mineralization associated with this type of vein was emplaced before and during the shortening episode, and also during dextral strike-slip faulting.

SESSION 12

Typology of gold mineralization along the Cadillac Fault

SILVAIN RAFINI (CONSOREM)

With more than 4,200 t Au, 37 world-class gold deposits (>10 t Au) and 4 giant ore deposits (>100 t Au), the Cadillac Fault (CF) ranks as one of the most important gold metallotects in the world. The variability of gold deposit types occurring along the CF is notorious and most likely reflects the long-lived activity of this structure and its trans-crustal root enabling the convergence of various hydrothermal drivers (magmatic, metamorphic, and meteoric). The work presented here is an attempt to better characterize this variability through an objective and comprehensive synthesis of the extensive library of descriptive data produced through four decades of intensive exploration along this metallotect.

It has been established that gold deposits along the CF can be categorized into one of eight different ore deposit types. The nature of discriminating characteristics for each deposit type is variable. For example, it may be the sulphide assemblage or abundance (very low sulphide content, dominated by pyrite, in the Marbanite-Norbenite fault-type vs. abundant sulphide content with 30% pyrite-chalcopyrite in the Bourlamaque type), the mode of occurrence of the mineralization (massive banded veins in the Bourlamaque type vs. stockworks and disseminations in the Malartic type), or typical alteration patterns (intense proximal albitization very characteristic of the "Albitite dyke"-type vs. carbonate-fuchsite).

This study has provided some insight on the various conditions in which gold deposits occur along the CF. It appears that the Malartic ore deposit type, which occupies a marginal segment of the CF given its ESE orientation, is markedly different from its neighbouring types, with a very strong metasomatic potassium enrichment (corroborated by nearly systematic field observations of microcline) and a distinctly polymetallic sulphide assemblage, which is atypical of classic orogenic gold occurrences. Moreover, its footprint erases or conceals the arsenopyrite signature associated with all deposits enclosed directly within the CF (resulting from the influence of juxtaposed clastic sediments). This hydrothermal footprint is interpreted as the result of an orthomagmatic gold mineralizing event (late-tectonic alkaline series) that postdates neighbouring mineral occurrences, which are most commonly "passively" hosted in pre-Au calc-alkaline intrusions. Finally, although the Kirkland Lake and Malartic ore deposit types exhibit some common characteristics (potassic alteration, late-tectonic syenitic host rocks, pyrite-molybdenite, absence of arsenopyrite), they cannot be categorized within a single "late-tectonic syenite" deposit type, mainly due to the radically different modes of occurrence of gold mineralization between the two deposit types, which indicate very dissimilar stress conditions and, notably, the strongly uneven influence of fluid pressure.

SESSION 13

Sustainable management of mineral resources in Wallonia (Belgium): A few lines of thought to promote better integration

JOHAN YANS (UNIVERSITÉ DE NAMUR-NAGRIDD)

Wallonia has a very prolific mining history: carved flintstone, iron ore, “Calamine” Pb-Zn ore, and coal—all of these resources have been mined from the subsurface throughout the ages. Today, the mining sector remains productive, with more than 160 active mining sites (mainly for limestone, dolomite, sand, sandstone, clay, and porphyry). These substances are used to manufacture various products and account for a significant proportion of Wallonia’s economy, forming the basis of an innovative and profitable technological potential that generates jobs for variously qualified workers.

In Wallonia, as elsewhere though to varying degrees, quarries and mines are perceived in the public opinion as places that “pollute”, “smell bad”, “destroy the landscape”, “increase truck transportation”, “feed big business”, “kill plants and wildlife”, places where inherently non-renewable natural resources are extracted, in apparent contradiction with the principles of sustainable development. In the midst of this transition period, we must consider the roles that geological commodities can play, as they are ubiquitously used to manufacture numerous products, and how they can be tolerated. The issue of mining in the future is clearly trans-disciplinary: geological, economic, social, political, and environmental approaches need to come together, at all scales (commune, region, country, continent, planet), lest we overlook one of these parameters in the discussion.

A prospective inventory of resources in Wallonia’s subsurface and procurement alternatives is required, including for shale gas and coal. To do so, a Wallonian geological survey must be created (the subsurface has been under regional jurisdiction for more than 20 years in Belgium). The latter could also serve as a reference, namely to advise political decision-makers in defining a clear strategy in this regard. Promoting recycling and reuse of waste rock, reviewing needs, and improving demand management and the life span of products are also interesting avenues to explore. But informing citizens remains essential. Both in terms of safety and environmental issues, mines in Wallonia should never bear comparison with the sometimes catastrophic situations related to mining activities in other parts of the world. It is in this framework that, over the past twenty years, industries, the public sector and research centres have been raising awareness among citizens and political decision-makers. The “local” quarry could well be, all things considered, an unexpected link in the transition to a globally sustainable path.

SESSION 13

Environmental impacts and management of abandoned mines scattered in the French Alps

MAGALI ROSSI AND DOMINIQUE GASQUET (UNIVERSITÉ DE SAVOIE)

Across the millennia, the Alps have represented a major mining province around which various civilizations, and more recently, industries have developed. Mines in the area were subsequently permanently abandoned (during the 19th and 20th century for the most part). In the Northern Alps, thousands of mines, openings, and quarries have been identified; former mining sites for iron, predominantly, or for Pb-Zn-Ag and Cu. Other metals (U, Ni, Co, Mn, Mo, Hg, etc.) were also extracted albeit in very small amounts and mining sites for these are widely scattered. Overall, the production of the Northern Alps is estimated at a few million tonnes of Fe, 200,000 t of Pb, 100,000 t of Zn, and 500 t of Ag.

The environmental impacts of these mining sites include: (i) risks associated with collapsing underground drifts in now-urbanized areas, such as the Mâcot-La Plagne ski resort in Savoie; (ii) flooding of certain drifts; (iii) water and soil pollution; and (iv) visual impacts on the landscape due to abandoned mining installations.

The management and responsibility for these ownerless mines is entrusted to local, regional, or national communities. Alpine mines pose a specific problem in that these sites, commonly modest in size, are very widely dispersed across the entire region. Due to the lack of monitoring after the cessation of mining operations and the revegetation of mountain sides, the location of mine tailings has long been forgotten. The management of mining hazards and particularly related pollution, and how these hazards are handled thus become problematic issues.

A few mining sites have been restored to become tourist attractions. For example, drifts at the Fournel Pb-Ag mine in the Hautes-Alpes region and the Saint-Georges d’Hurtières Fe-Cu mine in Savoie are open to the public. Other sites propose a mining museum or educational panels located near former mining sites, such as at the Saint-Véran Cu deposit in the Hautes-Alpes region and the Macôt-La Plagne Pb-Ag deposit in Savoie.

A comprehensive study of all Alpine deposits should be completed to reassess the mining potential of these deposits and their “waste rocks” in light of current metal prices and local procurement policies for mineral commodities.

SESSION 13

Occurrence of Rare Earth Elements in ecosystems and assessment of their ecological impacts: research approaches used in the French programme Labex Ressource 21

LAURE GIAMBERINI, CORINNE LEYVAL
AND VERONICA GONZALEZ (UNIVERSITÉ DE LORRAINE)

The increase of global production and uses of rare earth elements (REEs) in the last decades, as consequence of their many applications, has disrupted their geochemical cycles (e.g., gadolinium anomalies in freshwater and tap water, REEs enrichment of soils as a consequence of agricultural practices). Their use is expected to continue growing in the future, raising legitimate questions on the potential additive risk of these emerging microcontaminants to biota. Although geological and mineralogical aspects of these elements are broadly studied, the study of their ecotoxicity is practically in its infancy. The use of relevant atomic properties to predict ecotoxicity has been especially attractive for these elements, with heavier lanthanides (Gd-Lu) usually more toxic than light lanthanides (La-Eu). However, experimental results do not always fit into this general pattern because different reasons: the formation of insoluble species during exposure, which could underestimate ecotoxicity in some cases; and also due to differences in physiological processes at organism level, which could explain different patterns depending on endpoint and test organism considered.

Since colloidal forms play an important role in the aquatic geochemistry of lanthanides, the physical speciation of these elements is also an important factor to be considered in the environment. Anthropogenic lanthanides have been found as truly dissolved (<10 kDa) and colloidal/nanoparticulate forms (10 kDa and 0.2 µm), but still it is not well understood if these fractions can affect toxicity differently, which in fact could be also depending on the organism considered. Consider total soluble fraction (<0.22µm), environmental risk is currently acceptable but some exceptions in specific situations were detected, with higher risk quotients detected for Ce and Gd. This finding and the fact that anthropogenic emissions are not expected to decreased, makes necessary a better understanding of their bioaccumulation, ecotoxicity as well as their effect at biochemical level to properly predict their risk in the future.

SESSION 13

Strategy, tools and environmental policy of Variscan Mines in France: The sustainable mine

MICHEL BONNEMAISON (VARISCAN MINES),
ÉRIC MARCOUX (UNIVERSITÉ D'ORLÉANS),
JACK TESTARD AND PATRICK LEBRET (VARISCAN MINES)

The last metal mine in metropolitan France shut down in 2004, despite the existence of known mining targets, including some with defined ore blocks. Founded in December 2010, Variscan Mines is a French junior mineral exploration company, subsidiary of an Australian company, whose objective is to discover and develop base and precious metal deposits to the feasibility stage and eventually bring them into production.

Variscan Mines has implemented a modern exploration strategy in accordance with its current environmental and sustainable development policy. This permeates into every stage of exploration. As soon as the exploration licence (PER) application is prepared, extensive consultations take place locally with community stakeholders and elected officials. The work program is implemented using the best technologies available in order to delineate, if possible, many mining targets and thus ensure the mine's sustainability. In terms of mining operations, Variscan Mines has decided to opt for acceptable economic models and reduce environmental impacts as much as possible. Mining techniques using back-filling and underground ore preparation will be preferred, resulting in less material being brought to the surface and greatly reducing the volume of waste rock on surface. In the end, this type of immediate remediation will facilitate closure of the mine site. The installation of geothermal devices, during and after mining operations, will be entrusted to specialized companies.

All of these measures are assembled in a charter that will serve as a contractual guide and code of ethics, to be respected by Variscan Mines and all of its partners or service providers on active projects.

SESSION 14

The safety side effect: Things supervisors do that, coincidentally, improve employee safety

MIKE ALLEN (USA)

Why is it that supervisors whose safety records are the best also usually perform better across the board? They have better productivity, lower employee turnover and higher team morale. It turns out that good supervisors create what we call the “safety side effect.” This speech will discuss a few skills that the best bosses use to create this side effect.

SESSION 14

The contribution of morphology recognition technology in the prevention of machine-pedestrian collisions

FRANCK GAYRAUD (ARCURE, FRANCE)

The prevention of machine-pedestrian collisions constitutes a major challenge for the mining sector. Image-processing technologies, when combined with established best practices (training, traffic segregation), are now able to provide relevant detection of pedestrians to avoid false alarms, without adding to the workload of drivers.

SESSION 14

Development of the Visi+ camera

FABIEN MILLER (INN-OXX)

Visi+ is a portable optical camera placed on top of a vehicle. It helps mine rescue workers see through smoke, control fires, and helps rescue workers on surface face difficult weather conditions such as blizzards.

SESSION 14

TopVu™ eTag Board

MARC BRUNET (K4 INTEGRATION)

The TopVu™ e-Tag board was designed to electronically track the intended destination of mine personnel without having to install a mine-wide system. It is elegantly simple in that it uses existing behavior to produce a new set of results that go directly to the bottom line. In this session, you will be introduced to the many advantages and reports that come from the data produced by the TopVu™ e-Tag board and its database. The TopVu™ line of products also includes readers that report to the same database as the TopVu™ eTag board. By simply adding a few of these readers at strategic locations throughout the mine allows the operation to have a tracking system that is effective and easily expandable.

SESSION 14

Health and safety aspects to consider for drilling and blasting operations

CHRISTIAN ROY (CANADIAN MALARTIC MINE)

Canadian Malartic General Partnership acquired the Canadian Malartic mine in June 2014. Mining this high daily volume open pit is a challenge in itself for several reasons. From the beginning of exploration in 2005 to the opening of this world-class mine, management and workers have had to constantly come up with innovative ways to reduce the impact on the host community.

In addition to the usual operational constraints faced by a mine, additional constraints arose due to the proximity of the Town of Malartic. The majority of these issues were addressed in the feasibility study even before they became a problem. Despite all this, mining production demands coupled with the town's proximity led to unexpected problems on a regular basis, for which reliable and safe solutions had to be found quickly.

The final footprint of the Canadian Malartic pit will overlap the infrastructure of four past-producing underground mines that operated from the 1930s to the 1980s. This scenario creates its own set of operational constraints. These aspects lead to major challenges that must be accepted and overcome to ensure the success of the project.

The geographic setting and historical mining context of the Canadian Malartic site has given rise to major operational constraints. Canadian Malartic General Partnership will need to implement specific drilling and blasting measures to ensure a safer environment for workers and citizens.

SESSION 15

Elements of a porphyry Cu(Au-Mo) deposit: Formation and preservation

RICHARD M. TOSDAL (PICACHOEEX)

Tectonic setting plays a critical role in determining what type of ore deposit forms in a particular location at a particular time. In the case of the economically important porphyry Cu(-Au-Mo) deposits, a convergent plate margin or a collisional orogen is required, whereas other intrusion-related deposit types form in plate margins under extension. Within these orogens, porphyry deposits form during narrow time intervals in a particular segment of an arc. Generally, porphyry deposits form near the end of a magmatic episode or during a change of deformation styles when the arc is undergoing limited contraction. The ultimate tectonic trigger for these events is uncertain, with proposed scenarios including changing subduction geometry, collision and subduction of irregularities in the down-going plate.

Porphyry Cu deposits are associated with oxidized and hydrous porphyritic stocks and dikes intruded to depths of >1 to 6 km that emanate from a deeper upper-crustal magma chambers emplaced at depths of 6 to 12 km. To form a porphyry Cu deposit, a metaliferous and sulfate-rich hydrothermal fluid must escape from the pluton at depth and rise along a fracture system in advance of a porphyry intrusion with additional hydrothermal fluid exsolved as that magma rises, crystallizes and hydrofractures, leading to the characteristic multi-dimensional vein mesh that reflects the interplay between far field and local magmatic driven stress. There is little evidence that porphyry Cu deposits are accompanied by active deformation above the pluton in contrast to many other intrusion related hydrothermal systems such as VMS or epithermal deposits. As porphyry Cu deposits are upper crustal phenomenon subject to rapid degradation due to their formation in areas of positive topography, preservation in ancient (pre-Cretaceous) orogens depends entirely on tectonics, as the porphyry Cu systems must be rapidly buried by sedimentation or by thrust sheets.

SESSION 15

Reduced intrusion-related gold deposits (RIRG): A common Paleozoic perigranitic gold deposit model?

MICHEL JÉBRAK (UQAM) AND ÉRIC MARCOUX (UNIVERSITÉ D'ORLÉANS)

Reduced intrusion-related gold systems (RIRGS), previously scattered in various types of gold deposits (skarns, porphyries, gold-bearing shear zones, etc.), are now recognized as a new type of ore deposit, originally introduced by Hart in 2007. They were initially defined in the North American Cordillera, in the Tintina Province, a Mesozoic collisional orogen. It appears however that this ore deposit model may be more widespread. Criteria inherent to this new type of ore deposit must be clarified and validated in different orogens.

The Tighza gold deposit (central Morocco) belongs to this new type of ore deposit, based on a recent publication by Marcoux *et al.* (2014). Its characteristics indicate that the basic criteria defined for RIRGS are applicable to this late Hercynian (286 ± 1 Ma) deposit. The Tighza deposit, with its mainly lode-type morphology, exhibits a very typical metal association with Au-As-W-Bi $\pm$ Mo, without Sn. There is a strong perigranitic zoning pattern, with gold grades dropping from 12 g/t to <1 g/t about 500 m away from the granite. Base metals are present but do not seem to follow the same perigranitic zonation, directly related to the cooling of the pluton. Fluids are hot (300–350 °C), low-salinity (1 mole % NaCl) and carbonic (18 mole % CO₂). The slightly reduced conditions are indicated by the low-sulphide paragenesis, with commonly sulfur-poor varieties (loellingite, pyrrhotite, tetradymite). The coeval emplacement of the intrusion (286.0 ± 0.4 Ma) and the mineralized system (285.6 ± 0.5 Ma and 285.3 ± 0.5 Ma) has also been confirmed.

The characteristics of the Tighza deposit may also be observed in numerous ore deposits in Paleozoic orogens, specifically in slightly auriferous tungsten deposits (Salau, France) or disseminated gold deposits (Mokskro, Czech Republic). Their distribution is widespread, as there are known examples in Europe, North Africa, Central Asia, and Australia. In North America, the Appalachians may also host this type of ore deposit in southern Québec. Thus, on the basis of Hercynian examples, we propose in this presentation potential avenues to define RIRGS, namely to distinguish them from tungsten-only systems and shear zone-related (orogenic) gold deposits.

SESSION 15

Searching for subalkaline Cu-Au porphyries in high-grade metamorphic terrains in Québec: Geochemical criteria and exploration targets

STÉPHANE FAURE (CONSOREM)

First of all, the main geochemical characteristics of subalkaline porphyry intrusions hosting Cu-Au mineralization will be presented. The major element composition of protoliths was estimated by removing the effect of hydrothermal alteration, in an effort to identify discriminating geochemical elements that could be used to distinguish between mineralized and non-mineralized intrusions. The proposed approach was then used to identify several regional exploration targets, including in the Superior Province.

A lithogeochemistry database encompassing data from 60 subalkaline porphyry Cu-Au deposits was generated from available literature. The effect of alteration was neutralized by calculating predicted oxides in LithoModeleur software, using the mass balance method on modelled precursors. Data processing shows that this category of porphyry intrusions is tightly clustered along a differentiation curve, forming a series ranging from gabbroic diorites to granites, and also exhibits a remarkable lack of geochemical differences between Archean, Proterozoic and more recent Cu-Au porphyries.

It was a challenge to recognize, in high-grade metamorphic terrains present in Québec, the geochemical recipe that more closely resembled Cu-Au-bearing porphyries. To do so, the 6,393 geochemical samples of intrusions in SIGÉOM were compared to the geochemistry database for Cu-Au porphyries in order to assess, using filters, the performance of the most discriminating elements and element ratios characterizing this type of mineralization. The objective of this comparison is to keep the largest possible set of lithogeochemistry data in the Cu-Au porphyry database, and to eliminate as many as possible from the SIGÉOM database, which, in principle, should contain very few mineralized porphyries. The discriminating criteria that were most effective in reducing the number of samples in the SIGÉOM database were those based on rare earth elements and composite indices taking into account a series of filters on minor and trace elements. These new discriminating criteria are now used to recognize, in a lithogeochemistry database, subalkaline porphyries potentially favourable for Cu-Au mineralization.

In the southern Superior Province, the Eil Lake intrusion near the Roberto ore deposit, as well as several other magnetic intrusions along the contact between Laguiche metasedimentary rocks and volcanic rocks of the Eastmain Belt, were identified as potentially fertile. The gold-bearing Pau Lake porphyry intrusion, as well as other arc-related adakitic intrusions in the Ashuanipi Subprovince, are also considered as regional exploration targets.

SESSION 15

The Bachelor Lake gold mine: A new plutonic model for the Abitibi

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Gold deposits associated with recent alkaline intrusions are known worldwide (e.g., the Cripple Creek and Ladolam deposits). Late Archean ore deposits are also present in the Superior Province of Canada, and in particular in the Abitibi belt. Since the Canadian Malartic mine and the Bachelor Lake mine went into production in 2011 and 2013 respectively, gold deposits associated with late Archean alkaline magmatism have resulted in a diversification of the gold mining potential in Abitibi. Understanding these systems is a necessity to increase the chances of success during exploration.

The Bachelor Lake ore deposit is located 165 km WSW of Chibougamau, in the NE-SW-trending Wedding-Lamarck regional deformation zone, which encompasses Timiskaming-type basins. Gold mineralization occurs along the margins of the O'Brien pluton, a polyphase quartz syenite intrusive emplaced in Neoproterozoic andesites and tuffs. The two main facies, equigranular and porphyritic, are cut by aplites of similar composition that represent the last magmatic pulses. The mineralogy of the pluton is characterized by the abundance of sodic and potassic feldspar, with minor amounts of quartz, biotite and chlorite. Purplish fluorite is also present, either disseminated in the syenite or occurring in subhorizontal comagmatic Qz-FI-Py-(Au) veins that extend into tuffaceous country rocks.

A strong zoning pattern is observed from the core to the periphery of the system. Porphyritic facies characterized by stockworks of Mt veins, Qz veins, and Qz-FI-Py-(Au) veins appear in the intrusion and in country rocks at the contact. In more distal volcanic rocks, gold is essentially associated with disseminated iron oxides and sulphides (Py, Mt, Hm and more rarely, Po and Cpy) within intensely metasomatized zones (Hm-Cb). Fluids are inferred to have travelled along pre-existing discontinuities in the volcanic rocks bordering the syenite. Isotope studies focussing on $\delta^{18}\text{O}$ and δD in quartz veins indicate a magmatic source, for both porphyritic facies and more distal veins in metasomatized zones. In addition, cross-cutting relationships between intrusive phases and mineralized zones illustrate their relative timing and indicate that magmatism continued during the formation of mineralized zones.

The mineralizing hydrothermal event is thus related to late Archean alkaline magmatism. Consequently, the mineralized system at the Bachelor Lake ore deposit illustrates the complementary roles played by late Archean structural and magmatic processes.

SESSION 15

Hydrothermal alteration at the Canadian Malartic mine: Distribution, mineralogy, and geochemistry of a complex multiphase Archean gold system

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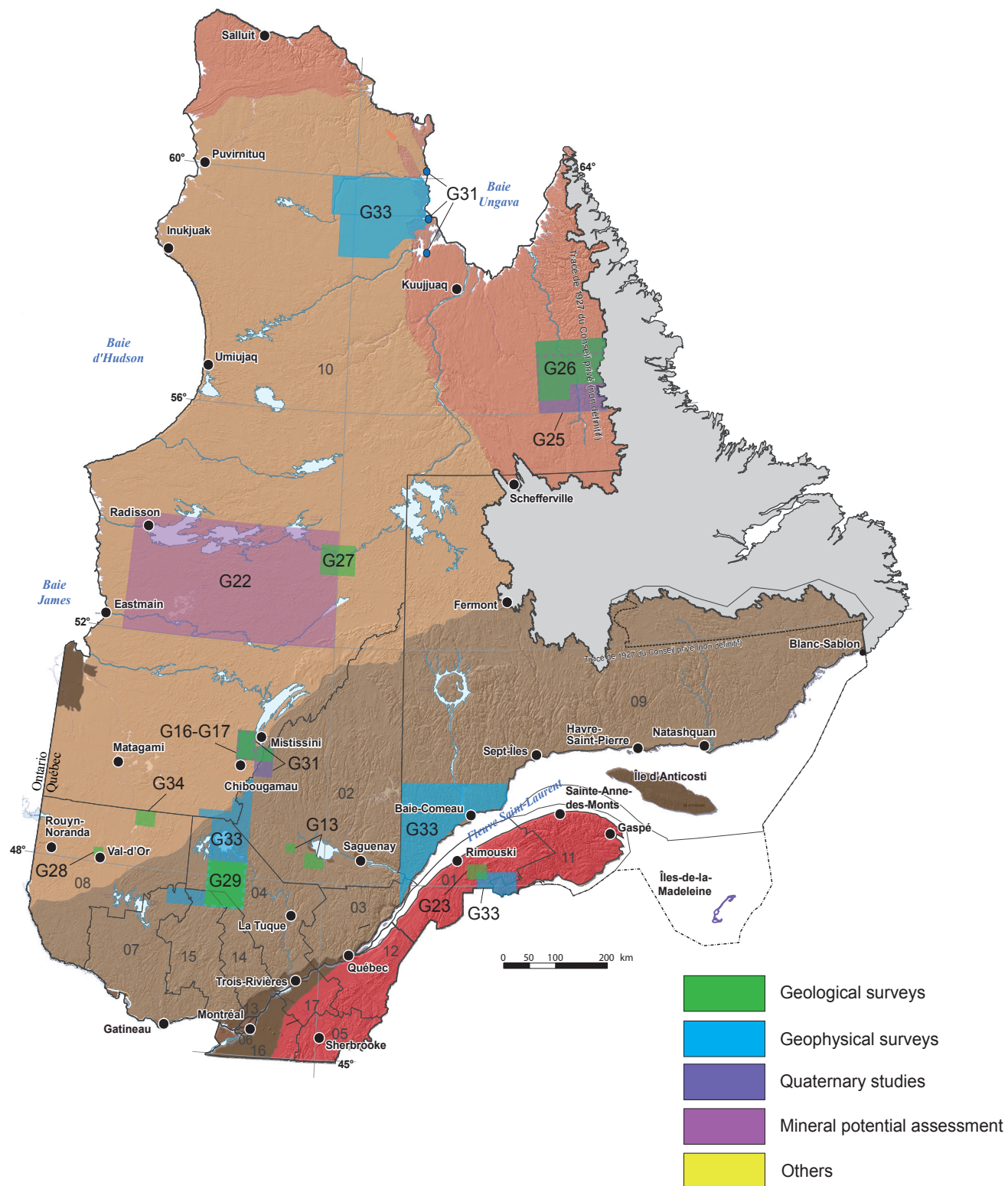
The Canadian Malartic mine is centred on a low-grade high-tonnage gold deposit (10.7 Moz in proven and probable reserves; 343 Mt at 0.97 g/t Au) located in the Abitibi Subprovince. Gold mineralization is mainly hosted in metasedimentary rocks of the Pontiac Group (~70%) and in Timiskaming-age (ca. 2678 Ma) quartz monzonitic and granitic porphyry intrusions, south of the Cadillac-Larder Lake Fault. The Pontiac Group consists of graywackes and mudrocks with $\text{ab-qtz-bt-mu-chl} \pm \text{py-po-ilm-mt}$ assemblages, deformed by F2 folds and exhibiting a NE-dipping (65-90°) S2 axial plane cleavage. Two main orientations are recognized for mineralized envelopes: NW-SE and E-W. These orientations respectively correspond to: 1- D2 deformation zones in F2 fold hinges and 2- the Sladen Fault, a S-dipping (45-80°) brittle-ductile fault that crosscuts quartz monzonite intrusions. Mineralized rocks mainly contain disseminated pyrite ($\leq 5\%$) and the metal assemblage is characterized by the presence of Au-Te-W-Bi-Ag. Pb and Mo are locally present. Hydrothermal alteration patterns may be divided into two main assemblages (proximal and distal) and their distribution is controlled by the Sladen Fault and by D2 deformation zones. This alteration is associated with $\text{qtz-cal}(\pm \text{ank})\text{-bt-chl-ab-fk}$ stockworks and veinlets. Gold-bearing, laminated and brecciated $\text{qtz-py} \pm \text{ab-ga-mo-sph}$ veins, and gold-bearing "pegmatitic" $\text{qtz-carb-tur-mica-felds}$ veins are also present. The main types of alteration are: carbonatization, albitization, and potassic alteration (biotite and microcline). In sedimentary rocks, the distal envelope is characterized by an assemblage of $\text{bt-ms-pl} \pm \text{cal-py-ilm}$, whereas proximal alteration corresponds to an albitic assemblage with variable proportions of phl-cal-py . Microcline is locally predominant along the main mineralized structures such as the Sladen Fault, and the Fe and Mg content of biotite increases from distal to proximal areas. In the quartz monzonite, hydrothermal alteration exhibits a strong zoning pattern, characterized by a distal carbonatized envelope with cal-hem , overprinted by a proximal alteration zone with fk-ab-dol-qtz-py centred on the Sladen Fault. The presence of molybdenite and potassic alteration, the Au-Te-W-Bi-Ag signature, and the presence of porphyry host rocks are consistent with a Timiskaming-age magmatic-hydrothermal mineralizing event. However, the distribution of gold-bearing alteration zones along the Sladen Fault and in the axial plane of F2 folds, as well as the strong carbonatization that characterizes the hydrothermal system, indicate the existence of a gold mineralizing or remobilization event coeval with the main D2 deformation. The Au-Te correlation, the types of alteration, the association with a brittle-ductile fault, and the age of the intrusions are similar to the context at Kirkland Lake, whereas the presence of albitization and carbonatization is analogous to the Harker-Holloway and Holt-McDermott deposits in Ontario.

ABSTRACTS OF POSTERS

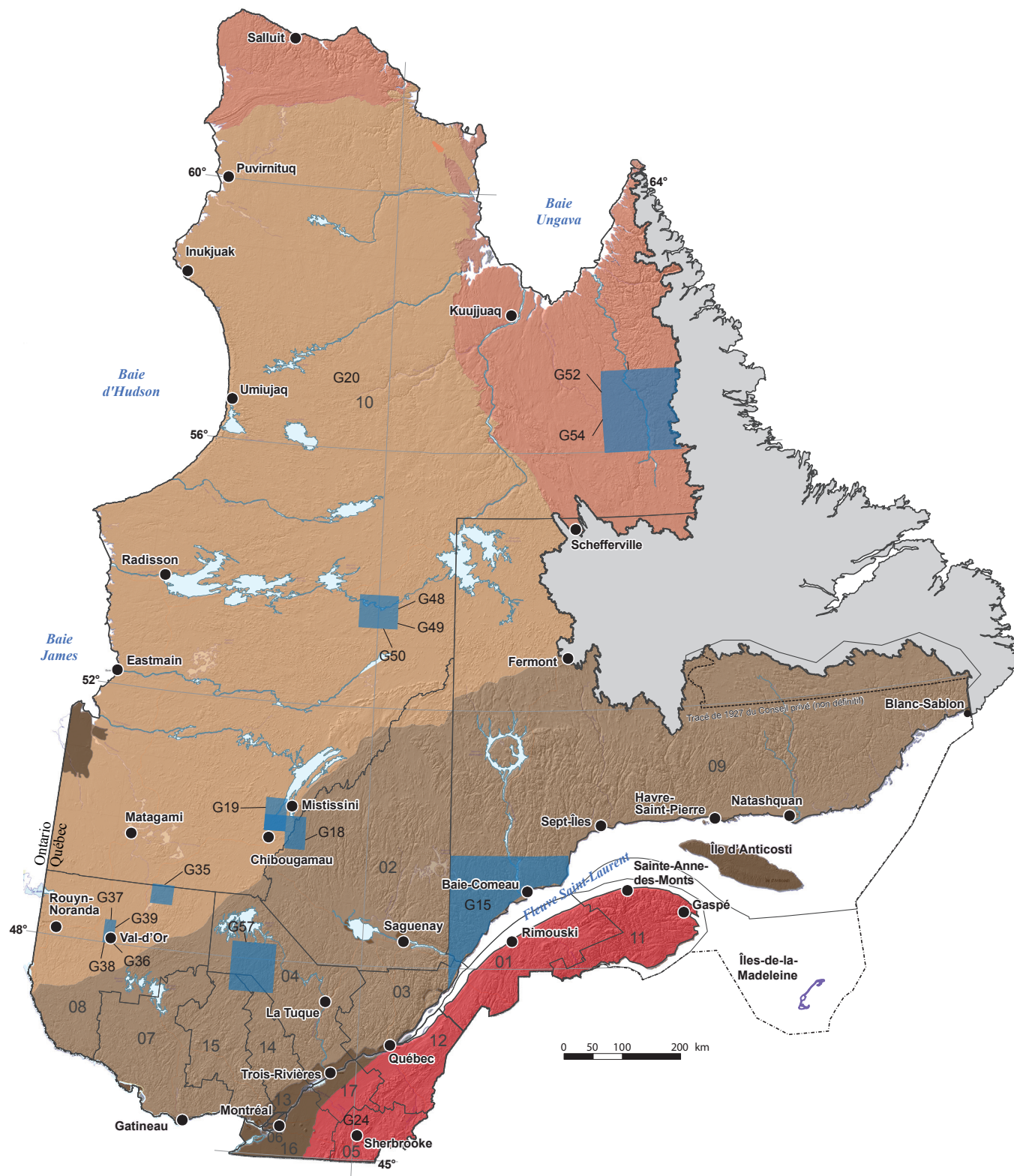
G01	Diamond, a precious resource in Québec	51	G34	Geology and mineral potential of the Lac Holmes area (NTS 32C15): Preliminary results	62
G13	Architectural stone in the Portneuf, Lac-Saint-Jean, Eastern Townships, and Côte-Nord regions	51	G35	Structural and metamorphic study of the Attic Complex (Phase 1): The Lac Holmes area, Lebel-sur-Quévillon, Québec.....	62
G14	Knowledge acquisition project focussing on granites, mineral occurrences, and geochemistry in the Saint-Félicien area, Saguenay-Lac-Saint-Jean (NTS 32A08, 32A09, and 32A10)	52	G36	Structural and metallogenic characterization of the Malartic Lakeshore gold showing, Abitibi, Québec.....	63
G15	Base and precious metal mineralization in the Escoumins Volcano-sedimentary Belt, Central Grenville, North Shore (Côte-Nord)	52	G37	Structural evolution of the Cadillac Fault, relationship with orogenic gold occurrences, and characterization of the Piché Group, Abitibi Subprovince, Québec	63
G16	Geology of the Lac Waconichi (NTS sheet 32J01) and Lac des Canots (NTS sheet 32I04) areas	53	G38	Evolution of the Pontiac Subprovince in the Val-d'Or-Malartic area: Metamorphism, deformation and gold mineralization	64
G17			G39	Geological setting at the Marbridge mine	64
G18	Tectonometamorphic evolution of the Abitibi-Opatika contact zone: Contributions from ⁴⁰ Ar/ ³⁹ Ar thermochronology	53	G40	Late Archean gold mineralization associated with the Destor-Porcupine Fault: The Duquesne-Ottoman property, Abitibi, Québec, Canada	65
G19	Structural analysis of the Rivière France shear zone and its gold occurrences, Chibougamau area, Québec	54	G41	Structural and metallogenic study of gold mineralization in the Belleterre area, Abitibi-Témiscamingue region, Québec.....	65
G20	Canada's first continental crust	54	G42	Assembly of the Superior Craton – Constraints from geophysical data.....	66
G21	Revision of geological maps in the Labrador Trough using high-resolution geophysical maps and RapidEye images.....	55	G43	Study of multi-parameter data from exploration drill core at the Bracemac- McLeod ore deposit, Matagami – Multivariate statistics and exploration vectors.....	66
G22	Potential for orogenic gold mineralization in the Baie-James region	55	G44	Volcanology and alteration, Waconichi Formation, Lemoine Member, Chibougamau (Abitibi Subprovince): Implications for exploration.....	67
G23	Geological compilation of the Lac Mitis area, Bas-Saint-Laurent region	56	G45	Geology and types of mineralization and alteration at the Mustang gold showing, Lower Eastmain greenstone belt, Superior Province, Québec	67
G24	Geological compilation of Siluro- Devonian rocks in the Connecticut Valley-Gaspé Synclinorium, southern Appalachians of Québec.....	56	G46	Geology and structural characteristics of the Roberto gold deposit, Eleonore property, Superior Province, Baie-James, Québec, Canada	68
G25	Glacial drift prospecting in the Southeastern Churchill Province: Combined sampling of glacial and fluvioglacial sediments - Preliminary results from the Lac Saffray (NTS 24G), Lac Henrietta (NTS 24H), and Lac Brisson (NTS 24A) areas.....	57	G47	Petrographic and geochemical characterization of the Baie Chapus Pyroxenite, Baie-James region: An example of Fe-Ti-V mineralization in the Superior Province	68
G26	Geology and economic potential of the Lac Brisson area, Southeastern Churchill (NTS 24A).....	57	G49	Opinaca-La Grande contact: A metamorphic and tectonic study	69
G27	Geology and mineral potential of the Lac Dalmas area, Baie-James (NTS 23E05, 23E12, 33H08, and 33H09).....	58	G50	Geochemical characterization of metasedimentary units in the La Grande and Opinaca subprovinces, Baie-James region	69
G28	Geology of the western Malartic Group: The Lac de Montigny area (NTS 32C04-NW), phase 4	58	G51	Characterization of a hydrothermal alteration zone in the De Pas Batholith, Churchill Province, Québec	70
G29	Geology of the Parent area, western Grenville, Québec (NTS 31O09, 31O10, 31O15, 31O16, 32B01, and 32B02).....	59	G52	Tectonometamorphic evolution of the Torngat Orogen, Southeastern Churchill: Using garnet as a geothermobarometer and geochronometer	70
G30	Potential for silica mineralization in Québec.....	59			
G31	Aggregate resource inventory in the Tasiujaq, Aupaluk and Kangirsuk areas	60			
G31	Quaternary deposits in the Chibougamau area (NTS 32H12, 32H13, 32J01 and 32J08): Preliminary results.....	60			
G32	Status of new geoscience compilations in Québec	61			
G33	Presentation of geophysical data published in 2014	61			

G53	The George River and Moonbase mylonites, Core Zone, Nunavik: Porphyroclasts, lineations, and recrystallization in crustal shear zones.....	71
G54	Petrological and geochemical characterization of the Nuvulialuk mafic-ultramafic Suite, Southeastern Churchill Province, Québec.....	71
G56	PGEs at the Delta deposit in the Cape Smith Belt (Nord-du-Québec): When metamorphism influences economic potential	72
G57	Phase diagram modelling as an exploration tool for iron oxide-copper-gold deposits in high-grade metamorphic terrains: Application in the Grenville Province.....	72
G58	Apatite rare earth characterization in an Fe-Ti-P deposit at Lac à Paul, Lac-Saint-Jean anorthositic Suite	73
G59	Characterization of the Lac à Paul P-Ti deposit, northern Lac-Saint-Jean Anorthosite Suite (Québec): Stratigraphy and mineral chemistry.....	73
G60	21 st century methodologies for mineral discoveries in Québec	74
G61	Block caving mining method	74
G63	Development of a new green technology for the revegetation of gold mine tailings using specific symbiotic microorganisms associated with white spruce	75
G64	Characteristics of surficial formations in the southern part of the PACES project, Chaudière-Appalaches region.....	75
G65	Re-assessment of the geology and gold exploration models of the southern Chibougamau mining camp (Abitibi)	76
G66	Opportunity for Ag-rich volcanogenic massive sulphides.....	76
G68	Charlevoix - a region sculpted by the skies above?	77
G69	Geoparks: What are they for?.....	77
G76	Ophiolitic cumulates at King Mountain, Cache Creek Terrane, British Columbia – Preliminary results.....	78
G77	Integration and interpretation of three-dimensional information for base metal, precious metal, and rare earth deposits	78
G78	Audio-magnetotelluric and petrophysical studies on the Champagne massive sulphide deposit	79
G82	Quality assurance and quality control (QA/QC) of geochemical analyses.....	79
G85	Social acceptability: Definition, factors and other things to think about	80

LOCATION OF PROJECTS AT GÉOLOGIE QUÉBEC



LOCATION OF UNIVERSITY PROJECTS



G01

Diamond, a precious resource in Québec

FANNY CHAPELLE (CÉGEP DE L'ABITIBI-TÉMISCAMINGUE)

Northern Québec is well known in the scientific community for its excellent diamond potential. Following the discovery of two kimberlite chimneys on the Foxtrot property (Renard) in December 2001, forty-two thousand claims were registered in the province's Mid-North.

Stornoway's Renard project on the Foxtrot property will be the first diamond mine in Québec. With 1.6 million carats produced each year, this future mine will make Quebec the sixth-largest producer of diamonds in the world. The province can expect the equivalent of \$1 billion in economic benefits and the creation of more than 500 jobs.

Diamonds found in the chimneys on the Renard project were formed under high pressure and temperature conditions at great depths, from 47 to 50 million years ago. Following the kimberlite eruptions, glaciers eroded the chimneys, leaving behind deposits containing diamonds.

After the discovery of the kimberlite chimneys, several steps were required to assess their diamond potential. An interpretation of geological data and a bulk sampling program were used to evaluate project viability. For the ore to be profitable, the mine will need to operate as an open pit with underground workings. The Renard 2 and Renard 3 deposits will be mined at surface and underground, whereas the Renard 4, located under Lac Lagopède, will only be mined underground.

The processing plant flow sheet comprises three crushing stages in order to obtain optimal grain size, followed by concentration using dense medium separation (DMS), and an x-ray and grease recovery system.

Diamond has many desirable properties that make it a unique precious gem. In addition to its exceptional hardness, diamond has a high refractive index, which imparts incredible beauty to the stone. It is used in different fields, notably jewelry, scientific research and high-tech industries.

However, the global market for diamonds has been tainted for several decades now. To eradicate the trade of "conflict diamonds", producing countries in southern Africa established a certification system for rough diamonds to control their production and trade. Since 2012, 81 countries have adopted this process to help prevent conflicts in favour of peace and security. Canada is among these countries whose aim is to promote stability in fragile countries. Diamonds from the Renard project will receive this certification.

Reference

Kimberley Process

Site: <http://www.kimberleyprocess.com/en/about>

G13

Architectural stone in the Portneuf, Lac-Saint-Jean, Eastern Townships, and Côte-Nord regions

N'GOLO TOGOLA AND RICARDO ESCOBAR (MERN)

During the summer of 2014, we completed a field campaign in the Lac-Saint-Jean (22D12, 22E06), Portneuf (31P01), Eastern Townships (31H03), and Côte-Nord (22I05, 22I06, 22I07, 22I08, 12L03, 12L05, 12L06) regions. This fieldwork consisted in updating information on existing architectural stone and crushed stone quarries, or in providing a detailed description of new architectural stone and crushed stone quarries, in order to prepare a detailed fact sheet for each quarry.

The field campaign took place from June 16, 2014 to July 14, 2014. During this time, we visited 32 existing architectural stone quarries and 10 new architectural stone and crushed stone quarries. We systematically sampled each quarry we visited in an effort to promote architectural stone from Québec.

In the Lac-Saint-Jean region, we visited architectural stone quarries in the Chute-du-Diable, Chute-des-Passes, Saint-Nazaire, and Bégin areas. The various lithologies quarried in these different locations include anorthosites, norites and leuconorites of the Lac-Saint-Jean anorthositic Suite, as well as quartz monzonites associated with granitic intrusions in the Saint-Ambroise Pluton.

In the Portneuf region, we visited several quarries in the Rivière-à-Pierre area. Rock types quarried in this area consist of farsundites, mangerites, and quartz mangerites of the Rivière-à-Pierre plutonic Suite.

In the Eastern Townships, we visited a few quarries where architectural stone, crushed stone, or industrial stone is produced in the Saint-Armand and Bedford areas. Quarried rock types mainly consist of calcilutites of the Strites Pond and Wallace Creek formations.

In the Côte-Nord region, we visited architectural stone and crushed stone quarries between Sept-Îles and Baie-Johan-Beetz. Lithologies quarried in this area include anorthosites and mangerites of the Havre-Saint-Pierre anorthositic Suite, granitic gneisses of the Manitou Complex, limestones of the Mingan Formation, and dolomites of the La Romaine Formation.

Knowledge acquisition project focussing on granites, mineral occurrences, and geochemistry in the Saint-Félicien area, Saguenay-Lac-Saint-Jean (NTS 32A08, 32A09, and 32A10)

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

This study constitutes the second phase of a knowledge acquisition project in the Saguenay-Lac-Saint-Jean region and covers the area southwest of Lac Saint-Jean, in NTS sheets 32A10, 32A09, and especially 32A08. Particular attention was paid to the various facies of granitic rocks (in a larger sense), namely in map sheet 32A08. During the field survey, reconnaissance geological mapping was also carried out in map sheets to the west (NTS sheets 32A07, 32A06, and 32A11). The study area is located in the central Grenville Province.

The Barois Complex, the oldest unit in the area, occupies the western part of the study area. It consists of an assemblage of foliated paragneisses and granodiorites/charnockites with local amphibolite layers. The eastern part of the study area is underlain by rocks of the Belley Complex, dominated by foliated K-feldspar-phyric monzonites although it also contains commonly foliated granites and syenogranites. The Lachance Complex, a commonly massive, porphyritic mangerite unit, is injected into these two major units and occurs in the form of rounded massifs. The Claire Gabbronorite, which hosts the Lac Touladi showing, is mainly observed in rocks of the Lachance Complex. Along the shores of Lac Saint-Jean, Ordovician limestones of the Trenton Group and Utica shales overlie the Grenvillian basement.

The structural fabric of the area is broadly N-S-trending but is disturbed by mangerites of the Lachance Complex. Several Grenvillian regional faults produce mylonitic zones that may be followed over several kilometres. The graben structure imposes a NW-SE morphology that produces many lineaments with the same orientation.

From an economic standpoint, the Lac Bouchette corridor (map sheet 32A08) hosts the Lac Bouchette silica deposit, as well as another silica showing located near Rivière Metabetchouan.

Reconnaissance work carried out in areas further west revealed the presence of many outcrops mainly consisting of metasedimentary rocks with sulphides and graphite (map sheet 32A07). Quartzites were also observed in paragneiss sequences. Map sheet 32A06, although only partially covered by the mapping survey, shows interesting potential for architectural stone, given the presence of extensive mangeritic massifs with very little jointing.

Base and precious metal mineralization in the Escoumins Volcano-sedimentary Belt, Central Grenville, North Shore (Côte-Nord)

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The Les Escoumins and Petit-Saguenay areas, located in the Grenville Province of Québec, are characterized by the presence of volcanic rocks metamorphosed to the amphibolite facies. Major units in the area are the Tadoussac Complex and the Saint-Siméon Group and were defined during previous mapping campaigns. The Tadoussac Complex is composed of migmatites and tonalitic, granodioritic or granitic gneisses, whereas the Saint-Siméon Group is composed of an assemblage of supracrustal metasedimentary rocks (quartzite, meta-arkose, conglomerates, calcisilicate rocks, metagraywacke and a few rare layers of marble and paragneiss) and mafic to felsic metavolcanic rocks (basalt, andesitic basalt, andesite, dacite and rhyolite). Mafic metavolcanics are dominant and occur as relatively massive amphibolite layers interpreted as flows and volcanoclastic deposits (hyaloclastites, breccias, and ash, lapilli, pumice, fiamme and bomb tuffs). Felsic facies (dacitic to rhyolitic), probably of volcanoclastic origin, are locally observed in the amphibolites. All of the supracrustal rocks are cut by intrusive rocks (felsic to ultramafic dykes, sills and plutons). Intrusive and extrusive rock geochemistry indicates an arc/back-arc environment. This finding is consistent with the Pinwarian age (1492 Ma) obtained for a felsic tuff. This type of geological setting is very favourable for the formation of base and precious metals deposits. Several Cu-Au-Ag showings associated with quartz veins in supracrustal rocks are already known, and the associated alteration (biotite-fluorite-quartz) and mineral parageneses (chalcocite-malachite-azurite-chalcopyrite-pyrite) are favourable to the mobilization of metals contained in the volcanic rocks. Near Sacré-Coeur, metasedimentary rocks (paragneiss and marble) in direct contact with amphibolites contain sillimanite- and phlogopite-bearing quartzitic units mineralized with sphalerite-chalcopyrite-pyrite-galena that may represent SEDEX-type exhalative horizons given the concordant nature of the mineralization. Mafic to ultramafic intrusives that served as feeder dykes and magma chambers for volcanic rocks are also present with local occurrences of Au-PGE-Cu-Ni mineralization. The richest zones are associated with NE-SW shear zones that promoted the circulation of hydrothermal fluids, thereby enriching the mineralization. At the regional scale, the presence of quartz-epidote-magnetite±garnet±titanite±chlorite±amphibole±sulphide veins in amphibolites and the discovery of two new Cu-Ag ± Au showings associated with zones of intense hydrothermal circulation are typical of VMS environments in an arc/back-arc setting. All these features make the under-explored Les Escoumins Volcano-sedimentary Belt a promising target for base and precious metal exploration.

G16-G17

Geology of the Lac Waconichi (NTS sheet 32J01) and Lac des Canots (NTS sheet 32I04) areas

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YANNICK DAOUDENE, AND CHRISTINE VÉZINA (UQAM)

The mapping revision of the Lac Waconichi (NTS sheet 32J01) and Lac des Canots (NTS sheet 32I04) areas is carried out within the scope of a survey covering the Chapais-Chibougamau area. The objectives of this project are to: a) improve the geological understanding of the Lac Chevrillon and Lac du Sauvage area, where the last mapping survey dates back to 1956; b) characterize the nature of the contact between the Abitibi and Opatica subprovinces; c) refine mapping east of the Grenville Front Tectonic Zone (NTS sheet 32I04) based on the recent aeromagnetic survey and the addition of new geochemistry and geochronology data; and d) investigate the potential for VMS and lode gold mineralization. The study area straddles the boundary between volcanic and sedimentary rocks of the Abitibi Subprovince, metamorphosed to the greenschist and amphibolite facies (2.80-2.63 Ga), and volcano-plutonic rocks of the Opatica Subprovince metamorphosed to the amphibolite facies (2.81-2.66 Ga). This boundary is partly covered by an erosional unconformity overlain by sedimentary rocks of the Chibougamau (2.49-2.45 Ga) and Albanel (1.95-1.75 Ga) formations. In the Abitibi Subprovince, prospective targets for VMS exploration are located north of the Lac France Pluton, where mafic volcanic rocks of the Bruneau Formation host massive sulphides and stringer zones with sphalerite and galena (Zn-Pb). Along the north and south limbs of the Waconichi Syncline, volcanoclastic rocks of the Blondeau Formation include tuffs with massive sulphide clasts and pyrite-rich massive sulphide lenses. The best targets for lode gold mineralization occur in the form of quartz-tourmaline-pyrite veins in the E-W-trending Fari-bault and Lac France deformation zones. Volcanic rocks of the Bruneau Formation and stratiform gabbroic intrusions appear strongly chloritized and ankeritized, whereas pyrite-bearing felsic tuffs and quartz-feldspar-phyrlic felsic dykes are sericitized. Mapping and preliminary structural interpretation of the Baie Pénicouane area in the Opatica Subprovince (NTS sheet 32J08, north of the study area) reveal a series of granitoid domes, outlined by the presence of discontinuous lenses of ultramafic (peridotites) to mafic (amphibolites) rocks. In the eastern part of the study area, Archean rocks of the Abitibi and Opatica subprovinces are obliterated by the Grenville Front Tectonic Zone and intrusions in the Parautochthonous. These rocks have undergone amphibolite-grade Grenvillian metamorphism (1.3-1.0 Ga). Geochronology studies currently underway will prove useful to better characterize the evolution of plutonic assemblages and deformation.

G18

Tectonometamorphic evolution of the Abitibi-Opatica contact zone: Contributions from $^{40}\text{Ar}/^{39}\text{Ar}$ thermochronology

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JEAN GOUTIER AND FRANÇOIS LECLERC (MERN)

The Superior Province is mainly composed of greenstone belts and TTG-type plutonic belts that amalgamated during the Kenorean orogeny around 2.72-2.68 Ga. While the geology of these units is generally well understood, the nature of their contacts and the age and duration of related regional tectono-metamorphic episodes still remain poorly known. This is the case for the contact between the Abitibi Greenstone Belt and the Opatica Plutonic Belt. Such information is crucial if we are to discuss the tectono-metamorphic evolution of these parts of the ancient crust or debate models of crustal deformation during the Archean.

Our structural and metamorphic analysis of an area centred on Lac au Goéland, 90 km east of Matagami and Chibougamau demonstrated that the Abitibi series of volcanic and sedimentary rocks overlie the plutonic rocks of the Opatica Belt. The entire assemblage is affected by regional E-W schistosity-foliation and cut by late strike-slip shear zones. From south to north, towards the contact with the Opatica, metamorphic conditions of the Abitibi volcanic and sedimentary rocks gradually increase, passing from greenschist facies to amphibolite. Although rarely observed, the contact between the Abitibi and Opatica belts does not appear to be marked by particularly intense deformation. We believe the Opatica rocks formed the basement for the Abitibi series.

Micas and amphiboles from metamorphic and igneous rocks were dated by the $^{40}\text{Ar}/^{39}\text{Ar}$ method. The results suggest that regional metamorphism, associated with compressive N-S tectonics, started around 2685 Ma. Between ~2685 and ~2632 Ma, the deep domains of the Abitibi and the underlying Opatica rocks attained amphibolite facies conditions, and compressive deformation was accompanied by N-S flattening and vertical creep in the crustal material. Following this, localized deformation was initiated as the rocks were cooling; starting ~2600 Ma, this deformation was characterized by sinistral and dextral strike-slip movements along NE-SW and NW-SE deformation corridors, respectively. This characteristic indicates that lateral creep of the “deep” crust had become predominant.

The compilation of our thermochronological data and other data previously acquired for the southeastern Superior Province suggests that the age of regional metamorphism and associated deformation episodes are approximately the same throughout the region. The geochronological and structural characteristics of the study area support a “verticalist” model, which is not very compatible with the hypothesis proposed not so long ago of a subduction dynamic at the contact between the Abitibi and Opatica belts.

Structural analysis of the Rivière France shear zone and its gold occurrences, Chibougamau area, Québec

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

The Chibougamau mining camp, in the Abitibi region, was the second-biggest mining area in Québec from 1955 to 2008 (60.09 Mt of ore producing 994,802 t Cu, 160 t Au and 102 t Ag). Renowned for its lode copper-gold deposits, this mining camp also hosts deposits of gold-bearing quartz-carbonate-tourmaline veins in volcanic and sedimentary sequences metamorphosed to greenschist facies. Previous regional studies have demonstrated the spatial association between this type of gold deposit and E-W shear zones, but chronological relationships still need to be elucidated. The main objective of this study is to assess the relative ages of deformation episodes and establish the timing of gold vein mineralization. To attain this goal, the study will rely on a detailed structural analysis of a typical gold vein showing in the Chibougamau camp, the Monexco showing, in addition to a regional-scale structural characterization.

The Monexco showing is situated 30 km north of Chibougamau, along the Rivière France shear zone. The volcanic and sedimentary rocks of the Bruneau and Blondeau formations are cut by quartz-feldspar porphyry dykes and gabbro sills. All lithologies are deformed by an E-W deformation corridor (150-250 metres wide), characterized by an E-W foliation (S2) and a NE-SW schistosity (S3) related to the late development of dextral shear zones. At the regional scale, structural observations suggest the existence of a deformation corridor with an average width of 450 metres, represented by a network of anastomosing shear zones. The essentially vertical kinematics (D2) were later affected by dextral strike-slip faulting (D3). Gold mineralization is concentrated in extensional veins composed of quartz, ankerite, tourmaline and auriferous sulphides, principally pyrite. Wall rocks contain disseminated pyrite. The dominant alteration minerals are chlorite, sericite, tourmaline and ankerite. The extensional veins, mainly oriented N-S and NNE-SSW, experienced D3 deformation and were likely penecontemporaneous with D2. By refining the chronology of deformation and lode gold mineralization in a typical Chibougamau-area shear zone, this study will serve as a regional exploration guide for this type of deposit.

Canada's first continental crust

CHRISTOPHE AZEVEDO, MICHEL JÉBRAK (UQAM),
ANDREA AMORTEGUI (MERN) AND JEAN-FRANÇOIS
MOYEN (UNIVERSITÉ JEAN MONNET)

The Northeastern Superior Province (NESP) is one of the largest Neoarchean continental blocks in the world. It is mainly composed of felsic plutonic rocks, mostly tonalites, granites, granodiorites and charnockites, as well as rare monzonites and syenites. This differentiated plutonic environment manifests the first stages of magmatic evolution recognized in Archean cratons. In the core of the NESP, magmatism evolved from a primary sodic stage (TTG suites; 2830-2740 Ma) to potassic magmatism (2740-2680 Ma), represented by the emplacement of potassic granodiorite and granite units. A third stage corresponds to the emplacement of late syenite and carbonatite units (2680-2640 Ma).

Approximately 1,400 samples were processed from a database of 6,100 samples collected during the MERN's Far North mapping program (1998-2003). In addition to characterizing magmatic processes involved in NESP crustal growth during the late Archean, these geochemical data are also of interest in the search for favourable plutonic environments for porphyry-style rare earth mineralization or Sn-W granites.

Most of the tonalitic and diatexitic complexes have compositions that can be interpreted as a mixture (or an incomplete separation) of solid and liquid phases, representing the partial melting of initially contrasting lithologies (first-cycle tonalites, sediments...). In this model, late granitic suites can be interpreted as areas where the liquid phase was extracted and concentrated. Consequently, the NESP can be considered as a vast melted crust from which extracted liquid formed the granitic continental crust observed in the field.

From a metallogenic viewpoint, the redox state of intrusive rocks controls the precipitation of sulphides and magnetite, and thus mineralization. Iron oxide concentrations can be used to classify the NESP plutonic suites as a function of their oxidation state. Cu-Au and Cu-Mo mineralization is generally associated with poorly fractionated oxidized intrusives (magnetite series). In contrast, Sn and Sn-W mineralization is associated with fractionated reduced intrusives (ilmenite series). The results of iron analyses on samples of differentiated NESP intrusives support a potential for Cu-Au and Cu-Mo mineralization in the region. The majority of the analyzed intrusives belong to the evolving magnetite series, suggesting a significantly oxidized state for this crust during the Archean (average $\text{Fe}_2\text{O}_3/\text{FeO}$ ratio of 0.84). This Archean crust is more homogenous and slightly more oxidized than Phanerozoic continental crusts.

G21

Revision of geological maps in the Labrador Trough using high-resolution geophysical maps and RapidEye images

THOMAS CLARK (URSTM-UQAT) AND KATHLEEN O'BRIEN (MERN)

The *Ministère de l'Énergie et des Ressources naturelles du Québec* is proceeding with a revision of the 1/50,000-scale geological maps of the Labrador Trough (New Quebec Orogen). To date, all maps in the northern half of the region (about 45 map sheets) have been updated. To do so, we mainly used high-resolution magnetic and spectrometric maps derived from airborne surveys carried out since 2009 by *Géologie Québec* and Natural Resources Canada, magnetic maps derived from an earlier federal survey, as well as RapidEye satellite images. This revision is based on the following two principles: (1) the established stratigraphy of the Trough must be respected, and (2) the truncation of a geophysical anomaly by another suggests the presence of a fault. The application of these principles has important consequences: for example, each mapped lithological unit must be included in a recognized or postulated stratigraphic unit, and the structural superposition of an older unit onto a younger unit must have an explanation on the map, such as the presence of a thrust fault or a fold. As a result of the revision, we were able to complete the geology in areas covered by unconsolidated deposits, follow geological units previously patchy and fragmented on existing maps, better define faults and folds, and develop a better understanding of the overall structural framework of the Trough. The revision will also result in a more accurate assessment of the mineral potential of the Trough.

The revision of the geological maps is carried out in two stages. First, the geologist corrects, on hard-copy maps, geological contacts, the names of geological units, faults and folds, mainly with the help of high-resolution geophysical maps (total residual magnetic field and vertical gradient) and RapidEye images. Subsequently, the GIS specialist corrects the geometrical elements (polygons and lines) and descriptive elements (definitions and lithological codes attributed to each zone) in the SIGÉOM database, validates the corrections, and prepares the map for public dissemination.

To illustrate the results of this revision, four contiguous maps (24F01 to 24F04) extending from the western margin of the Trough (Superior Province) to its eastern margin (Core Zone) are presented. We compare the geology known prior to this exercise with the revised geology and as a reference, we also show the magnetic vertical gradient map. Several areas of interest are indicated and discussed.

G22

Potential for orogenic gold mineralization in the Baie-James region

GUILLAUME ALLARD, JEAN GOUTIER AND DANIEL LAMOTHE (MERN)

A project to assess the mineral potential for orogenic gold mineralization has resulted in the definition of high-favourability zones (HFZ) for this type of ore deposit in the Baie-James region (NTS 33A, 33B, 33C, 33F, 33G, and 33H). This project is an update of report EP-2008-01 (Lamothe, 2008).

Methodology

There are two main categories of processing methods used in potential assessment studies:

- 1) Empirical methods (data-driven); and
- 2) Conceptual methods (knowledge-driven).

The selected approach, hybrid fuzzy logic, takes into account both types of methods, empirical and conceptual. This hybrid method makes it possible to combine the user's judgment to attribute fuzzy favourability values, and a semi-empirical approach (probability of association calculated using the weights of evidence method).

Data processing

Data processing was entirely carried out in Model Builder. Alteration models (mass balance calculations) were generated using the LithoModeleur standard developed by Consorem. Spatial analysis processing was performed to attribute contrast values to 32 different parameters that showed a positive spatial association with a set of 113 gold deposits (worked deposits, deposits with estimated tonnage, and mines) in the Baie-James region. These parameters were subdivided into six major categories:

- ▶ Lithological controls;
- ▶ Structural controls;
- ▶ Alteration;
- ▶ Sulphides and metals;
- ▶ Geophysics;
- ▶ Secondary environment.

These various parameters were weighed using the weights of evidence (WOFE) technique and combined with tools based on fuzzy logic.

Results

The minimum threshold for high-favourability zones was determined by statistical analysis, taking into account known deposits in the Baie-James region. HFZ cover a surface area of 1,062 km², 27% (288 km²) of which remained open for staking as at October 18, 2014. These high-favourability zones will be available directly in GESTIM during the Québec Mines convention.

Geological compilation of the Lac Mitis area, Bas-Saint-Laurent region

ROBERT THÉRIAULT, CLAUDE DION AND STÉPHANE BEAUSÉJOUR (MERN)

The geology of four map sheets (22B04-201, 22B05-101, 22C01-202 and 22C08-102) was mapped at a scale of 1:20,000 in June 2014, in the Lac Mitis area of the Bas-Saint-Laurent region. Many new roads in the area provided access to land that had seen little previous study.

The mapped area is part of the Connecticut Valley-Gaspé Synclinorium in the Gaspé Belt, and is mainly underlain by Siluro-Devonian rocks deposited in an intracratonic basin that formed following the Taconian Orogeny. The mapped sedimentary sequences belong to the Cabano Group, the Chaleurs Group and the Upper Gaspé Limestones. Younging is to the northeast. The sequences are characterized by a series of open folds oriented NE-SW, commonly cut by normal or strike-slip faults with the same trend.

The Cabano Group (Ordovician-Silurian) is found in the southwestern part of the study area. It consists of dark grey mudstones with slaty cleavage, interbedded with grey lithic wackes. The Chaleurs Group (Siluro-Devonian) overlies the Cabano Group along an erosional unconformity. In the study area, it comprises the Awantjish, Val-Brillant and Sayabec formations in the lower part of the group, and the Saint-Léon Formation representing the upper part. The Awantjish Formation has poor outcrop exposure on adjacent map sheets, but considerable exposure in the study area. It is composed of red and green mudstones that are locally very dark grey in the upper part of the sequence. The mudstones are overlain by the Val-Brillant Formation, composed of thick beds of whitish to yellow-white quartz sandstone with local conglomerate beds. The basal part of this formation consists of fine-grained, dark grey quartz sandstone beds intercalated with very dark grey mudstone typical of the summit of the Awantjish Formation. As for the Sayabec Formation, it consists of fossiliferous calcarenite that only crops out in the western part of the area. The Sayabec Formation is overlain by the Saint-Léon Formation, a thick sequence of calcareous to non-calcareous siltstone and laminated fine-grained sandstone, locally containing calc-silicate layers. Calcareous conglomerate is present near the base of the unit. Upper Gaspé Limestones (Devonian) crop out in the northeastern part of the area, mainly as calcilutite belonging to the Forillon Formation, overlain by mudstones and calcareous rocks of the Shiphead and Indian Cove formations, respectively. Finally, gabbro sills of Devonian age belonging to the Lemieux Intrusive Suite were also observed in places.

Although no mineralized showings were found during our mapping work, there is potential for Pb-Zn mineralization and for industrial minerals such as silica (Val-Brillant Formation) and alumina (Awantjish Formation). The region also has good hydrocarbon potential based on the presence of numerous antiformal structures, among other features.

Geological compilation of Siluro-Devonian rocks in the Connecticut Valley-Gaspé Synclinorium, southern Appalachians of Québec

MORGANN PERROT AND ALAIN TREMBLAY (UQAM)

In the Appalachians of Québec, the majority of Siluro-Devonian rocks within the Gaspé Belt crop out along the Connecticut Valley-Gaspé Synclinorium (CVGS). In southern Québec, the CVGS is found in the hanging wall of the La Guadeloupe Fault, a major reverse fault related to the mid-Devonian Acadian Orogeny. The CVGS comprises sedimentary and volcanic rocks of the St-Francis Group and the Seboomook, Frontenac and Rivière Clinton formations. From base to summit, the St-Francis Group comprise the Lac Lambton Formation, a series of conglomerates and calc-silicate rocks that crop out in the Lac Saint-François area, the Ayer's Cliff Formation, a series of impure limestones and calcareous mudstones, and the Compton Formation, a sequence of feldspathic sandstones and mudslates divided into the basal Milan Member and the overlying Lac-Drolet Member. The mudstones of the Saint-Ludger Member (Lebel and Tremblay, 1993) are redefined herein as a lithological facies of the Lac-Drolet Member. The rocks of the Seboomook, Frontenac and Rivière Clinton formations crop out to the southeast of the St-Francis Group, in the hanging wall of the Bella Fault, a SE-dipping reverse fault that marks the contact between the St-Francis Group to the northwest and the Frontenac Formation to the southeast. The latter is considered the lateral equivalent of the Milan Member, distinguished primarily by the presence of a significant volcanic component (basalt, gabbro ± rhyolite) intimately associated with sedimentary rocks. Southeast of the Frontenac Formation are volcanic and sedimentary rocks belonging to the Rivière Clinton Formation, overlain by the Seboomook Formation, which is considered the equivalent of the Compton Formation in Maine (U.S.). In the southeast corner of Québec, these formations are in tectonic contact with the Proterozoic (?) to Cambrian (?) rocks of the Chain Lake Massif.

In the CVGS, regional metamorphism varies from prehnite-pumpellyite facies in the Beauce region, to greenschist facies (biotite zone) at the Québec-Vermont border. Regional deformation is characterized by tight to isoclinal F1 folds overturned to the northwest in the Sherbrooke area. Deformation became increasingly polyphase closer to the American border: F1 folds were overprinted by D2 deformation associated with S2 schistosity and open to tight SE-verging folds. These D2 structures were in turn affected by a large domal structure associated with crenulation cleavage (S3). Several Devonian granitic intrusions cut the sedimentary and volcanic rocks of the CVGS, generating "late" metamorphic aureoles that overprint regional structures.

Reference

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G25

Glacial drift prospecting in the Southeastern Churchill Province: Combined sampling of glacial and fluvioglacial sediments - Preliminary results from the Lac Saffray (NTS 24G), Lac Henrietta (NTS 24H), and Lac Brisson (NTS 24A) areas

HUGO DUBÉ-LOUBERT (MERN-UQAM), VIRGINIE DAUBOIS (MERN) AND MARTIN ROY (UQAM)

Areas affected by the great Quaternary glaciations represent still today an obstacle to bedrock mapping and to mineral exploration due to the presence of several metres of glacial sediment cover. As a result, many exploration campaigns resort to glacial sediment sampling to overcome this problem and to target areas with the highest potential for mineral resources.

The *Bureau de la connaissance géoscientifique du Québec* launched in the summer of 2012 a large-scale Quaternary mapping and glacial (till) and fluvioglacial (esker) sediment sampling program in the area south of Ungava Bay. This project pursues various objectives: firstly, the Ungava Quaternary project may help with mineral potential assessment using drift prospecting tools. In addition, data derived from Quaternary sediment sampling will be supported by detailed mapping at a scale of 1/250,000.

During campaigns conducted in 2012, 2013, and 2014, nearly 1000 till and esker samples were collected and analyzed in an effort to characterize the major and trace element geochemistry of the till matrix. Heavy mineral concentrates were also prepared to identify indicator minerals associated with various types of deposits (kimberlite intrusions, base metals, sulphides, etc.). This poster presents the results of mapping efforts and geochemical and heavy mineral concentrate analyses (indicator minerals) for samples collected in 2012 (Lac Saffray) and in 2013 (Lac Henrietta), as well as preliminary results for the year 2014 (Lac Brisson).

G26

Geology and economic potential of the Lac Brisson area, Southeastern Churchill (NTS 24A)

DANIEL BANDYAYERA, ISABELLE LAFRANCE AND CARL BILODEAU (MERN)

This new geological survey at 1:250,000 scale was carried out during the summer of 2014 in the Lac Brisson area, 225 km southeast of Kuujuaq. The mapped area lies within the southeastern part of the Churchill Province, and covers the eastern Core Zone and the western Torngat Orogen, separated by the Blumath Deformation Corridor oriented N-S to NNW-SSE.

The Core Zone represents ancient Archean craton, deformed and remobilized in the Paleoproterozoic during the New Québec orogeny to the west and the Torngat orogeny to the east. The main units in the Core Zone are Archean gneisses and migmatites, in addition to volcano-sedimentary and metasedimentary units. Numerous Paleoproterozoic syntectonic to late tectonic felsic intrusions cut the older rocks. The largest is the De Pas Batholith, which extends for more than 600 km in the Core Zone and has been interpreted as a continental magmatic arc. The Core Zone also contains kilometre-scale intrusions of alkaline gabbro, diorite and syenite, associated with strong magnetic anomalies. From the eastern end of the Blumath Deformation Corridor, the rocks of the Torngat Orogen comprise orthopyroxene gneisses of tonalitic to dioritic composition, paragneisses, and enderbite and charnockite intrusions.

The structural arrangement of the region was the result of an oblique collision between the Nain and Superior provinces, and the crushing of Core Zone blocks against the New Québec Orogen. To the west, the region is crossed by the N-S to NNW-SSE George River Shear Zone (GRSZ), interpreted as a dextral fault. To the east, the Core Zone is divided into two blocks by the Moonbase Shear Zone (MSZ), oriented NW-SE and interpreted as a sinistral crustal fault. A series of late E-W faults also cross the mapped region.

Our work enabled us to follow the Tunulic Belt for more than 100 km. The Tunulic Belt is a kilometre-wide volcano-sedimentary belt discovered in 2013 in the northern part of the study area. New sites of economic interest have been grouped into four major geological environments: 1) hydrothermal systems associated with De Pas Batholith intrusions; 2) rare metals associated with granites and alkaline intrusives; 3) sulphides in a volcanic environment (Tunulic Belt); and 4) mafic-ultramafic intrusions. A new Ni-Cr showing was discovered in the ultramafic intrusions of the Nuvulialuk Suite.

Geology and mineral potential of the Lac Dalmas area, Baie-James (NTS 23E05, 23E12, 33H08, and 33H09)

PÉNÉLOPE BURNIAUX, MEHDI GUEMACHE, JOSÉPHINE GIGON AND JEAN GOUTIER (MERN)

The geological survey carried out at a scale of 1/50,000 during the summer of 2014 in the Lac Dalmas area (Baie-James) covers NTS sheets 33H08, 33H09, 23E05, and 23E12. Located in the eastern part of the La Grande Subprovince, the map area is essentially composed of Archean rocks characterized by a dome-and-basin tectonic style. Archean sedimentary basins (Dalmas, Thor, and Mercator formations) and volcanic belts (L'Escaie and Trieste formations) form several dislocated bands around large felsic to intermediate syn- to post-tectonic intrusions (Coates and Joubert suites, La Savonnière Pluton, and Polaris Batholith). Volcanic belts are composed of metavolcanic rocks, ranging from mafic to felsic in composition, with mainly silicate-facies iron formation horizons. This area is distinctive from other parts of the La Grande Subprovince given the abundance of altered volcanic rocks. The north-central part of the map area is characterized by a significant amount of decametre-scale ultramafic dykes and sills. Four sites were sampled for U-Pb age determinations, in an attempt to better define volcanic and sedimentary units since, immediately to the west, volcanic rocks and plutons dated at 2.8 Ga are in contact with volcanic rocks dated at 2.7 Ga. Neoproterozoic (N-S to NNW-SSE) and Paleoproterozoic (NE-SW and NW-SE) mafic dyke swarms crosscut all other rock units. A study is also underway to characterize the metamorphism in the Lac Dalmas area, which ranges from the greenschist to the amphibolite facies. Metasedimentary rocks and felsic volcanic rocks are characterized by the presence of garnet, cordierite, sillimanite, staurolite, andalusite, and chloritoid. New alteration zones and metasomatic zones characterized by assemblages with quartz-amphibole-diopside-garnet, amphibole-diopside-epidote, sericite-amphibole-garnet-tourmaline, amphibole-epidote-calcite, and biotite/phlogopite-calcite-amphibole-pyrrhotite, were also identified. Known mineral occurrences and new targets discovered during our fieldwork show that this area has interesting potential for the discovery of orogenic gold occurrences, polymetallic volcanogenic massive sulphides, Cu-Ni-PGE and Cr-PGE occurrences in ultramafic intrusions, and lithium deposits associated with spodumene-bearing pegmatites.

Geology of the western Malartic Group: The Lac de Montigny area (NTS 32C04-NW), phase 4

PIERRE PILOTE, PIERRE LACOSTE, VÉRONIQUE LAFRANCE, JEAN DAVID (MERN), VICKI MCNICOLL (GSC-O) AND RÉAL DAIGNEAULT (CERM-UQAC)

The Lac De Montigny area is situated in the southern part of the Abitibi Subprovince, north of the Cadillac Fault. During the summer of 2014, a mapping project to revise the Malartic Group covered this area at a scale of 1:20,000, corresponding to the western half of NTS map sheet 32C04. The mapping results will be used to link this study to other work carried out in the western part of the Malartic Group (2006–2009) and previous work in the Val-d'Or area.

The Lac De Montigny area is underlain by Archean volcanic rocks (Malartic and Louvicourt groups) and sedimentary rocks (Mont-Brun, Cadillac, Caste and Pontiac groups), representing the extension of volcanic units found to the east of Val-d'Or, an area renowned for its fertility in terms of gold and volcanogenic massive sulphide deposits. In the Lac De Montigny area, the Malartic and Louvicourt groups comprise the formations of La Motte-Vassan (2714 $\pm$ 2 Ma), Dubuisson (2708 $\pm$ 2 Ma), Jacola (2706 $\pm$ 2 Ma), Val-d'Or (2704 $\pm$ 2 Ma) and Héva (2702 $\pm$ Ma). The extent and thickness of these formations are highly variable. The general trend of the stratigraphic surfaces also varies, passing from WNW-ESE in the northwestern corner of the map, to E-W in the southern part. An S1 schistosity, moderately to intensely developed, is typically subparallel to S0 stratification. The La Motte Vassan Anticline, a NW-trending F1 fold, crosses the map region. An S2 cleavage, oriented E-W, cuts the S1 fabric. Stretching lineations are contained within the S1 fabric and plunge moderately to steeply to the east. This area also has large-scale shear zones and strike faults, trending W to WNW and dipping steeply to the north: La Pause, Parfouru, Rivière Héva, Manneville South, Norbenite, Marbenite, K-Zone and Cadillac. These faults contain dykes or stocks of monzonitic or tonalitic composition with highly variable ages — pre-, syn- or post-tectonic — and are spatially associated with several gold mines and showings (Norlartic, Kiena, Snow Shoe, Sullivan, Goldex, Siscoe, Joubi, Sigma and Lamaque). The observed diversity in the styles and ages of gold mineralization demonstrates that several distinct episodes of mineralization occurred, and that they reached their peaks at different times.

Two enormous intrusions, the synvolcanic Bourlamaque Pluton (2700 Ma) and the late- to post-tectonic La Corne Pluton (2680–2642 Ma), as well as several other smaller isolated satellite bodies cut and profoundly disrupted the initial volcanic and structural architecture. Regional metamorphism reached greenschist facies, except along the margins of the larger intrusions.

The results of this work will highlight and characterize the mineral potential of this region. The study will also promote exploration of early to late vein-style gold mineralization of the Abitibi Subprovince.

G29

Geology of the Parent area, western Grenville, Québec (NTS 31O09, 31O10, 31O15, 31O16, 32B01, and 32B02)

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

The map area constitutes the first phase of a five-year regional mapping project aimed at acquiring new geological and metallogenic knowledge in the Gouin Reservoir area, in the Haut-Saint-Maurice region. The map area is entirely underlain by rocks of the Grenville Province. This mapping campaign was completed 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. A recent high-resolution aeromagnetic survey, combined with field mapping, was used to help identify and constrain several geological units.

Metasedimentary rocks, including paragneiss with (lilac pink) garnet, graphite, and sillimanite, pyrite-bearing quartzite, and minor amounts of marble and calc-silicate rocks cover part of the map area. The region also contains numerous intrusions of mangerite, monzonite, charnockite, and granite. All these rock units are intruded by granitic pegmatite sills or dykes and by mafic dykes. Other intrusions, scattered across the map area, are composed of strongly magnetic pink or grey syenite ($\pm$ orthopyroxene $\pm$ clinopyroxene $\pm$ biotite), gabbro, and ultramafic rocks (phlogopite-bearing lamprophyre and minette).

Metamorphosed hydrothermal alteration zones were identified in many areas and over several kilometres. These zones consist of siliceous gneisses with pyrite, pyrrhotite and traces of chalcopyrite, garnet-rich mafic rocks (garnetite or cotecule?), and whitish felsic rocks with sillimanite and garnet, which are probably volcanic in origin.

Rocks are generally strongly deformed and exhibit isoclinal folds corresponding to phase of deformation D2. The third phase of deformation generated mostly open folds. These two phases of deformation are responsible for the dome-and-basin structural style in the region. Dykes and plutons of syenite, gabbro, gabbro, and pegmatite exhibit primary magmatic textures and may be considered as syn- to post-Grenvillian. The deformed rocks have generally undergone prograde granulite-facies metamorphism, namely indicated by the ubiquitous presence of orthopyroxene. Major reverse, normal, oblique, and strike-slip faults were recognized in the area. These faults correspond to wide mylonitic corridors trending NNE-SSW to N-S. These zones also surround most of the syenitic intrusions and may have favoured their emplacement as well as that of other ultrapotassic magmas.

The map area offers excellent mineral potential given its hydrothermal alteration zones and the presence of exploration targets for rare earth elements, iron and titanium oxides, Ni-Cu, and architectural stone.

G30

Potential for silica mineralization in Québec

N'GOLO TOGOLA (MERN)

Sources of silica are abundant in Québec: sandstone formations or quartzites, massive quartz veins or lenses, and quartzose sand deposits. The latter can be found in the Grenville or Superior geological provinces, in the Appalachians and in the Saint Lawrence Lowlands, as well as in recent Quaternary deposits.

The Grenville Province hosts numerous silica deposits associated with quartzites derived from metasedimentary assemblages. These consist of pure to very pure quartzite horizons, where the average silica content ranges from 98.2% to 99.5% SiO_2 . Certain high-purity quartzite horizons locally exhibit grades up to 99.7% SiO_2 .

In the Appalachians, silica deposits are associated with quartz-rich sandstone units. These namely consist of thick, continuous beds of quartz-rich sandstone that generally exhibit average grades of more than 96% SiO_2 . Certain high-purity quartz-rich sandstone horizons may exhibit grades on the order of 99.7% SiO_2 . In certain locations, massive quartz veins crosscut sedimentary units. These hydrothermal quartz veins form lens-shaped geological bodies of limited extent, rarely exceeding 100 m in length by 10 to 20 m in width. They occasionally exhibit high silica grades reaching 98.6% to 99.9% SiO_2 .

Silica deposits in the Superior Province are associated with Paleoproterozoic siliceous sandstone units (sedimentary inliers). In addition, quartz veins hosting metal mineralization may also constitute potential sources of silica.

In the Saint Lawrence Platform, silica deposits are associated with quartz-rich sandstone units. The purest quartz-rich sandstone beds, which may contain up to 99.3% SiO_2 are found in the Cairnside Formation (Potsdam Group).

Quartz masses in granitic pegmatites and quartz lenses also constitute potential sources of silica in the Grenville geological Province. Quartz masses associated with granitic pegmatites, hydrothermal quartz veins or lodes injected in quartzites, marbles and granitic gneisses locally exhibit high silica grades ranging from 97.6% to 99.2% SiO_2 . The Lac Bouchette silica deposit, hosted in a quartz vein, was mined in the past.

Natural sand deposits, from marine or deltaic settings and strongly reworked or derived from high-silica rocks, also constitute sources of silica in Québec. A relatively pure silica sand, with grades ranging from 95% to 97% SiO_2 , is extracted from these deposits by washing and screening.

Aggregate resource inventory in the Tasiujaq, Aupaluk and Kangirsuk areas

ANDRÉ BRAZEAU AND ÉRIC LEDUC (MERN)

In the summer of 2014, an inventory was taken of aggregate resources in the northern communities of Tasiujaq, Aupaluk and Kangirsuk. This work completed the characterization of aggregate resources available to villages on the western coast of Ungava Bay.

The village of Tasiujaq (58°41'00"N – 69° 56'00"W) is situated on the shores of Baie aux Feuilles, at the mouth of Rivière Bédard, more than 70 km southeast of Ungava Bay. The population is 303 inhabitants (Statistics Canada, 2012). Baie aux Feuilles is known for its exceptional tides of up to 17 metres. This phenomenon had an enormous impact on morphosedimentary dynamics at the time the lithostratigraphic units of the region were laid down.

The village of Aupaluk (59°18'00"N – 69° 36'00"W) forms the smallest community in Nunavik, with a population of about 195 inhabitants (Statistics Canada, 2011). This village is situated on the southern shore of Hopes Advance Bay, more than 150 km north of Kuujuaq. The period of submersion and regression of the Iberville Sea left behind many vestiges, such as numerous terraces, raised beaches and spits.

The village of Kangirsuk (60°01'00 N – 70° 00'00 W) is situated on the north shore of Rivière Arnaud, 13 km inland of Ungava Bay. It has a population of 549 inhabitants (Statistics Canada, 2012). The village is bounded to the north and west by rocky hills that were sculpted into their present shapes by the Laurentide Ice Sheet.

Many northern villages are experiencing strong population growth, and lodging and municipal infrastructure demands are very high. Permafrost coupled with global warming renders it increasingly difficult to build the needed infrastructure, which requires greater amounts of aggregate material for the construction of road and building foundations.

The inventory provides the locations and characteristics of aggregate materials and their quantities. Field work consisted of visiting natural cuts and sand pits, in addition to digging numerous test pits by shovel. A total of 15 samples of sand or gravel were collected from the villages and sent to a laboratory to determine their physico-mechanical properties.

The main sources of available aggregate in the study area are glaciomarine deposits (intertidal, deltaic and prodeltaic sediments, as well as littoral and pro-littoral sediments) and glaciofluvial deposits (ice-contact sediments) dating back to the last glacial retreat, around 7,900 years ago. The glaciomarine deposits were emplaced along the margin of the Iberville Sea, which submerged the land to an altitude of 152 metres in the south and up to 138 metres in the north. The biggest source of aggregate is a segment of an esker located 4 kilometres north of Kangirsuk.

Quaternary deposits in the Chibougamau area (NTS 32H12, 32H13, 32J01 and 32J08): Preliminary results

MOHAMED EL AMRANI (MERN) AND OLIVIER LAMARCHE (UQAM)

During the summer of 2014, a mapping survey of Quaternary deposits was carried out in the areas to the north and east of the town of Chibougamau. The work focused on an area of roughly 3,985 km² at a scale of 1:50,000 (32H12, 32H13, 32J01 and 32J08).

The present study has three principal objectives: 1) document the main geomorphological features of the region; 2) describe the lithological, stratigraphic and sedimentological characteristics of the documented units; and 3) sample and analyze till and esker sediments to identify areas of potential interest for mineral exploration.

Preliminary results indicate the sedimentary cover was emplaced during the last glacial period. The cover is essentially composed of glacial deposits (basal till, ablation till and melt-out till) followed by glaciofluvial deposits concentrated in valleys. Some glaciolacustrine deposits have also been observed, mainly in the northern part of the study zone where large expanses of reworked till record the influence of Lake Ojibway. The extent of this proglacial paleolake is not precisely known (estimated maximum level of 445 m), but its presence in the region during glacial retreat was reported in previous work (Prichonnet *et al.*, 1984). Postglacial sediments are represented primarily by present-day alluvium and slope deposits, and by a few rare undifferentiated eolian deposits near the glaciofluvial deposits. In depressions, poor drainage led to the formation of peat.

Three episodes of glacial flow have been identified. The first is to the SE (110–140°), with little evidence of its passage except for some glacial striations. The second more recent flow was a major and well-recorded episode to the SSW (195–240°). It was identified by the direction of glacial erosion marks (striations, chattermarks, grooves) and by landforms (drumlins, sheltered moraine trails). The third flow, fairly well recorded by striations (170–190°), is more recent than the first, although its chronology with respect to the second flow is difficult to establish. These movements, which were also identified west and north of the study area (Prichonnet and Beaudry, 1990, Paradis and Boisvert, 1995), reflect how the centre of glacial dispersion was displaced from the NW (Hudson Bay) to the NE (Nouveau-Québec) (Prichonnet *et al.*, 1984).

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G32

Status of new geoscience compilations in Québec

GHYSLAIN ROY, PIERRE LACOSTE, SIMON AUCLAIR, MONA BAKER, CHARLES ST-HILAIRE, N'GOLO TOGOLA, NATHALIE BOUCHARD, RICARDO ESCOBAR AND JEAN MARIE NZENGUE (MERN)

Processing and dissemination of geoscience knowledge are important components of Géologie Québec's mandate. Again this year, Géologie Québec presents new compilations that were integrated into the SIGÉOM database. For each specific geoscientific data set, areas where new data were integrated into SIGÉOM or where existing data were updated are shown. The status of compilations provides information on new data acquired for the following geoscientific data sets:

- ▶ Bedrock geology;
- ▶ Quaternary geology;
- ▶ Deposits and showings – metallic substances;
- ▶ Deposits and showings – non-metallic substances;
- ▶ Deposits and showings – architectural, industrial and crushed stone;
- ▶ Drilling.

G33

Presentation of geophysical data published in 2014

RACHID INTISSAR AND SIHAM BENAHMED (MERN)

Géologie Québec continued its large-scale airborne geophysical surveys in various geological provinces during the 2013/2014 fiscal year, namely in the Grenville and Churchill provinces. A total of 277,310 line kilometres were flown during the past year, covering a surface area of about 69,860 km². The ultimate goal of these high-resolution surveys is to provide a tool to support geological mapping efforts by Géologie Québec and for private companies, and to encourage mineral exploration. These datasets also stimulate private investments in exploration by generating targets of interest.

The results of recently completed surveys are published by Géologie Québec in the following reports:

- ▶ **DP 2014-04:** Airborne magnetic survey covering, in whole or in part, 21 NTS sheets at 1/50,000 scale in the Gouin Reservoir area, Grenville Province. The survey was completed by Geo Data Solution;
- ▶ **DP 2014-03:** Airborne magnetic and spectrometry survey covering, in whole or in part, 44 map sheets at 1/50,000 scale in the northern Ungava Orogen, Churchill Province. The survey was completed by Fugro Airborne Surveys;
- ▶ **DP 2014-02:** Airborne magnetic and spectrometry survey covering, in whole or in part, 16 map sheets at 1/50,000 scale in the north part of the George River area, Churchill Province. The survey was completed by Eon Geosciences;
- ▶ **DP 2014-01:** Airborne magnetic and spectrometry survey covering, in whole or in part, 25 map sheets at 1/50,000 scale in the south part of the George River area, Churchill Province. The survey was completed by Fugro Airborne Surveys.

The latter two surveys complete the coverage of the Southeastern Churchill Province undertaken in recent years in the form of high-resolution magnetic and spectrometry surveys.

Geology and mineral potential of the Lac Holmes area (NTS 32C15): Preliminary results

HANAFI HAMMOUCHE (MERN) AND ABDEL-ALI KHARIS (URSTM)

A geological survey at 1:20,000 scale was carried out during the summer of 2014 in the Lac Holmes area, south of the town of Lebel-sur-Quévillon. The work covered the northern half of map sheet 32C15. The area is composed almost exclusively of Archean rocks. These are cut by mafic dykes of Proterozoic age.

A large part of the study area is underlain by syn-kinematic plutons affiliated with the Attic Complex (2677 Ma), surrounded by metavolcanics. The latter, more widespread in the northeastern part, belong to the Quévillon Group (2716 to 2718 Ma). Preliminary analyses reveal that these volcanics are tholeiitic metabasalts, calc-alkaline meta-andesites and transitional to tholeiitic basaltic meta-andesites. The metagabbro sills and ultramafic rocks are intercalated in the volcanic sequence. Equivalents of these rocks are found to the south where the level of metamorphism is higher. The rocks are strongly recrystallized and often contain a large amount of garnet. The pillows of the basalt flows are highly stretched and boudinaged, and contain garnet and epidote.

There are few outcrops in the western part of the study area, where calc-alkaline meta-andesites and sedimentary rocks are predominant.

The Holmes Pluton, the largest intrusion, is roughly 22 km long by 12 km wide. In its centre, the pluton is composed of finely foliated to gneissic tonalite and slivers of gneiss, in addition to a multitude of small granodioritic intrusions. Along the margins, it is composed of medium- or coarse-grained tonalite. Farther east, the Cuvillier Pluton displays the same facies and appears to be related to the Holmes Pluton.

The structural grain, roughly E-W, is controlled by syn-deformational intrusions. Regional foliation (S2) is generally E-W to ENE-WSW and dipping to the north, which gives the Holmes Pluton the appearance of a dome overturned to the south. The contact with the volcanic sequence to the north corresponds to a ductile NW-SE ductile shear zone, with strong mineral lineations and stretching lineations that plunge steeply to the north. To the south, the eastern contact is also an E-W shear, but with well-developed subhorizontal lineations. D2 deformation affected the entire area, producing syn-deformational intrafolial folds.

Metamorphism varies from north to south, from greenschist facies to amphibolite.

Several rusty horizons and some iron formations were observed within the metavolcanics. Sulphide zones (Py-Po-Cp) were sometimes present.

The area has good potential for the following types of mineralization:

- ▶ orogenic gold mineralization;
- ▶ VMS-type mineralization; and
- ▶ Cu-Ni-PGE mineralization in ultramafic rocks.

Structural and metamorphic study of the Attic Complex (Phase 1): The Lac Holmes area, Lebel-sur-Quévillon, Québec

NICOLAS REVELLI, YANNICK DAOUDENE (UQAM), HANAFI HAMMOUCHE (MERN) AND ALAIN TREMBLAY (UQAM)

The Superior Province comprises several subprovinces that amalgamated at around 2.72 Ga and 2.68 Ga, composed of TTG-type felsic intrusive rocks and greenstone belts. Although the geology of these subprovinces is fairly well understood, the nature of their contacts is still a matter of debate. For example, on the basis of seismic data, the contact between the Abitibi and Opatica subprovinces is interpreted as the trace of a subduction zone. Ongoing work, however, reveals that this contact is not marked by particularly intense deformation or by significant metamorphism, suggesting these two subprovinces represent a single portion of Archean crust exposing different crustal domains. Moreover, in a number of areas of the Abitibi Subprovince, TTG-type intrusive rocks are found in the core of huge antiforms bordered by greenstone rocks. This is the case of the Attic Complex, bounded by the Grenville Front to the east and by a meridian passing through Lebel-sur-Quévillon and Senneterre to the west. The Attic Complex, which presents comparable geological characteristics to the Opatica Subprovince, may constitute a structural window that exposes a crustal suite representing the “bedrock” of Abitibian sequences. The goal of this doctoral project, which started in early summer 2014, is to examine this hypothesis.

To begin the project, we studied the northwest edge of the Attic Complex during the MERN's geological mapping of Lac Holmes. In this area, the Holmes tonalitic pluton cuts the mafic volcanic and plutonic series of the Quévillon Group. Regional S2 foliation, dominantly east-west and dipping to the north, developed in the Holmes Pluton and its country rocks. Folds with S2 as axial planar schistosity also affected these lithologies. The northern margin of the pluton is marked by a subvertical NW-SE shear zone with as of yet unknown kinematics. The conditions of metamorphism on either side of this shear zone, which vary from greenschist in the north to amphibolite in the south, suggest relative downdropping of the northern block. Our observations and preliminary interpretations indicate that the Holmes Pluton is a syn-kinematic (D2) intrusion preferentially emplaced in the shear zone along the northern limit. The acquisition of geochronological dates (U-Pb dating underway) and the detailed analysis of regional metamorphic conditions should allow us to constrain the tectonic and metamorphic evolution of the Lac Holmes region. In the next few years, geological mapping of other parts of the Attic Complex will improve our understanding of crustal architecture, not only in the Lebel-sur-Quévillon region, but for the Abitibian Archean crust in general.

Structural and metallogenic characterization of the Malartic Lakeshore gold showing, Abitibi, Québec

FRANCIS GUAY (UQAC), PIERRE PILOTE (MERN) AND RÉAL DAIGNEAULT (CERM-UQAC)

This Master's project, carried out at UQAC in collaboration with the MERN, is a study on the Malartic Lakeshore Property, held 100% by the Golden Share Mining Corporation. The property is situated in the Southern Volcanic Zone of the Archean Abitibi Subprovince (NTS map sheet 32D01), approximately 0.5 km south of Lac Malartic. The study area covers two large strippings: the West outcrop measures 150 m x 40 m, and the East outcrop is 90 m x 65 m. Metamorphism attained greenschist facies.

Stratigraphically, the rocks on the property are part of the lower Malartic Group. They mainly comprise mafic volcanic rocks and felsic volcanoclastics. Deformation is moderate to intense. The West outcrop displays a major bend in the dominant schistosity, passing from N160° to N105° over a distance of about 70 metres. At the East outcrop, the deformed contact between mafic volcanics (basalt) and felsic volcanoclastics (rhyolite tuff) is interpreted as the Rivière Héva Fault, a major regional fault with dextral strike-slip movement.

The West outcrop contains an exceptionally dense network of centimetre- to decimetre-scale dykes of felsic to mafic composition. The dykes can be grouped into five distinct families. They display cross-cutting relationships that can be used to establish their timing relative to gold mineralization, magmatism and deformation. U-Pb dating is underway to determine the age of some of the dykes and their host lithologies.

Multiple decimetre-scale extensional veins composed of quartz, carbonates, chlorite and feldspar cut across the West outcrop. These veins, highly deformed and subparallel to schistosity are mineralized with pyrite, chalcopyrite and galena. They yielded gold grades of up to 178 g/t over 0.6 m in a channel sample (data from Golden Share). Gold grains are locally visible. The quartz veins are cut by all dyke families, with the exception of the synvolcanic gabbro dykes.

Our fieldwork in the summer of 2014 focused on taking structural measurements, sampling the different lithologies, and mapping specific areas in detail. This ongoing study will concentrate on the lithogeochemistry and alteration of the units, the characterization of structural fabrics and deformation, and the petrographic description of thin sections. The goal is to determine the relative timing of the events and the environment of gold deposition.

Structural evolution of the Cadillac Fault, relationship with orogenic gold occurrences, and characterization of the Piché Group, Abitibi Subprovince, Québec

PIERRE BEDEAUX (UQAC), PIERRE PILOTE (MERN), SILVAIN RAFINI (CONSOREM) AND RÉAL DAIGNEAULT (CERM-UQAC)

The Cadillac Fault (CF) is a major fault in the Abitibi Subprovince for which several deformation events have been documented: shortening, extension and strike-slip. To date, there has not been consensus in terms of chronological relationships or integration into a single tectonic model. Important occurrences of gold mineralization are spatially associated with the CF, but their temporal relationships to deformation are still not well understood. Moreover, there has been insufficient research on the Piché Group, which constitutes the physical manifestation of the CF. This project, which is supported by the MERN, aims to (1) synthesize the structural styles observed along the fault and integrate them into a model of structural evolution; (2) attempt to integrate gold mineralization into this model; and (3) characterize the Piché litho-tectonic unit.

In Québec, the CF can be divided into segments according to orientation: the western and eastern segments are oriented east-west, whereas the central segment is oriented southeast. A regionally developed east-west schistosity dips steeply to the north. It is related to isoclinal F1 folds and reverse shear zones, indicating a shortening regime. The associated stretching lineation has an overall vertical component. In the central segment, the regional schistosity tends to run parallel to southeast faults. In the western segment, a late subhorizontal cleavage indicates that shortening was followed by an extensional regime. Near the CF and second-order faults, evidence for a late strike-slip movement includes minor Z-folds, sigmoidal features, CS relationships, and variations in the plunge of the stretching lineations. A northeast-trending secondary cleavage is associated with this phase and constitutes the axial plane of the flexure in the CF, between the western and central segments.

The thickness of the Piché Group is variable at the regional scale. Ultramafic lithologies are dominant, although basaltic rocks and even andesitic rocks are locally present. Ductile deformation is generally very well developed, particularly near contacts, although in places it may be absent or only weakly developed, specifically in the core of the unit.

In the eastern segment, crosscutting relationships between quartz-tourmaline veins and some of the structural features indicate that mineralization associated with this type of vein was emplaced before and during the shortening episode, and also during dextral strike-slip faulting.

Evolution of the Pontiac Subprovince in the Val-d'Or-Malartic area: Metamorphism, deformation and gold mineralization

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PIERRE PILOTE (MERN) AND STÉPHANE PERROUTY
(UNIVERSITY OF WESTERN ONTARIO)

In collaboration with the MERN, fieldwork was carried out in the summer of 2014 in the Pontiac Subprovince between Val-d'Or and Malartic, with the aim of characterizing the relationship between metamorphic minerals, episodes of deformation and regional features of gold mineralization encountered in the Malartic area. The main goals of this Master's project are to contribute to our understanding of the geodynamic environments in which this geological subprovince evolved, and to clarify the temporal relationship between peak metamorphism and the widespread gold mineralization found along its northern boundary represented by the Cadillac Fault. The project involves a detailed survey of the region that will provide a framework for thermobarometric, structural and geochronologic studies.

The metamorphic gradient, which appears continuous, is characterized by an increase in the quantity of different porphyroblasts from north to south. Along this gradient, the metamorphic rocks of the Pontiac Subprovince are first characterized by the presence of biotite and muscovite, then by the gradual appearance of garnet porphyroblasts, followed by staurolite. Staurolite grains are gradually replaced by mica moving southward. The development of garnet and staurolite appear strongly related to protolith composition. Preliminary observations suggest the majority of metamorphic minerals are associated with, and developed along, the principal foliation. Biotite and muscovite are aligned along this foliation and sometimes record an anti-clockwise rotation, suggesting sinistral movement. Micas replacing staurolite are also aligned with the principal foliation. No large-scale structures, such as faults or folds, were observed in the field, although an anomaly oriented in the same direction as the stretching lineation suggests the presence of major regional structures and complexes. Upcoming work will include a detailed thermobarometric survey, as well as U-Pb dating on zircon and monazite, and Lu-Hf Sm-Nd dating on garnet, with the goal of constraining the temporal relationship between the burial of metasedimentary rocks and the gold mineralization of the region.

Geological setting at the Marbridge mine

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PHILIPPE PAGÉ (CRCMM) AND RÉAL DAIGNEAULT
(CERM-UQAC)

The Marbridge mine is located in the southeastern Abitibi Subprovince, about 60 km northwest of Val-d'Or (NTS sheet 32D08-0102). From 1962 to 1968, this mine was operated by two companies, Falconbridge Nickel Mines and Marchant Mining Company, who extracted more than 700,000 tonnes of ore grading 2.28% Ni and 0.17% Cu from four mineralized lenses associated with komatiites. The Marbridge mine area is stratigraphically located at the base of the Malartic Group, in the La Motte-Vassan Formation (2714 Ma). It is wedged between the Preissac Pluton (2681-2660 Ma) to the south, the La Corne Pluton (2680-2642 Ma) to the east, and the La Motte Pluton (2647 Ma) to the north. Rocks in the area are metamorphosed to the amphibolite facies.

Rocks in the Marbridge mine area are part of an intense deformation zone characterized by L-type tectonites, as they exhibit very strongly developed stretching lineations. The main S1 schistosity, commonly trending NW-SE, is overprinted by an S2 crenulation cleavage broadly trending E-W.

A lithogeochemistry study of the various units in the area led to the recognition of two distinct suites: (1) a calc-alkaline suite composed of andesitic, dacitic, and rhyolitic units with various associated volcano-sedimentary rocks; and (2) a tholeiitic suite mainly comprising komatiitic flows, ultramafic intrusions, and basalts. The existence of these two, nearly coeval, magmatic suites suggests the coexistence or rapid transition of subduction-type (active margin or island arc) and extensional (back-arc basin or passive margin) tectonic settings. In addition, the presence of felsic volcanic units intensely altered to sericite and chlorite, as well as the strong epidote alteration in surrounding andesites and basalts, suggest the existence of an early VMS-type hydrothermal system in this area.

Upcoming work will focus on lithogeochemistry data processing, recognition and extent of the various known alteration patterns, petrographic description of volcanic units, and the importance and geometric impact of the main structural elements. Finally, the results of all these efforts will be integrated in order to reconstruct the probable sequence of geological events in the Marbridge mine area. This reconstruction will enable us to target areas of interest for the study of various types of mineralization in other terrains with comparable metamorphic settings.

G40

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

SACHA LAFRANCE AND MICHEL JÉBRAK (UQAM)

Gold mineralization in the greenstone rocks of the Abitibi Subprovince displays a wide range of styles and geologic environments. In the Duparquet mining district (Québec, Canada), several deposit models coexist along the Porcupine-Destor Fault: volcano-genic, porphyritic felsic intrusive (Beattie Mine) and auriferous shear zone. This district appears to be a key area where relationships among different models can be resolved. Using field observations, this study will establish the relationship between an “orogenic-type” gold deposit and the porphyritic felsic intrusions observed nearby and elsewhere in the region.

The study area is situated north of the Destor-Porcupine Fault in a transpressional zone produced by a local bend in the fault. Deformation is marked by subsidiary faults averaging 10 metres wide. These deformation zones are generally oriented 070N to 090N with a dip of 75° to 90°, and stretching lineations plunging 60° to the east. They display reverse-dextral movement.

The geology of the area is dominated by mafic volcanics, with lesser rhyolites and komatiites. This assemblage belongs to the Kinojevis Group (2718 Ma). Also present are massifs and enclaves of syn-orogenic (2689 Ma) quartzo-feldspathic porphyries, syenitic intrusions and late-orogenic Timiskaming-type volcano-sedimentary rocks (2700-2687 Ma).

Mineralization is found in sheared mafic volcanics and along the margins of deformed quartzo-feldspathic porphyries. Hydrothermal mineralization along subsidiary faults is characterized by a swarm of deformed quartz-ankerite veins accompanied by disseminated sericite and pyrite. Mass balance calculations and a microscopic study demonstrated gains in CO₂, K, S and SiO₂, as well as Mo, W, As and Sb (trace elements). Gold mineralization post-dates the quartzo-feldspathic intrusions, concentrating mainly in tholeiitic basalts due to their greater physico-chemical permeability and reactivity. The concentration of mineralization along basalt-porphyry contacts is explained by the competency contrast.

Is this “orogenic-type” mineralization genetically associated with the felsic porphyries observed in the field? Does it compare to other similar metallogenic coexistences in other mining districts, such as Malartic (Québec, Canada)? The timing of events suggests that the “orogenic-type” mineralization is not genetically related to syn-orogenic porphyries. If this is the case, then Duparquet is a polyphase district.

G41

Structural and metallogenic study of gold mineralization in the Belleterre area, Abitibi-Témiscamingue region, Québec

MAHAMED KOÏTA, MARC RICHER-LAFLÈCHE AND LYAL B. HARRIS (INRS-ETE)

The Belleterre area, located roughly 150 km south of Rouyn-Noranda, is part of the Pontiac Subprovince. Mineralization is hosted in volcano-sedimentary rocks of the Belleterre Group, in the southeastern part of the Belleterre-Angliers Belt. Numerous calcalkaline lamprophyre dykes and felsic intrusives (granodiorite and QFP) cut the volcanic rocks, and are also present at the majority of gold showings in the area.

Lode gold mineralization has been known in the Belleterre area since the early 1930s. Some of the veins were exploited at the former Belleterre mine, which produced more than 960,000 ounces of gold from ore with an average grade of 13.7 g/t. Our structural and metallogenic study of gold deposits and showings in the Belleterre area has demonstrated that its Archean supracrustal rocks still harbour promising gold potential.

The volcano-sedimentary assemblages, metamorphosed to greenschist facies, contain three principal types of gold veins: shear, fault-fill and extensional. All three types are controlled by structures with overall E-W or NE-SW strike directions and steep dips to the S or SE. The veins occupy one or more parallel fracture planes or shear planes that were also observed away from known mineralized areas.

The veins display a multiphase paragenesis typically enriched in sulphides (Py, Po, Sp, Ga, Cp...), with quartz, ankerite, calcite, electrum and gold. Gold is closely associated with the sulphides. Pyrite is the dominant sulphide mineral in some veins and pyrrhotite in others, despite the greenschist facies metamorphism that characterizes the region.

Assembly of the Superior Craton – Constraints from geophysical data

LYAL B. HARRIS (INRS-ETE) AND JEAN H. BÉDARD (GSC-Q)

Previous studies of the southern Superior craton of Canada have documented systematic Neoarchean N to S accretion of terranes, many considered exotic, with assembly resulting from subduction-related tectonic processes. We show that this uniformitarian interpretation is inconsistent with regional geophysical data. Gravity, seismic tomographic, and geochronological data suggest prior, E-W Mesoproterozoic accretion of the western and eastern Superior craton. An alternative model for Neoarchean fragmentation and reassembly of this early, composite “Superior I” craton through combined effects of upwelling mantle plume(s) and tractions at the base of deep cratonic keels through mantle flow is developed.

Edges of the horizontal gradient of Bouguer gravity at different crustal depths (gravity worms) and seismic tomographic data portray structures in the deep crust and sub-continental lithospheric mantle (SCLM) that are oblique to ~E-W Neoarchean terrane boundaries that were previously established from surface geology and aeromagnetic images. In the SW Superior, seismic tomographic data highlight a major ~N-S structure in the SCLM that separates the Superior craton into western and eastern domains. There is also a change in Hf zircon model ages from 3.5 Ga to 3.1 Ga (Lu *et al.*, 12th SGA Biennial Meeting, 2013) across this structure in the Wabigoon Subprovince. This, and parallel transverse structures, are highlighted by Bouguer gravity worms in accreted terranes. It would be highly fortuitous that these parallel transverse structures should be present in multiple accreted exotic terranes. The data are better explained if continental fragments in the SW Superior Province and intervening juvenile tracts like the Abitibi were derived by partial disaggregation of a heterogeneous older (Superior I) craton, rather than being unrelated exotic oceanic basins and Andean margins. Seismic tomographic data over the SE Superior imaged in 3D also show rifting of this older craton. Terrane accretion to the leading edge of the southward-drifting Hudson Bay terrane in the SW Superior, closure of the Abitibi oceanic rift, and regional deformation are interpreted to result from mantle traction on the deep lithospheric keel of the Hudson Bay terrane and not plate tectonic processes.

Venus is presented as an analog for the processes envisaged for the Archaean Earth, because it is a planet where there is no evidence for plate tectonics that nonetheless shows evidence of continental drift, orogenesis and Himalayan-style indentation and escape tectonics.

Study of multi-parameter data from exploration drill core at the Bracemac-McLeod ore deposit, Matagami – Multivariate statistics and exploration vectors

ALEXANDRE BOURKE, NATHALIE SCHNITZLER, PIERRE-SIMON ROSS, ERWAN GLOAGUEN (INRS-ETE), BASTIEN FRESIA, ROBERT BOUCHER, ROBERT NAMOUR AND PASCAL LESSARD (GLENCORE)

Drilling represents a major share of expenditures in advanced exploration programs, yet very little information is derived from this work apart from the visual description of drill core made by a geologist. The LAMROC laboratory for the physical, chemical, and mineralogical characterization of rocks was designed by the INRS in an effort to extract more value from drill core. The LAMROC can be used to analyze, in a non-destructive manner, several parameters almost simultaneously and at high spatial resolution.

Since 2010, the LAMROC has analyzed the density, magnetic susceptibility, alteration mineralogy, and geochemistry of more than 15,000 metres of drill core from the Matagami and Chibougamau areas. This represents more than 50,000 measurement points (more than 25,000 for geochemistry). Given the large amount of data and the variety of analyzed parameters, various approaches can be used to study and interpret the data. Within the scope of this project carried out with logistical support from Glencore, analyses conducted at the Bracemac-McLeod deposit in the Matagami VMS mining district will be used to conduct multivariate statistical analyses and to develop exploration vectors.

Multivariate statistics: Analysis techniques based on multivariate statistics are namely useful to group data or measurement points based on responses for each parameter. This analysis depends on the pre-processing performed on raw data and the prior conditions set by the user. This approach is used to help with lithological discrimination and characterization of alteration patterns.

Exploration vectors: Characterization of the alteration halo around an ore deposit may lead to the development of exploration vectors, by determining how the concentration of certain elements (geochemical vectors) or the composition of certain mineral groups (mineralogical vectors) varies as a function of distance from the ore deposit.

► **Mineralogical vectors:** Two mineral groups are targeted - white micas and chlorites. Infrared spectrometry is used to measure if white micas become enriched or depleted in aluminium, and if chlorites become enriched in magnesium or in iron closer to the ore deposit.

► **Geochemical vectors:** The concentration of certain elements such as iron, silica, potassium, magnesium, and aluminium can be measured by X-ray fluorescence (XRF). Spatial variations of these element concentrations may be used to develop geochemical vectors.

Volcanology and alteration, Waconichi Formation, Lemoine Member, Chibougamau (Abitibi Subprovince): Implications for exploration

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The Waconichi Formation (Roy Group) is the main host unit known in the Chibougamau area for polymetallic volcanogenic massive sulphide (VMS) deposits. It namely hosts the Scott Lake deposit and the former Lemoine mine, the second highest-grade VMS deposit mined in Canada, behind Eskay Creek in British Columbia.

Within the study area, the Waconichi Formation (Lemoine Member) is bordered to the north by the Lac Doré synvolcanic Complex and to the south by basalts of the upper Waconichi Formation. The main objective of this Master's project undertaken at INRS-ETE is to reconstruct the volcanic architecture of the Lemoine Member to the northeast of the former Lemoine mine. To do so, more than 150 outcrops were studied, about 15,000 m of drill core were described, and nearly 260 new samples were analyzed (for a total of 900) and studied in thin section.

The various units in the area, *i.e.*, the Alpha Rhyolite, the porphyritic Lac Coco Rhyolite, the Lemoine Dacite, the Lemoine Andesite, the porphyritic Marelle Dacite, the Lemoine Rhyolite, and the Hangingwall QFP (HwQFP), were thus characterized in detail. The Lemoine ore lens was stratigraphically located along the contact between the Lemoine Rhyolite (footwall), the Lemoine Andesite and the HwQFP. Detailed mapping has provided a deeper understanding of the sequence of emplacement of these units within the study area. The base of the volcanic sequence is represented by the Alpha Rhyolite, followed by the Lemoine Rhyolite, the Lemoine Dacite, the Lemoine Andesite and the HwQFP. In addition, our work clearly illustrates the intrusive nature of certain subvolcanic units, namely the Lac Coco Rhyolite and the Marelle Dacite, two porphyritic units with bluish quartz and idiomorphic feldspar phenocrysts. The Alpha Rhyolite corresponds to a subvolcanic unit intruded into the Lemoine Rhyolite, whereas further east, it forms an extrusive unit at the base of the volcanic sequence. This suggests the Alpha Rhyolite was emplaced during two distinct episodes separated by the effusion of the Lemoine Rhyolite.

The presence of effusive and intrusive units and the spatial distribution of extrusive units signal the proximity of a felsic volcanic centre that represents a key component for VMS formation.

Geology and types of mineralization and alteration at the Mustang gold showing, Lower Eastmain greenstone belt, Superior Province, Québec

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The Mustang gold showing is located on the Wabamisk property held by Virginia Mines, 60 km south of the Eleonore mine (Goldcorp). Located in the Lower Eastmain greenstone belt in the Superior Province, the structure was exposed on surface and traced in drill hole over a strike length of 570 metres and to a depth of 250 metres. The vein and its mineralized envelope range from a few centimetres to six metres in width. Gold values obtained for the vein reach 23.28 g/t Au over 4.6 m in channel sample and 22.65 g/t Au over 2.25 m in drill hole. Drilling completed in the Mustang area in the winter of 2014 also confirmed the presence of additional gold-bearing structures to the north, apparently subparallel to the Mustang vein.

The Mustang vein (N240°/80°) is a quartz vein enclosed in turbiditic metasedimentary rocks of the Auclair Formation located at the top of the stratigraphic sequence and metamorphosed to the greenschist facies. The sedimentary sequence has undergone at least three phases of deformation, including a first phase of NNW folding (F_1) that was refolded to form ENE-trending F_2 folds. The main S_2 foliation trends ENE and its axial plane is similar to that of F_2 folds. Phase of deformation D_3 is characterized by a SW crenulation cleavage. The Mustang vein is laminated, subparallel to the stratigraphy and folded into an S pattern. It was emplaced early relative to regional deformation D_2 , along the limb of an F_2 fold that underwent sinistral shearing. The vein and its altered wall rocks contain several visible gold grains, agglomerated and remobilized along the plane of the main S_2 schistosity, along with 1-10% arsenopyrite and pyrrhotite and traces of pyrite and chalcopyrite.

The Mustang showing is comparable, in terms of types of mineralization, alteration, and deformation, to syn-deformational deposits hosted in turbiditic sequences (*e.g.*, Meguma in Nova Scotia and Bendigo-Ballararat in Australia). Similarly to the Eleonore mine, the Mustang showing is yet another example that metasedimentary assemblages in the Baie-James region have strong potential to host significant gold mineralization.

Geology and structural characteristics of the Roberto gold deposit, Eleonore property, Superior Province, Baie-James, Québec, Canada

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The Roberto deposit, a major discovery in the Baie-James region, hosts 4 million ounces of gold in proven and probable reserves (at a grade of 6.5 g/t) and 4.1 million ounces of gold in inferred resources (at a grade of 9.6 g/t). Located a few kilometres south of the boundary between the La Grande and Opinaca subprovinces, gold mineralization is largely hosted in Timiskaming-age clastic sediments, within a N-S-trending corridor some 70 to 80 metres wide. The latter encompasses five to six high-grade (>3 g/t) mineralized zones. Typically associated with a potassic alteration zone and a Au-As-B signature, the main type of mineralization (Roberto-type) consists of a stockwork with replacement zones composed of an assemblage of quartz-dravite-microcline-phlogopite-arsenopyrite-loellingite-pyrrhotite, as well as quartz-diopside-arsenopyrite veins. The bulk of the gold mineralization predates the metamorphic peak and also predates or is early relative to the main D2 deformation. It is mainly confined within a steeply dipping N-S-trending envelope, coplanar with an F2 fold and concentrated in the fold hinge.

Observed structural relations confirm that: 1) phase of folding F2 overprints the mineralization; 2) specific stratigraphic horizons constrain the development of Roberto-type mineralization; and 3) certain pegmatites are late orogenic as they are undeformed and include metamorphosed and foliated Roberto-type fragments. At depth, Roberto-type mineralization and its host rocks undergo significant textural changes resulting from prograde metamorphism. Underground mapping led to a better definition of intense, occasionally mylonitic, E-W-trending deformation zones that crosscut the stratigraphic sequence. The hangingwall zones are geometrically controlled by these structures and are characterized by an echelon quartz-tourmaline veins, disseminated arsenopyrite-pyrrhotite-pyrite mineralization, dislocated quartz veins with visible gold, and diffuse silica and epidote alteration. These zones are inferred to be late relative to D2 to coeval with D3, as they modify the pre-existing S2 schistosity and occasionally include pegmatite fragments (2616-2603 Ma). These shear zones are probably present within the Kasak volcanic Formation (2704 ±1.1 Ma), the polygenic conglomerates (2702 ± 3 Ma) and the Ell Lake intrusive (2705 ±1.9 Ma). These observations suggest that phase of deformation D2 is related to the prograde burial phase of the turbiditic sequence, whereas phase of deformation D3 is related to the retrograde late orogenic exhumation of the sequence.

At a regional scale, N-S-trending corridors that crosscut Timiskaming-age clastic sediments at the top of the Low Formation, strong E-W-trending deformation zones, and the presence of two distinct phases of folding and of proximal calcic or potassic alteration with As and B are important exploration metallotects in the Baie-James region, particularly if they occur near the boundary between the La Grande and Opinaca subprovinces.

Petrographic and geochemical characterization of the Baie Chapus Pyroxenite, Baie-James region: An example of Fe-Ti-V mineralization in the Superior Province

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JEAN GOUTIER (MERN) AND VICKI MCNICOLL (GSC-O)

The Baie Chapus Pyroxenite was discovered in 1996 during regional mapping work carried out by the MERN in the Robert-Bourassa Reservoir area, James Bay region. It is part of a series of ultramafic intrusions in the La Grande Subprovince of the Superior Province.

The Baie Chapus Pyroxenite is an ultramafic-mafic intrusion approximately 1 km x 3 km that was emplaced in tonalites near the volcano-sedimentary Yasinski Belt. It is composed mainly of pyroxenite, plagioclase pyroxenite and olivine pyroxenite, in addition to gabbro, peridotite and dunite. The primary mineralogy is composed essentially of pyroxenes (particularly clinopyroxene), which represent the principal cumulate phases, with variable amounts of thoroughly serpentinized olivine, typically interstitial plagioclase, and magnetite as an accessory phase. However, some significant accumulations of magnetite were found near the summit of the intrusion. These form a magnetite zone at least 70 metres long and estimated to be several metres wide. This layer of titaniferous and vanadiferous magnetite, grading up to 66.0% $\text{Fe}_2\text{O}_{3(\text{total})}$, 9.19% TiO_2 and 0.74% V_2O_5 , is composed of magnetite enriched in Ti (340–49860 ppm) and V (1310–7300 ppm), and poor in Cr (<260 ppm), Al (<140 ppm) and Ni (<450 ppm).

The parent magmas for this intrusion were contaminated by continental crust during their ascent, as suggested by the presence of felsic enclaves and trace element signatures. In the assemblage, ultramafic and mafic rocks are enriched in highly incompatible elements (HILE) compared to moderately incompatible elements (MILE). However, they are less enriched in Nb and (locally) Ta with respect to other HILE, as well as in Hf-Zr-Ti compared to other MILE.

Although the Fe-Ti-V mineralization observed to date appears to be relatively modest, the compositions of the analyzed magnetites are similar to those of magnetites from the vanadiferous intrusions of McFaulds Lake (Ontario) and Pipestone (Manitoba), and of the Lac Dorée and Rivière Bell complexes in the Abitibi region (Québec). In light of these results, we suggest that this area of the James Bay region has potential for Fe-Ti-V mineralization, which should be taken into account when planning exploration programs related to mafic and ultramafic intrusions in the area.

Opinaca-La Grande contact: A metamorphic and tectonic study

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AND ADINA BOGATU (UL)

An understanding of the Archean phenomena that shaped the present-day assemblage of the Superior Province still remains incomplete. In the James Bay region, the contact between the Opinaca and La Grande subprovinces, host to many gold showings, is no exception in terms of its nature and evolution. The aim of this ongoing study is to characterize lithologies, deformation styles and the metamorphic evolution of both subprovinces, with the goal of assessing the applicability of existing geodynamic models. This project is being carried out as part of the MERN's mapping work in the region.

The La Grande Subprovince is an Archean volcano-plutonic assemblage. It formed primarily as ancient tonalitic basement (3.45 to 2.79 Ga) on which volcano-sedimentary sequences, injected by a variety of ultramafic to felsic intrusions, began developing at 2.88 Ga. The region is characterized by an E-W structural grain and a dome-and-basin pattern. Metamorphic conditions in the La Grande Subprovince range from greenschist in the west to amphibolite in the east. The Opinaca Subprovince represents a large Neoarchean sedimentary basin that developed along the edge of the La Grande Subprovince. It is mainly composed of greywackes and various syntectonic granitic intrusions. Ovoid domes and basins define the structural style of the Opinaca Subprovince. The radial metamorphic gradient reached granulite facies in the core of the basin, where anatexis conditions are widespread. The contact between the two subprovinces is marked by a corridor of intense deformation and frequent transcurrent faulting, injected by felsic to intermediate late-tectonic intrusions.

To date, the work consists of a regional sampling program jointly carried out with the MERN. Fieldwork took place in the summer of 2014. Samples were collected along two transects across the contact in the Lac Dalmas and Poste Lemoyne areas, south of La Grande Rivière. Additional samples from the Corvet-Est and Orfée showings, and from the archives of the MERN, will also be studied. The next stage of the project will include microscopic petrography, total geochemical analysis, mineral chemistry analysis by microprobe, modal and textural analysis by SEM-MLA, and geochronology on garnets (Lu-Hf and Sm-Nd), zircons and monazites (U-Pb). These data will be used to complete a thermobarometric survey and pseudosections. Ultimately, the goal is to quantify the metamorphic conditions of the two subprovinces, presented as P-T-t paths, and establish the environment in which they were assembled.

Geochemical characterization of metasedimentary units in the La Grande and Opinaca subprovinces, Baie-James region

QUENTIN DUPARC (UQAC) AND JEAN GOUTIER (MERN)

Geochronology and field observations (faults, unconformities, contacts between formations) are, for now, the only available tools for correlating sedimentary formations in the northeastern La Grande Subprovince. The goal of this study is to test new correlation tools for deformed and metamorphosed Archean sedimentary rocks. These tools are faster and less costly than U-Pb dating. The first step in this project will be to synthesize the geology of the La Grande Subprovince. Recent work (Duparc, 2014) has shown that the most reliable correlation tools are geochemical.

Rare earth patterns were used to characterize metasedimentary units. It was assumed that diagenesis and metamorphism did not affect the rare earth profile, which is important for a correlation study. Rare earth patterns for sandstones demonstrated that each formation has a characteristic signature, reflecting the different patterns of the original source materials. This method appears to be discriminant and less costly for quickly establishing correlations between Archean formations.

A statistical study of the geochemical data can also be used to discriminate geological units with similar megascopic characteristics. Principal component analysis and subsequent variance analysis are essential tools for a comparative study between formations. They can be used to determine, quantitatively and objectively, whether one group of representative samples from a formation is significantly different from another. Other statistical tools, such as comparative permutation analysis using distance matrices, automated hierarchical classification or even dissimilarity indices, may also be useful for comparing or dissociating sedimentary units.

These different statistical tests could also be used to compare different populations of felsic rocks (e.g., tonalites, granites), mafic rocks (e.g., komatiites) or predefined groups of intrusions, in order to identify a magmatic series or distinguish intrusions. A more precise re-analysis of rare earth elements using samples from the MERN's large database could provide the data for such a study.

Characterization of a hydrothermal alteration zone in the De Pas Batholith, Churchill Province, Québec

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Regional mapping carried out by the *Ministère de l'Énergie et des Ressources naturelles* in the summer of 2014 in the Lac Brisson area (NTS 24A), in the Southeastern Churchill Province, resulted in the definition of a new mineralized hydrothermal alteration zone. This zone extends over a few kilometres and is associated with rocks of the De Pas intrusive Suite, a Paleoproterozoic (1.84-1.81 Ga) assemblage of syntectonic granitoid rocks exposed on surface over more than 600 kilometres in the central part of the Core Zone. The objective of this project is to define the mineralogy of the various sampled facies, their spatial distribution, the possible relations that may exist between the different facies, and their respective economic potential.

The study area covers a specific section of about 800 metres in length by 350 metres in width and borders a major regional magnetic lineament. The alteration zone is broadly located along the contact between two magnetite-rich lithologies: a porphyritic quartz monzodiorite and a unit inferred to be gabbroic in composition. The most abundant phase is a fine-grained mesocratic metasomatic rock with a heterogeneous texture, which also appears to have undergone potassic alteration. In certain locations, this facies is coarse-grained, it locally takes on a pinkish colour and is composed of elongated clinopyroxene grains isolated in a plagioclase matrix. Altered corridors several tens of metres in thickness are characterized by strong potassic alteration. They occasionally exhibit a brecciated texture with complex millimetre-scale to centimetre-scale quartz masses showing atypical borders with evidence of dissolution and corrosion, almost always surrounded by a thin magnetite rim. These masses may be the result of a hydrothermal replacement phenomenon, also suggested by the presence of centimetre-scale cavities filled with epidote and calcite. The exact nature of the host units remains to be determined however.

Fine disseminated pyrite masses with occasional chalcopyrite were observed in most rock units but are more abundant in strongly altered corridors. The same altered phases were observed in three different locations to the south of the study area, suggesting the alteration zone and its economic potential extend over more than six kilometres. The typology of this mineralization remains to be determined: the sulphides may be associated with magnetite and potassic alteration zones related to an IOCG system or a porphyry Cu system.

Tectonomorphic evolution of the Torngat Orogen, Southeastern Churchill: Using garnet as a geothermobarometer and geochronometer

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The Southeastern Churchill Province is an Archean block reworked during the Proterozoic by two orogenies. To the east, the Torngat Orogen formed during the collision between the Core Zone and the Nain Province, from 1.87 to 1.82 Ga. To the west, the New Québec Orogen was the product of the collision between the Core Zone and the Superior Province, from 1.82 to 1.77 Ga. In the Torngat Orogen area, this successive accretion of Archean cratons was marked by three tectonometamorphic phases: a D1 convergent event that produced granulite facies conditions, representing the peak of metamorphism (1.87-1.86 Ga); a D2 transpression event that produced major shearing and amphibolite to granulite facies metamorphism (1.85-1.82 Ga); and a period of D3 cooling and uplift (1.82-1.78 Ga).

The ongoing tectonometamorphic study aims to refine the metamorphic evolution of the western part of the Torngat Orogen, and determine the influence of this collision on the Core Zone. This study will establish the burial (pressure) and thermal (temperature) conditions of metamorphic rocks now exposed at surface, and reconstruct how these conditions evolved during the orogenesis. Using mineral phase equilibria models (pseudosections), it should be possible to retrace the pressure-temperature-time-deformation paths (P-T-t-D) of different sections across the orogeny based on metamorphic textures, relationships to deformation phases, and age dating using several isotopic systems such as U-Pb on zircon and monazite, and Lu-Hf and Sm-Nd on garnet.

The findings to date indicate that the Québec portion of the Torngat Orogeny attained peak conditions of 9.0-12.0 kbar and 850-1000 °C, as preserved in garnet pyroxenites. Lu-Hf and Sm-Nd ages from garnets indicate prograde conditions around 1839 ±5 Ma, and cooling at approximately 800 °C around 1820 ±12 Ma. Retrograde conditions of neosome crystallization were determined using samples of migmatized metasedimentary rocks, indicating pressures and temperatures of 5.5-8.0 kbar and 650-800 °C. U-Pb dating of monazites and zircons from a garnet-sillimanite diatexite constrains the crystallization of anatectic melts at 1822-1815 Ma. Preliminary results suggest a distinct evolution between the Core Zone and the core of the Torngat Orogen. Nevertheless, they appear to have been exhumed together, exposing two blocks that had been subjected to anatectic conditions for nearly 20 Ma before cooling began around 1820 Ma at the onset of the New Québec Orogen.

G53

The George River and Moonbase mylonites, Core Zone, Nunavik: Porphyroclasts, lineations, and recrystallization in crustal shear zones

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The Churchill Province, located in northern Québec, is the least known geological province in Québec. Consisting of an Archean basement, this area was subjected to two orogenic events during the Paleoproterozoic, giving it a three-part structure. The Core Zone forms a central block some 200 km wide, which is welded to the Archean Superior craton to the west by the New Québec Orogen, and to the Archean Nain craton by the Torngat Orogen to the east.

Available reconnaissance studies suggest the Core Zone underwent migmatization during the Archean, followed by recrystallization phases during the Paleoproterozoic, with the metamorphic grade increasing from the amphibolite to the granulite facies. Subsequently, between 1.84 and 1.81 Ga, the DePas and Kuujuaq batholiths were emplaced, forming a magmatic arc from the north to the south of the province. The region was stabilized at about 1.75-1.65 Ga, before a phase of granitic and anorthositic plutonic intrusions took place from 1.45 to 1.2 Ga.

Numerous shear zones reflecting oblique collisions are present throughout the region, including the George River, Moonbase, Abloviak, Falcoz, and Mistastin River crustal-scale fault zones.

The objective of this undergraduate project is to characterize microstructures associated with two of these zones, the George River (GRSZ) and Moonbase (MBSZ) shear zones. Although they appear to be two branches of the same shear zone, these two zones exhibit fundamentally different characteristics, for example the absence of lineations in the MBSZ. Oriented samples were collected in the field on ten representative outcrops during the summer of 2014 by a MERN field crew. A petrographic study of these samples will serve to inventory microstructures in an effort to understand the distinctions between the two zones. Based on the results, we will attempt to interpret these differences in terms of temperature and depth of deformation, rates and finite amounts of deformation, orientation of stress fields, and nature of sheared material. Aeromagnetic maps, photographs of outcrops, and descriptions (*géofiches*) of each outcrop will also be put to contribution to complement our observations.

In conclusion, this project will lead to a better understanding of the inherent characteristics of the two deformation zones, will facilitate their recognition in the field, and will clarify the tectonic context of this region and its evolution.

G54

Petrological and geochemical characterization of the Nuvulialuk mafic-ultramafic Suite, Southeastern Churchill Province, Québec

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The Nuvulialuk mafic-ultramafic Suite is located near the boundary between the Core Zone and the Torngat Orogen, in the Southeastern Churchill Province (NTS sheets 24H10 and 24H15). This suite consists of several kilometre-scale intrusions oriented N-S that were emplaced along the Blumath deformation zone. It is composed of metamorphosed mafic and ultramafic rocks that intrude the Paleoproterozoic Lake Harbour Group, a clastic sedimentary sequence dominated by paragneisses, quartzites or an alternation of these two lithologies. Some paragneiss horizons at the base of the sequence contain disseminated sulphides (3-15%). The mafic-ultramafic intrusions are the result of increased magmatic activity within a continental intraplate setting associated with mantle plumes. This is an interesting setting from an economic standpoint for the formation of Ni-Cu and platinum group element (PGE) mineralization.

Mapping and systematic sampling of these intrusions was carried out during the summer of 2014, with ~150 observation points. Subsequently, fifty samples were selected for petrographic and litho-geochemistry analyses. Our observations indicate that the Nuvulialuk mafic-ultramafic Suite is dominated by two rock groups consisting of peridotitic facies and mafic facies (pyroxenites and gabbros). Ultramafic rocks exhibit various textures ranging from olivine cumulates (with crystals ≤ 5 cm) to olivine and pyroxene mesocumulates (with crystals $\leq 2-3$ cm and ≤ 30 cm, respectively), whereas mafic rocks are mostly massive. Deformation is variable, resulting in some very weakly deformed facies to locally mylonitic zones. Foliations exhibit two preferential orientations: i) NE-SW ($\sim N30^\circ E$) and ii) WNW-ESE ($\sim N310^\circ E$), with variable dips ranging from 50° to 90° . Folds trending $\sim N180^\circ E$ and $\sim N275^\circ E$ with shallow dips ($5-25^\circ$) were also observed.

Based on preliminary results for eight samples collected in 2013 by the *Ministère de l'Énergie et des Ressources naturelles*, four groups were established: i) wehrlite with Pd = 17 ppb and Pt = 11 ppb, ii) pyroxenite with Pd = 12 ppb and Pt = 8 ppb (average grades), iii) amphibolite with Pd = 6 ppb and Pt = 3 ppb, and iv) gabbro with Pd < 0.5 ppb and Pt = 2.5 ppb.

Upcoming work will aim to characterize the petrography, mineral chemistry, and geochemistry of these rocks to assess the economic potential of the intrusions and determine their emplacement setting.

PGEs at the Delta deposit in the Cape Smith Belt (Nord-du-Québec): When metamorphism influences economic potential

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AND PHILIPPE PAGÉ (UQAC)

Regional metamorphism triggers many processes that can influence a deposit by redistributing metals. In certain extreme cases, the mineralization may be entirely modified and the metals remobilized. The Cape Smith Belt in the Nord-du-Québec region has undergone upper greenschist-facies metamorphism (400-450°C). The objective of this project is to determine if regional metamorphism has modified the mineralogy and has resulted in a redistribution of metals in the Ni-Cu-PGE massive sulphide lenses of the Delta deposit (50 km west of the Raglan mine).

Petrographic observations of massive sulphides indicate that the mineralization is indeed magmatic (pyrrhotite, pentlandite, chalcopyrite) but is recrystallized (triple junctions, pentlandite eyes). Whole-rock geochemistry analyses confirm the magmatic origin of the massive sulphides. Laser ablation (LA-ICP-MS) analyses of sulphides coupled with whole-rock geochemistry are used to perform mass balance calculations to determine which phases control the metals in mineralized zones. Mass balance calculations show similarities and anomalies in the metal distribution relative to other magmatic deposits: (i) IPGE (Os, Ir, Ru), generally almost exclusively controlled by pyrrhotite and pentlandite are, at Delta, controlled at 20-80% by these sulphide phases; (ii) Rh, generally controlled at 40% by pyrrhotite and pentlandite is, at Delta, controlled at only 10% by the same phases; (iii) Pd, generally controlled at 40% by pentlandite is, at Delta, controlled up to 80% by pentlandite; (iv) chalcophile elements (Ag, Cd, Zn), generally weakly controlled (<5%) by chalcopyrite are, at Delta, controlled at more than 30% by chalcopyrite. Consequently, mass balance calculations clearly show a redistribution of certain metals in the deposit. This redistribution translates into the presence of IPGE in platinum group metals (PGM) such as sperrylite ($\text{PtAs}_2 \pm \text{Rh}$) which, at Delta, incorporates Ir, Os and to a lesser extent, Ru.

The Delta deposit is associated with sills in the feeder system of komatiitic basalts that formed ore deposits along the Raglan Trend. These sills are supposed to be depleted in metals compared to deposits associated with the flows. However, our results indicate that regional metamorphism may have redistributed PGE and favoured their exsolution in the form of PGM. PGE have greater economic interest in the form of PGM, such that the metamorphic character of a deposit, even at low grade (greenschist), should not be overlooked as it may substantially modify the economic status of a deposit.

Phase diagram modelling as an exploration tool for iron oxide-copper-gold deposits in high-grade metamorphic terrains: Application in the Grenville Province

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Growing interest for hydrothermal Iron Oxide-Copper-Gold (IOCG) deposits in high-grade metamorphic terrains calls for the development of new exploration tools. In unmetamorphosed terrains, IOCG deposits are characterized by advanced hydrothermal alteration that has a profound impact on the composition of rocks. Mineral assemblages produced by this alteration are subdivided into various systemic types. The chemical composition of these rocks is not so much a function of their protolith, and their degree of metamorphism should therefore also produce specific parageneses. We present the preliminary results of metamorphic phase equilibria modelling aimed at predicting assemblages that will form at the upper amphibolite to granulite facies for various types of hydrothermal alteration. Modelling results will then be compared with observed assemblages in rocks of the Gouin Reservoir area in the Grenville Province. The results of this Ph.D. project are expected to provide a solid basis for the development of effective exploration tools for IOCG deposits in the Grenville Province of Québec.

Apatite rare earth characterization in an Fe-Ti-P deposit at Lac à Paul, Lac-Saint-Jean anorthositic Suite

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The objective of this study is to characterize rare earth elements (REE) in apatites occurring in P-Ti-rich zones within the Lac-Saint-Jean anorthositic Suite (1.1-1.0 Ga) on the Lac à Paul property, in an effort to determine the composition of the parent magma or magmas and to study crystal fractionation processes in this type of ore deposit. This study is part of a research program on REE in Québec headed by the DIVEX research network and the MERN.

The Lac à Paul property held by Arianne Phosphate hosts a deposit currently being developed, which contains 590 Mt of measured and indicated resources grading 7.1% P_2O_5 (NI 43-101). Mineralization is hosted in a nelsonitic peridotite, a rock generally composed of iron oxides, apatite and olivine in proportions ranging from 20% to 35%. Two mineralized zones were defined: the northern zone corresponds to a massive fine-grained nelsonite grading 7-12% P_2O_5 , whereas the southern zone is a coarse-grained to megacrystalline nelsonitic gabbro-norite grading 4-6% P_2O_5 . The objectives of this study are to: 1) establish if apatite occurring in the deposit is truly the main REE-bearing phase; 2) determine if the REE content of apatites is homogeneous and if not, determine what factors influence their distribution; 3) investigate the petrogenetic relationship between the two zones; and 4) retrace the parent magma or magmas. To do so, samples will be collected along a stratigraphic section of the deposit, as well as along the same stratigraphic horizon. Samples will be analyzed by microprobe and laser ablation (LA-ICP-MS), and will also be used to conduct isotopic analyses (samarium-neodymium, and strontium-rubidium) in an effort to determine if the parent magmas of each zone are cogenetic.

This study should result in a better understanding of the genesis of this type of deposit.

Characterization of the Lac à Paul P-Ti deposit, northern Lac-Saint-Jean Anorthosite Suite (Québec): Stratigraphy and mineral chemistry

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Developed by Arianne Phosphate since 2008, the Lac à Paul P-Ti (apatite-ilmenite-magnetite) deposit is situated in the northeastern part of the Lac-Saint-Jean Anorthosite Suite. This subvertical stratiform mineralized body 100 to 350 m thick can be followed for nearly 4 km in an east-west direction. The aim of this research project is to characterize the petrography and mineral chemistry of a series of samples taken along a N-S section, perpendicular to deposit stratigraphy. Observations to date indicate that the rocks of the deposit have a wide range of textures (grain size, degree of recrystallization), modal proportions, mineral compositions and structures (intensity of foliation, faults).

Mapping has demonstrated the deposit is divided into two domains. The northern domain is represented by nelsonitic peridotite containing a cumulate of apatite (20-35%, 0.5-2 mm) and olivine (20-35%, 0.5-2 mm) floating in a matrix of 20-35% net-textured oxides (ilmenite/magnetite ~ 3/2). This nelsonitic peridotite is interlayered with anorthosite, troctolite and norite, all of which also contain apatite (8-15%). These layers, typically composed of mauve plagioclase with protoclastic and coronitic textures, have variable thicknesses (<2-50 cm) and are often boudinaged. Apatite is usually associated with the oxide minerals, but is also common as inclusions in olivine and plagioclase. It appears to be more abundant along the margins of thin plagioclase bands in the nelsonitic peridotite. The southeastern domain consists of norite, leuconorite and coarse-grained to pegmatitic troctolite with a nelsonite matrix (8-15% apatite). This domain is characterized by homogenous apatite grades but heterogeneous grain size.

Rocks to the north of the deposit comprise layered norites, gabbro-norites, troctolites and pyroxenites, with medium-grained granoblastic textures. These rocks are ilmenite-rich (15-30%) but apatite-poor (1-3%). Rocks to the south of the deposit (anorthosite, leuconorite, troctolite and leucotroctolite) are more closely related to those of the deposit, at least in terms of apatite content (4-10%) and plagioclase features (mauve colour, protoclastic texture).

The preliminary results of our mineral chemistry study reveal stratigraphic variations, but additional analyses are needed to better define these variations.

21st century methodologies for mineral discoveries in Québec

MYRIAM BOUKACHABIA (UNIVERSITÉ DE LORRAINE-UQAT-UQAM) AND MICHEL JÉBRAK (UQAM)

Québec is an important mining producer, both in Canada and on the international scene. For nearly 100 years, Québec's mining sector has been growing: more than one mineable deposit is discovered every year. This growth is due mainly to the success of exploration companies that play an essential role in ensuring continuity of new mining projects. Moreover, research is becoming more innovative, thereby allowing mining companies to focus on increasingly detailed and specific systems. Is this the case in Québec? Which processes explain the province's discovery rate? These are the questions we will attempt to answer during our study.

From March to June, a survey was conducted of fourteen junior companies in Québec on a selection of mining projects. The goal of the survey was to collect information on the methods and the means by which these companies discovered potential ore deposits in Québec. The results were compared to the work by Sillitoe (published in 1996) on Pacific rim deposits during the period 1970–1995. Our comparison revealed the differences between junior companies in Québec and majors. The results also emphasize how ore deposit discovery methods and field-based exploration strategies have changed over the course of the last twenty years.

Presently, the theoretical exploration model is linear and based on strategic and tactical approaches to mineral exploration. A slightly different model emerged from our study. The Québec exploration model is not linear; instead, it is "punctuated" over time. The exploration scene experiences frequent periods of inactivity of variable duration, which are caused by a number of external factors. The bulk of mineral potential at the global scale is discovered over relatively short periods of time that succeed one another in a cyclical manner, corresponding to mining booms. The latter are related to factors of variable complexity, such as the needs of the economy, the technical capabilities of the mining industry and rising metal prices, which will determine the frequency, amplitude and duration of these mining booms.

Block caving mining method

STÉPHANE TREMBLAY (UL)

There is growing interest for underground bulk mining methods, as they are the only way to extract ore in a continuous fashion, at a high production rate and a low operating cost, which explains why these methods are so popular. They are used to mine low-grade ore deposits that are not amenable to open pit mining due to their depth.

The block caving mining method is defined as the controlled collapse of a mineralized zone without resorting to continuous drilling and blasting. Instead, it takes advantage of the natural jointing in the rockmass, fracturing induced by the redistribution of stresses, the limited resistance of the rockmass to these stresses, and gravity.

When all favourable conditions are in place, the block caving mining method is by far the most advantageous underground mining method. It is relatively poorly known in Québec. However, the mining industry is moving towards a new context where block caving may in fact be, in many cases, the only mining method likely to ensure profitability.

G63

Development of a new green technology for the revegetation of gold mine tailings using specific symbiotic microorganisms associated with white spruce

MARTIN BEAUDOIN NADEAU, AIDA AZAIEZ AND DAMASE KHASA (UL)

Traditional mine revegetation practices are known to be expensive. Research in recent decades has demonstrated nutritional benefits brought to plants by several edaphic symbiotic fungi and bacteria associated with their roots. For this reason, there is now a growing interest, in agriculture and forestry, to use these microorganisms as biofertilizers to improve plant growth and nutrition.

In this research project, we aimed to examine the role and importance of soil microorganisms – plant growth promoting rhizobacteria (PGPR) and ectomycorrhizal (ECM) fungi – in promoting the health, growth, and nutrition of *Picea glauca* on biotite-quartz-rich waste rocks and fine tailings of Sigma-Lamaque gold mine located in the Abitibi region of Quebec. The project was divided into three studies. First, the community structure of ECM fungi associated with *Picea glauca* roots was analyzed at four locations near the mining site. Results showed that the mining site had a significantly different ECM fungal community compared to the surrounding forest edge, natural forest, and nursery locations. Second, a laboratory experiment was performed in order to *in vitro* select promising ECM fungi adapted to and growing well on the mine tailings. Results demonstrated that the two ECM fungi isolated from roots of healthy *Picea glauca* of the mining site (*Cadophora finlandia* and *Tricholoma scalpturatum*) had greater growth in poor liquid medium containing tailings than ECM fungi from natural forest (*Hebeloma crustuliniforme*). Third, a greenhouse experiment involving the growth of *Picea glauca* seedlings on waste rocks and fine tailings was conducted and the performance of different treatments of ECM fungi and PGPR was evaluated. After 32 weeks of growth, treatments of *C. finlandia* and *T. scalpturatum* improved significantly the health of *Picea glauca* seedlings while *H. crustuliniforme* did not. *Pseudomonas putida*, a PGPR isolated from the mining site, ameliorated considerably seedling aerial growth.

Our results suggest that site-adapted ECM fungi and PGPR play a very important role in the health and growth of *Picea glauca* on biotite-quartz-rich waste rocks and fine tailings. Next step will be to confirm our results in the field. If field results are positively conclusive, we will propose a new green technology for the revegetation of old abandoned mining sites.

G64

Characteristics of surficial formations in the southern part of the PACES project, Chaudière-Appalaches region

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The surficial formations in a large area of the Chaudière-Appalaches region were mapped as part of the PACES project in 2013-2014. The twelve resulting maps (1:50,000 scale) provide a detailed overview of the spatial distribution of the main groups of unconsolidated sediments found at surface. Results indicate that the vast majority of these surficial deposits were related to the last period of glaciation. Ancient undifferentiated Quaternary formations observed along the upstream part of Rivière Chaudière and some of its tributaries account for less than 1% of the mapped area. Till constitutes the most widespread mapped unit, occupying almost 60% of the area. Continuous layers of till (37% of the study area), without any particular shape or form, cover the low-lying areas of the Appalachians. Thin and discontinuous till deposits (22%) are found mostly on the slopes of hills and mountains. Ice-proximal deposits (eskers, moraines, kame terraces) and proglacial deposits (subaerial and subaquatic spreads) cover 1% of the area. These units, which constitute an important source of aggregate material, are concentrated mainly in the Notre-Dame region, to the southwest of Sainte-Marie. Champlain Sea deposits, which occupy 15% of the area, are found in the St. Lawrence Lowlands and the Appalachian foothills, at elevations below 185 m. At surface, they mainly comprise littoral and sublittoral sediments (11%), often overlying marine deposits of finer material (deep water marine deposits and deltaic deposits). In the Appalachians, sediments related to the development of a glacial ice-dam occupy 1% of the land. Units that were laid down after the last glacial retreat can be divided into organic sediments (5%), alluvial sediments (3%) and eolian sediments (2%). Overall, our work has improved our knowledge about the physical environment of Appalachian Quaternary geology, mainly by providing new details for the events that characterized the last period of glaciation and by refining the paleogeographic context of deglaciation in this region.

Re-assessment of the geology and gold exploration models of the southern Chibougamau mining camp (Abitibi)

STÉPHANE FAURE (CONSOREM)

The Caopatina-Desmaraisville segment, south of the Chibougamau and Chapais mining camps, was the subject of a geological revision and gold potential assessment study. Member companies of CONSOREM provided large databases of geological, lithogeochemical and geophysical information. These were combined with data from SIG"OM, and then processed and analyzed to produce a new high-resolution geological map. The highlights are as follows: 1) the Waconichi Formation (host to volcanogenic massive sulphides (VMS) in the Chibougamau camp) and the Gilman Formation were recognized over a large area south-west of the La Dauversière Pluton; 2) several laterally extensive and often conductive calc-alkaline volcanoclastic horizons were identified in the Obatogamau Formation; 3) the complex of gabbro and pyroxenite dykes in the area of the Philibert deposit (1.4 Mt to 5.3 g/t Au) were correlated with the Cummings Complex, which is found in the Chapais and Chibougamau region. This correlation is explained by, among other things, the effect of the La Dauversière anticline that crosses the centre of the region from east to west.

The study also focused on: 1) gold-VMS mineralization; and 2) disseminated gold-bearing sulphide mineralization or gold-bearing quartz-carbonate veins associated with synvolcanic or syntectonic intrusions. The environment that appears to be the most favourable for VMS mineralization is that of the Lac des Vents Complex (2798–2759 Ma), an assemblage of felsic lavas and pyroclastic rocks recognized over 40 km, forming a belt around the southern part of the Eau Jaune Pluton (synvolcanic). Semi-massive to massive bodies of pyrite, pyrrhotite or pyrite-pyrrhotite, sometimes auriferous, are interdigitated with calc-alkaline volcanoclastics considered to be fertile for VMS mineralization based on geochemical criteria. According to the new interpretation, it is one of the largest felsic complexes in the Abitibi, comparable in size to those of the Matagami, Selbaie and Val-d'Or camps.

In the area of the former Joe Mann mine (production: 4,754,375 t at 8.26 g Au/t and ~0.3% Cu), the geological reinterpretation revealed a vast complex of mineralized felsic to intermediate intrusions, wedged inside a wide brittle-ductile deformation corridor altered over a width of 3 to 5 km. Two groups of intrusions can be distinguished based on rare earth element (REE) patterns. Group 1 displays geochemical characteristics that are very similar to the La Dauversière Pluton (synvolcanic, 2720 Ma), whereas Group 2 displays comparable signatures to the Boisvert Pluton (synvolcanic, 2697 Ma).

Opportunity for Ag-rich volcanogenic massive sulphides

LUCIE MATHIEU (CONSOREM)

Volcanogenic massive sulphides (VMS) associated with volcanic activity are generally mined for Cu, Zn, and occasionally Pb. Some deposits show interesting grades in Au and Ag. This project documents the main parameters that influence the Ag content of VMS-type massive sulphide lenses.

It is well known that Cu is mobilized by hotter fluids, whereas Zn and Pb are controlled by pH. A study of physico-chemical parameters also reveals that Ag appears to be mobilized by relatively hot fluids. The physico-chemical parameters may indeed control essentially all aspects of the system. However, these parameters are difficult to define in fossil hydrothermal cells and are thus hardly useful in exploration.

Mineralogical constraints, such as those imposed by galena and grey copper ores (*fahlore*), can shed some light on correlations observed between Pb and Ag in VMS and may be useful to establish correlations between Ag and As, Bi, Cu, Pb, Zn, and Sb. Normative calculations developed from mineralogy data yielded interesting results for the Hackett River area, indicating that mineralogy is a reliable tool which may lead to a better understanding of massive sulphide lenses.

The characteristics of host rocks also appear to play a key role. Felsic rocks are commonly associated with Ag-rich VMS, either because they are often porous and may thus promote the formation of sub-surface-type VMS, either because they are rich in Pb and Ag and may thus lead to the formation of greater amounts of Ag-rich galena. An overview of geochemistry data in the Abitibi reveals the existence of a correlation between high Ag, Zn and perhaps Bi concentrations in host rocks and the presence of Ag-rich VMS.

This project shows that mineralogy is a promising tool for exploration. Tests performed in the Abitibi also indicate that it is possible to establish correlations between the geochemical composition of host rocks and that of VMS, opening a new field of possibilities for VMS exploration.

G68

Charlevoix - a region sculpted by the skies above?

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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 astrobleme, 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.

G69

Geoparks: What are they for?

PIERRE VERPAELST (COMITÉ NATIONAL CANADIEN POUR LES GÉOPARCS) AND DOMINIQUE RICHARD (MERN)

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. The development of a geopark is generally from the grassroots up through local initiatives. It aims to protect and explain the geological and mining heritage. Geotourism and socioeconomic development are encouraged. In this way, a geopark becomes a tool for regional development. A geopark is not limited to its geological elements: it may include sites of archeological, historical, cultural or environmental interest (plants and wildlife).

The Global Network of National Geoparks currently has 111 geoparks in 30 countries, two geoparks are in North America: the Stonehammer geopark in New Brunswick, which was created in 2009, and the Tumbler Ridge geopark in British-Columbia. Several projects are underway in Canada, five of which are in Québec: Charlevoix, Haute-Gaspésie, Percé, Anticosti and Saguenay.

Ophiolitic cumulates at King Mountain, Cache Creek Terrane, British Columbia – Preliminary results

ANNE-SOPHIE CORRIVEAU (INRS-ETE), JEAN H. BÉDARD (GSC-Q), ALEXANDRE ZAGOREVSKI (GSC-O) AND MARC RICHER-LAFLÈCHE (INRS-ETE)

The Cache Creek Terrane extends across British Columbia over a distance of nearly 1,300 km from north to south. This vast terrane namely includes mafic and ultramafic complexes, limestones, and marine cherts. This assemblage was previously considered as a chain of submarine volcanoes or an oceanic plateau. However, the geochemistry of most lavas and hypabyssal rocks, the abundance of mantle-derived harzburgites, and the juxtaposition of dislocated fragments of crust with mantle rocks suggest a back-arc core complex setting. Efforts to reconstruct the Cache Creek Terrane geodynamic setting, under the GEM2 project by Natural Resources Canada, will focus on the layered sequence of the King Mountain ophiolitic cumulates, where a section of the lower crust is well preserved and exposed. A study of textural, mineralogical, geochemical, and thermometry variations within the layered sequence will be conducted in an effort to define the tectono-magmatic setting. To this end, a continuous section of about 350 m was sampled. The cumulate sequence consists of decimetre-scale layers, most of which are isomodal with a gabbroic to noritic composition. Gabbroic layers containing 2 to 10% iron-rich sulphides, including pyrrhotite, occur at regular 1-metre to 2-metre intervals. The mineral foliation is generally parallel to layering. Isoclinal fold hinges and boudinaged layers are observed, suggesting strong plastic deformation at high temperatures. The presence of basaltic to trondhjemitic dykes exhibiting variable degrees of folding indicates this deformation is synmagmatic. Hornblendite veins are boudinaged and transposed along the gabbroic foliation, to form hornblende flaser gabbro. The entire outcrop is riddled with late trondhjemite veins and locally, metre-scale brecciated zones where hornblende is incorporated into the country rocks. The absence of olivine and the lithological uniformity suggest a steady-state magmatic chamber. In this context, do sulphide-rich layers reflect the repetitive occurrence of sulphur-saturated conditions or are they the result of late fluid injections? If so, could they be related to the hydrothermal system that produced hornblendite and trondhjemite veins?

Integration and interpretation of three-dimensional information for base metal, precious metal, and rare earth deposits

LI ZHEN CHENG, BAHMAN ABBASSI (UQAT) AND PIERRE MARTZ (UNIVERSITÉ DE LORRAINE, FRANCE)

Using three-dimensional interpretations of three types of mineralization, we demonstrate that certain geophysical anomalies may reveal the presence of mineral resources, whereas others provide structural indications or may be useful to understand the geological setting. Integration of multiple sources of information (geophysics, geology, geochemistry) is essential and results in a more realistic interpretation.

The Iso massive sulphide deposit is located near the contact between felsic (rhyolite) and mafic (andesite) volcanic rocks. It is composed of fine-grained massive pyrite, sphalerite, and chalcopyrite with minor amounts of galena, magnetite, silver and gold. Based on a strong electromagnetic and gravity anomaly located above the deposit, we were able to recognize, using 3D inversions, the economic (Cu-rich) portion of the deposit and the main body of mineralization. The physical model coincides perfectly with the known geological model.

The Newton deposit is an epithermal Au-Ag deposit associated with felsic intrusions in a volcano-sedimentary terrain. Gold mineralization occurs in the form of disseminated pyrite and marcasite in quartz-sericite veins (phyllitic zone). A series of 3D models (magnetic, conductivity, chargeability) demonstrates that geophysical anomalies refer to different sources. Integration of the results with physical property measurements supports the interpretation that a porphyry system is present underneath the Newton deposit.

The Montviel alkalic-carbonatitic complex contains REE and Nb mineralization, disseminated in Ca-carbonatites and Fe-carbonatites in the central part of the alkaline intrusion. Three (unconstrained) inversions of magnetic data were carried out at various scales (regional, intrusion, and carbonatite core of the intrusion). The results clearly illustrate vertical structures and the geological setting at Montviel.

Audio-magnetotelluric and petrophysical studies on the Champagne massive sulphide deposit

MARC RICHER-LAFLÈCHE (INRS-ETE) AND DANY BOILARD (GOLDEN HOPE MINES AND DANY BOILARD EXPLO-
RATION)

We present the results of an audio-magnetotelluric (AMT) and petrophysical study carried over the Champagne deposit area (Saint-Magloire de Bellechasse) in 2013-2014. The aim of the study is to establish the nature of strong conductivity anomalies detected by a VTEM-type heliborne survey (TDEM survey).

The Champagne massive sulphide deposit of Golden Hope Mines is a hybrid deposit that displays both SEDEX-type and VMS-type characteristics. The deposit is hosted by rocks belonging to the Magog Group, specifically those near the base of the Beauceville Formation (Paradis et al., 1995). Historical resources for the Champagne deposit amount to roughly 250,000 metric tons at grades of 2.7% Zn, 0.45% Pb, 0.4% Cu, 4 g/t Au and 19.7 g/t Ag (Bergman, 1954). Massive sulphides are composed mainly of pyrite, some pyrrhotite and variable amounts of sphalerite, chalcopyrite and galena.

The presence of faults, argillite units and bands of organic-rich rocks (graphite) complicate the interpretation of the geoelectric units. The principal conductors determined by the VTEM survey are formational, and data inversion generated unrealistic models that do not reflect field-based geological observations (dip, stratigraphy). Inversion of the high-resolution AMT data enabled us to generate electrical resistivity imagery that corresponds to the main lithological contrasts between volcanoclastic units, shales, dioritic dykes and massive sulphide bodies.

The petrophysical data reveal that the massive sulphides of the Champagne deposit have very low resistivity ($1.55 \pm 0.32 \Omega \text{ m}$), but very high chargeability ($441 \pm 102 \text{ mV/V}$). The resistivity and chargeability of organic-rich shales and mudstones, which are partly responsible for the formational anomalies (high conductivity values at the regional scale), are on the order of $130 \Omega \text{ m}$ and 97 mV/V , respectively. Mafic dykes and volcanoclastic units yielded high resistivity values of 3,758 and 5,042 $\Omega \text{ m}$, respectively, and low chargeability values of 10 and 26 mV/V. These electrical contrasts of several orders of magnitude can be used to distinguish the different geological units associated with the Champagne deposit.

Quality assurance and quality control (QA/QC) of geochemical analyses

MARIE-FRANCE BEAULIEU, GUILLAUME ALLARD
AND PATRICE ROY (MERN)

Quality assurance and quality control (QA/QC) systems provide an estimate of the accuracy and precision, and help reduce errors associated with analytical procedures. Given the cost and amount of work involved in mapping campaigns carried out by the BCGQ, implementation of a reliable QA/QC system represents a minor investment that will guarantee a certain level of quality in the data.

The QC/QA process involves two main steps. The first step, prior to analysis, consists in the systematic insertion of control samples and in consistent sampling procedures. The second step, after analysis, is the verification of results: to detect anomalies, make sure all samples have been processed and have not been switched or mixed up, and verify that all values are accurate and precise.

During the first step, prior to analysis, blanks, certified standards and duplicates are indispensable control measures. They must be inserted systematically as soon as sampling begins. Their combined rate must represent at least 10% of the total number of samples, including about 2 to 5% for blanks and standards and at least 5% for duplicates. Data processing of values obtained for these samples is performed to detect contamination, inadequate calibration, or analytical bias. It can also be used to determine if analytical results are representative and reproducible. The use of 3 to 7 certified reference materials with representative lithologies and grades in the range of expected results is recommended. Alternating between commercial reference materials (CRM) and in-house standards (matrix-matched) provides a good assessment of precision and helps reduce costs.

During the second step, after analysis, verification of control samples must be systematically applied for all geochemistry analyses. In addition, a QA/QC system may be improved in several manners, namely with checks of the laboratory's internal control system. Verifications of pulps and rejects, reanalysis of high-grade samples, mass balance calculations, compatibility of grades for various elements according to rock types, and various element ratios also provide good indications of the validity of results.

A QA/QC system is useless if it is not verified appropriately and if no corrective measures are applied when errors are detected. When an analytical problem occurs, several corrections can solve the problem, especially the increase of the sample mass, the reduction of the particle size, the sample splitting, the modification of the selected methods for pulp homogenization, fusion, dissolution or analysis are a few examples of corrective measures that may greatly reduce analytical problems.

Social acceptability: Definition, factors and other things to think about

VÉRONIQUE YELLE (MERN)

Social acceptability is at the heart of every mining project's success and sustainability. The technical and economic feasibility of a project is not enough; it must also be socially feasible. What is social acceptability? How do we define it? What are the influencing factors? And what factors should we take into consideration?

ACRONYMS

ACPE : Association canadienne des prospecteurs et entrepreneurs

AEM: Agnico Eagle Mines

AMQ : Association minière du Québec

ATIAT: Abitibi -Timiskaming Institut(e) d'Abitibi-Témiscamingue

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

CRCMM-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

GESRIM : Chaire de recherche CRDI (Canada) en gestion et stabilisation des rejets industriels et miniers, Université de Cadi Ayyad, Marrakech

GSC: Geological Survey of Canada

GSC-O: Geological Survey of Canada – Ottawa

GSC-Q: Geological Survey of Canada – Québec

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

MDDELCC : Ministère du Développement durable, de l'Environnement et Lutte contre les changements climatiques

MERC: Mineral Exploration Research Centre

MERN : Ministère de l'Énergie et des Ressources naturelles

MISA : Mines, innovations, solutions et applications

MPMPS: Mineral potential maps production system

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)

UL : 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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