Geological Association of Canada

ABSTRACTS

Newfoundland Section 2011 Spring Technical Meeting February 21–22, 2011

JOHNSON GEO CENTRE, SIGNAL HILL, ST. JOHN'S, NEWFOUNDLAND

The 2011 Spring Technical Meeting was once again held in the depths of the Newfoundland winter in the Johnson GEO CENTRE on scenic Signal Hill in St. John's.

The meeting featured a special session entitled "Red Earth to Rare Earth: Resource Commodities for a New Generation" which was intended to highlight the mineral resources of Labrador and adjacent regions of Québec. The title of the session refers to the intersection of an established and vital commodity from the 20th century (iron ore) and the potential for a new and equally vital commodity for the 21st century (rare earth elements). In addition, a general session included papers on an eclectic range of topics, as is normally the case at these meetings.

The 2011 meeting featured the fourth of the "Topical Geoscience Lecture" series, co-sponsored by the GAC Newfoundland and Labrador Section and the Professional Engineers and Geoscientists of Newfoundland and Labrador (PEG-NL). The speaker was Dr. Raymond Goldie, Salman Partners Incorporated, who spoke on the "Minerals in the 21st Century: Surging Demand, Restricted Supplies and Economic Challenges."

The Newfoundland and Labrador Section of the Geological Association of Canada is pleased to have once again hosted an interesting and diverse meeting, and we are equally pleased to see the abstracts published in Atlantic Geology. Our thanks are extended to all of the speakers and the editorial staff of the journal.

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TECHNICAL PROGRAM CHAIR
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An overview of geochemical exploration for rare earths and rare metals, with particular reference to Newfoundland and Labrador

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This paper describes the application of surficial geochemistry in the search for rare-earth elements and rare metals (REE/RM). Examples of the responses to known occurrences, as well as some untested anomalies, are described, as well as some of the issues in analysis, and interpretation of the results thereof.

The regional-scale provincial lake-sediment and water database comprises multielement analyses for samples from 16,657 sites in the island of Newfoundland and 18,648 sites in Labrador. In addition, samples of lake sediment and water have been collected at 6,600 sites in more than 20 focused, detailed studies in Labrador, and this database continues to be expanded. Till coverage in Labrador has also been selective, with 2,610 samples collected from five detailed surveys, although the coverage of the island has been more systematic, with 7% currently covered, at a density of about 1.6 per km².

There are numerous REE/RM anomalies in both Newfoundland and Labrador. Of the eight known occurrences or districts in Labrador, six have an expression in either lake sediments or tills, or both. The Misery Lake occurrence in Quebec, located close to the border with Labrador, also has a strong geochemical and geophysical expression. In Newfoundland, only one of three known occurrences or districts is spatially associated with such a feature. Some anomalies are present on a regional scale: for example, the Flowers River Complex and Letitia Lake regions, and the glacial dispersion train from the Strange Lake deposit. Others are more restricted in extent, indicating that detailed examination of the regional geochemical databases is necessary; in some cases information in the assessment files may also prove useful, since it may have been acquired in the search for other metals with the REE/RM potential overlooked.

The behaviour of certain rare metals is strongly controlled by the relative amounts of clastic and chemically-precipitated material in lake sediment, and by high background content of certain rock types. These environmental factors may give rise to false anomalies or in some cases the masking of the response to mineralization. The apparent extent of anomalies in till may also be interrupted by variations in the type of glacial sediment that is available for sampling. The track record of various Canadian geochemical labs in performing REE/RM analyses is variable, but some are capable of delivering high-quality analyses for all of the rare earths and rare metals, at all concentration levels. It may not be advisable to apply a blanket single method for all of these elements and the potential for inter-element interferences, in particular, should not be underestimated. It is also highly recommended that detailed examination be made of QAQC data, both external and internal, before making any recommendations based on the results.

Midland's new rare-earth element (REE) discoveries at Ytterby 2 and 3 near the Québec-Labrador border

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Midland Exploration Inc., in partnership with Japan Oil, Gas and Metals National Corporation (JOGMEC) has explored for Rare Earth Element (REE) deposits only since Fall 2009. Direct field work began in late July, and continued up until the end of August, 2010. Midland took a large land position in Labrador and Québec based on compilation of Provincial and Federal Government lake sediment geochemistry, geological maps, mineral occurrences and airborne geophysical surveys.

Midland's new properties are marked by extensive strong unsourced yttrium, uranium, lanthanum and beryllium lake bottom sediment anomalies combined with uranium (eU) and thorium (eTh) airborne radiometric anomalies. The project consists of 2690 claims covering a surface area of about 910 km². The Ytterby project comprises 4 distinct claim blocks located between 200 to 230 km east and northeast of Schefferville, Québec. Reconnaissance mapping and prospecting, following up a detailed airborne radiometric survey commissioned by Midland, led to the discovery of two new REE-enriched alkaline granitic systems on its Ytterby 2 and Ytterby 3 properties located respectively 65 km and 100 km south of the Strange Lake – B-Zone REE project area.

On Ytterby 2, 29 new mineralized areas were discovered with total REE oxides plus yttrium oxide (TREO + Y_2O_3) values varying from 0.3% to 18.0%. The heavy REE oxides plus yttrium (HREO + Y_2O_3) content represent 1.43% to 83.7% of the (TREO + Y_2O_3). Four styles of REE-bearing mineral assemblages have been recognized, and all appear magmatic in nature. One consists of light-REE-enriched (LREE) quartz + K-feldspar pegmatite with large skeletal amphibole; one consists of LREE-enriched biotite-rich mixtures of alkaline pegmatites and gneissic rocks interpreted as roof pendants; one consists of amphibole + quartz + K-feldspar, and an unidentified heavy-REE-bearing mineral; and the last is characterized by iron oxides, carbonate, amphibole, chlorite and k-feldspar. These complex mineral assemblages observed in pegmatite-aplite dykes on Ytterby 2 may witness a possible zoning of a common magmatic chamber.

On Ytterby 3, 63 new mineralized areas were found with TREO + Y_2O_3 values varying from 1.03% to 7.94% with an average TREO + Y_2O_3 value of 2.72%. The heavy-REE oxides plus yttrium (HREO + Y_2O_3) content represents 2.4% to 15.4% of the (TREO + Y_2O_3). Two styles of magmatic mineralization are recognized. One consists of disseminations of iron oxide +

amphibole + monazite + fluorite, and the second shows iron oxide + amphibole + monazite enrichment in pegmatite-aplite dykes and in plurimetric iron-oxide-enriched pods hosted in alkaline granite.

This presentation examines the petrographic, mineralogical, geophysical and geochemical characteristics of the Ytterby 2 and Ytterby 3 alkaline complexes. Processes that may have been involved in the transportation, concentration and deposition of the REE are investigated and compared to other similar deposits elsewhere in the world.

Stratigraphic studies of the Watts Bight Formation (St. George Group), Port au Port Peninsula, western Newfoundland

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Trilobites along with other macrofossils were systematically recovered from the lower part of the Tremadocian Watts Bight Formation (St. George Group) 1.5 km west of Ship Cove and from the Isthmus Bay Section, Port au Port Peninsula. The trilobite genera Bellefontia and Symphysurina are identified for the first time from the west Newfoundland platformal sequence. The presence of Bellefontia gyracantha, "Hystricurus" ellipticus and Symphysurina myopia indicates a correlation with the Tribes Hill Formation of New York State, U.S.A. Millardicurus sp. cf. M. armatus provides a faunal linkage with the Antiklinalbugt Formation of North-East Greenland.

The lithostratigraphy of the Watts Bight Formation is best known in the Isthmus Bay Section where it includes superb microbial mound complexes. Twenty kilometres to the west, however, the mounds are no longer dominant although still sporadic near the base. The succession instead consists of monotonous, thickly bedded, stylonodular lime mudstone and wackestone with frequent thin sheets and lenses of grainstone and rudstone supporting a more open, subtidal shelf setting in the west of the peninsula.

Strange Lake: an overview of geology, mineralization, and alteration of Quest Rare Minerals' B-Zone

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The Strange Lake alkalic complex, located along the Labrador and Québec border, hosts abundant rare earth element (REE) showings, one historic non-NI43-101 resource (IOC; 52 Mt at 0.92% TREO, including Y_2O_3) and one 43-101 compliant resource (B-Zone: @ 0.850% cut-off, 114.8 Mt at 0.999% TREO, including Y_2O_3). The complex is compositionally zoned, with grossly concentrically distributed, progressively REE-enriched phases of granite and localized pegmatite-aplite. The B-Zone, controlled 100% by Quest Rare Minerals, is located along the north western contact between the Complex and Proterozoic quartz monzonite and Archean gneiss and occurs in the carapace of the intrusion. REE mineralization is hosted in sheeted pegmatites that vary from several centimetres to nearly 50 metres of vertically continuous pegmatite. Drilling and interpretation suggest the thicker sheets are continuous over more than 1000 m along strike. Within these sheets, REE-bearing minerals are commonly concentrated in late interstitial fluorite-rich pods. An important aspect of mineralization at the B-Zone is the high proportion of heavy REE, a feature not common in many other REE deposits. B-Zone alteration is complex: major Na, Ca, and Fe metasomatic events are documented overlapping each other and affecting granite and pegmatite mineralization both destructively and constructively.

Assessing the utility of hydrogen isotopic composition as a tracer for terrestrial dissolved organic matter in estuaries

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Estuaries are the interfaces between river systems and oceans where freshwater and its terrestrial dissolved organic matter (DOM) mixes with seawater and marine-derived DOM. Terrestrial DOM can be a key source of energy and nutrients for estuarine ecosystems, as it comprises ~60% of riverine organic matter input to marine environments. This is especially important where concentrations of riverine DOM are high, such as at boreal and arctic latitudes. The role of terrestrial DOM in regulating estuarine ecosystem processes is poorly understood in part because of difficulties in tracking terrestrial DOM in marine environments. Analysis of multiple stable isotopes (C, N, and S) is often required due to poor separation of the carbon isotope signatures of marine and terrestrial sources. However, hydrogen isotopes exhibit greater fractionation. We propose that hydrogen isotopes may be an excellent tool for tracking terrestrial DOM, because of the large differences that exist between marine (0 per mil) and terrestrial (up to −270 per mil) organic hydrogen isotopic signatures.

Riverine discharge into marine environments introduces terrestrial DOM to water of different physicochemical and isotopic compositions. Hydrogen isotopes can undergo exchange between water and organic matter, which may obscure terrestrial signatures. We investigated the magnitude of this effect by exposing terrestrial DOM to freshwaters with hydrogen isotopic compositions up to +1000 per mil for as long as two months. As much as 15% of organic hydrogen exchanged, and enrichments of up to 40 per mil were observed. We are now investigating measurement of the non-exchangeable fraction to compensate for this by equilibrating samples with waters varying in known isotopic composition. We also use surface water samples along a salinity transect at the Salmonier Arm, Newfoundland, Canada, to investigate the effects of changes in water mass conditions (pH, salinity and water isotopes) and recovery techniques on terrestrial DOM elemental and isotopic composition. Initial results indicate that the size range of recovered DOM is correlated with its isotopic signature and therefore results from different techniques are not directly comparable.

Hydrogen isotopes have the potential to provide high resolution separation of terrestrial and marine DOM signatures in a single measurement rather than the multiple analyses required currently. This could be a very useful tool for assessing both estuarine ecosystem health and quantifying the carbon cycling that occurs in these environments, however, careful consideration of isolation technique and H isotopic exchange is important when exploiting this approach.

Rare earths along the Trans Labrador Highway – a new REE camp in the making?

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Silver Spruce Resources Inc. (SSE – TSXV) has discovered significant REE mineralization in the Popes Hill Area, along the Trans Labrador Highway, approximately 100 km from Goose Bay. The mineralization, hosted in Paleoproterozoic pelitic and granitic gneisses affected by the Labradorian Orogeny (~ 1.6 Ga), which have been overprinted by the Grenville Orogeny (~ 1.0 Ga), occurs as veins, pods and disseminations in road cuts, a bedrock pit (the MP showing) dug for construction material for the highway, and as outcrops and float boulders in brooks and the Pinus River. The mineralization appears to be related to a structural zone defined by linear monzonite bodies of uncertain age, which parallel a thrust or reverse fault dipping at approximately 45 degrees to the south-southeast, also generally parallel to the banding in the gneisses. Thirty-one selected grab samples, over a 7 km strike length, all gave anomalous TREE + Y values averaging 5.73% with 16 samples >5%, and 5 samples >10%, with a high value of 24% TREE+Y. These include 7 "host rock" samples, with values <0.4%. The highest REE values are in a dark grey to black, sub-metallic to glassy, mineral in veins which are variably non-magnetic to moderately magnetic. All of the REE-bearing samples are weakly to moderately radioactive with significant thorium content and minor uranium values generally <100 ppm. The presentation will describe the regional and local geological setting, the mineralization and the ongoing mineralogical studies and exploration, including diamond drilling.

Urban geochemical hazard mapping of St. John's, Newfoundland, Canada

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The surface soil concentrations (n = 997) of ten metals with Canadian Council of Ministers of the Environment soil quality guidelines were mapped on residential properties across the city of St. John's, Newfoundland and Labrador, Canada. Concentrations of all metals were elevated above background levels, five of the ten metals, As, Ba, Cu, Pb, and Zn, had concentrations above environmental health guidelines in more than 20% of samples, and three metals, As, Pb, and V, exceeded human health guidelines in 34 to 47% of samples. Using a contamination index, surface soil was shown to be highly contaminated in the downtown area, primarily on residential properties predating the 1950s. In order of influence, the four metals with the highest contamination factor were Pb, As, Cu and Zn. Compared to background levels, surface soils were significantly enriched in Pb and Cd and moderately enriched in Cr, Cu and Zn. A hierarchical clustering procedure indicated strong statistical relationships between the occurrences of two metal groups across all soil samples. One group, Pb-Zn-Cd, has consistently elevated concentrations in soil sampled adjacent to the exterior walls of buildings, though high values were also recorded in roadside samples and from open spaces on properties. The second group, Cr-Ni-Cu, has moderately elevated concentrations in all sample locations, though slightly higher concentrations along roadsides. The clusters of metals and their spatial concentration patterns suggest that weathered paint, vehicular emissions, and coal burning were important sources for the main contaminants in sampled soils. Of the three metals with significant human health guideline exceedences, Pb and As pose the greatest potential health risk and require further assessment. It is likely that other cities in the Atlantic region that share similar urban history and characteristics have a potentially hazardous geochemical landscape.

Mining and community relations – marketing the brand

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Fifteen years ago, many people in the mining industry viewed community relations as an activity to occupy the time of fuzzy-minded liberals while clear-headed engineers did all the important work. But today, mine explorers have reached a consensus that "if you don't have community support, you don't have a mine".

We propose that companies approach the process of obtaining community support as a campaign of "marketing the brand", where the "brand" is the company's project. This presentation considers examples from locations as diverse as Guatemala, Papua New Guinea, Congo, Madagascar and New Zealand.

The making of the geological map of eastern Labrador

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The Geological Survey of Newfoundland and Labrador recently released a 1:500 000-scale compilation map and 25 1:100 000-scale individual geological maps for eastern Labrador. The full-colour maps cover roughly 80 000 km², which represents about 20% of the land area of the Province or 0.8% of Canada. They are the final cartographic product of a 25-year reconnaissance mapping program in eastern Labrador. This presentation will review the evolution of the geological map of eastern Labrador, culminating in the preparation and features of the newly released 1:100 000-scale maps.The history of geological mapping in eastern Labrador is divided into five stages, namely (i) an explorer stage (1860–1890), (ii) a coastal mapping stage carried out during various government surveys (1890–1960), (iii) systematic reconnaissance geological mapping by the Geological Survey of Canada (1960–1975), (iv) targeted geological mapping of specific areas (1975–1978), and (v) systematic 1:100 000-scale mapping by the Geological Survey of Newfoundland and Labrador. In particular, the manner in which early mapping indirectly identified fundamental tectonic features of the region will be addressed, as will be the role attributable to changing field methods in refining the resultant geological maps.

The database that underpins the 1:100 000-scale maps includes information from nearly 29 000 field data stations, over 24 000 structural measurements, over 15 000 samples, over 6 000 field photographs, over 6 000 petrographic thin sections, 1 763 whole-rock geochemical analyses, 545 mineral occurrences, 318 paleomagnetic results and 355 U-Pb age determinations (plus other isotopic data). Except for small fringe areas, all geological mapping data have been included from previous federal and provincial projects, from university studies and from mineral exploration company mapping, utilizing original field notebook data and petrographic thin sections.

Although uncoloured preliminary editions of many of the 1:100 000-scale maps are already available, the present versions can be considered to be new products because of incorporation of extensive new petrographic, geochemical, isotopic and geophysical data; utilization of geological knowledge from formerly unmapped adjacent regions; and revised interpretations drawing on regional geological knowledge. Key and/or innovative features of the new maps are, (i) a common legend for all 25 1:100 000-scale maps, (ii) colour-coding of various dyke swarms, (iii) listing of data sources according to individual geoscientist that collected the data, (iv) comprehensive detailing of isotopic data, (v) tabulation of mineral occurrence information, (vi) locating paleomagnetic sites, (vi) cryptic extrapolation of geological features under inland and coastal waters, and (vii) inset maps for areas of detailed information.

Much of the geological knowledge generated from the mapping has already been disseminated in the geoscientific literature, but regional features for which the new maps provide a revised perspective are (i) the nature of the Grenville front, (ii) the configuration of the dextral ramp that terminates the eastern end of the Grenville orogen, (iii) the position of the northern boundary of the Pinware terrane, (iv) the disposition of a reclined regional fold in the Pinware terrane, and (v) the distribution of Iapetus-related faults and dykes.

Petroleum potential and exploration activity for onshore western Newfoundland (Anticosti Basin)

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The Anticosti Basin of Western Newfoundland lies at the northeast terminus of the Appalachian Structural Trend and like counterpart basins to the southwest, a working petroleum system appears to be in place and capable of generating commercial quantities of both oil and/or gas. This is evident in the hundreds of live and dead oil shows observed in coastal exposures and within mineral and petroleum drill holes between Port au Port and Pistolet Bay. In addition to surface shows, historical records attest to limited production approximately 100 years ago at both Shoal Point and Parson's Pond. Rough estimates place production somewhere in the range of 5000 to 10,000 barrels, with the bulk of this derived from the Parson's Pond wells.

Today exploration geoscientists have a better understanding of Anticosti Basin geology, basin stratigraphy, tectonic, subsidence and thermal histories plus an appreciation for the character and distribution of petroleum source rocks. This increased level of understanding translates directly into exploration confidence and ultimately leads to further seismic programs and drilling in the basin. This has certainly been the case since the mid-1990s and this exploration round continues at present with drilling activity taking place at Garden Hill and Shoal Point on the Port au Port Peninsula and at Parson's Pond on the Northern Peninsula.

Rare-earth element (REE) mineralization in Labrador: a review of geological settings, features, and exploration results

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Since 2007, increased interest in exploration for deposits of Rare-Earth Elements (REE, i.e., La, Ce, Pr, Nd, Sm, Nd, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu) and associated rare metals (RM, e.g., Zr, Y, Nb, and Be) has been driven by commodity price increases linked to demand-supply imbalance. In Labrador and adjacent Québec, this has led to renewed evaluation of previously-defined deposits, and to grass-roots activity in prospective but unexplored regions. REE deposits in this region are all associated with peralkaline igneous suites of known or presumed Mesoproterozoic age, which in part represent the extension of the well-known Gardar igneous province in Greenland.

The largest resource sits near the Québec-Labrador border at Strange Lake, hosted by a ~1240 Ma peralkaline ring complex. Previous exploration outlined 56 Mt of 2.9% ZrO_2, 0.38% Y_2O_3, 0.31% Nb_2O_5, 0.08% BeO, and ~0.54% total REE oxides (TREO; Y_2O_3 excluded), including a smaller high-grade near-surface zone containing up to 1% Y_2O_3 and 1.3% TREO. The deposit is presently exempt mineral lands (EML), but similar mineralization a few kilometres inside Québec is now part of an advanced exploration project, where substantial resources of similar grade are defined. Strange Lake is enriched in the more valuable "heavy" REE, which make up about 30% of total REE oxides (excluding Y_2O_3). The potential for definition of large bulk-tonnage resources in this complex is good. REE-Nb-Be deposits also occur in central Labrador, in the ~1330 Ma volcanic rocks of the Letitia Lake Group and the coeval Red Wine Intrusive Suite. The original geological relationships are locally obscured by locally intense Grenvillian deformation, but mineralization is still viewed as broadly syngenetic with respect to host peralkaline suites. Volcanic-related mineralization is enriched in Be and light REE, but mineralization in undersaturated metasyenites is entirely different, consisting of disseminated to semi-massive eudialyte (Na-Ca-Zr silicate). This style of mineralization is enriched in Zr and heavy REE, and could be the cumulate counterpart to the incompatible-element-enriched association seen at inferred higher levels. Outside these previously defined areas, early-stage exploration programs have given encouraging results. In southeastern Labrador, at least two styles of mineralization are defined in the Port Hope Simpson area, and these also represent contrasting light-REE- and heavy-REE-enriched signatures, hosted by felsic gneisses and later pegmatites, respectively. Prospecting discoveries in correlative areas of central Labrador suggest that the Grenville Province as a whole demands evaluation. A remote stretch of territory near the border, within the largely unmapped Mistastin Batholith, is now known to contain smaller (later?) bodies of compositionally evolved granite, associated with locally high-grade REE mineralization. In conjunction with other discoveries in Québec, exploration results indicate that this entire region of the Canadian Shield represents an important target area for deposits of this type.

Why REE?

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The dramatic increase in exploration for rare-earth elements (REE), since 2008, reflects the interplay of several factors that have coalesced to cause robust commodity price increases. The growing demand for these elements in high-technology applications plays a role, in conjunction with supply restrictions imposed by China, which currently supplies >95% of global REE production.

The REE include the lanthanide elements (La to Lu) and the geochemically similar elements Y and Sc. Aside from one member (Europium) the REE behave as a coherent group in most geological processes, which lends them great importance in fingerprinting rocks and tracing their origins. The REE also possess unusual catalytic, optical, diamagnetic and electrical properties, which lend them growing commercial importance. Modern usage of REE is amazingly diverse, but the largest markets by value are in high-strength magnets (e.g., computers and wind turbines), phosphors (e.g., flat-screen TVs) and specialized alloys. In general, the less abundant heavy REE (Gd to Lu) command higher prices than the light REE (La to Sm), although the prices for light REE are currently elevated compared to historical levels. In exploration, assay results for REE are commonly reported as total REE oxides (TREO, including Y), but the balance of the individual elements influences potential value, and should be examined closely in assessing such data.

The most important and largest primary REE deposits are associated with carbonatites and peralkaline igneous rocks, and are generated by a combination of igneous and hydrothermal-metasomatic processes. Virtually all primary REE deposits are dominated by light REE, and those hosted by carbonatites typically show marked heavy-REE depletion. Some (but not all) deposits in peralkaline rocks are relatively enriched in heavy REE. Relatively small vein-style REE deposits are also known, and some of these may be very high in grade. Their origins are unclear, but a distal connection to carbonatites is postulated for some. The REE also form paleoplacer deposits, and are potential by-products from large iron-oxide-copper-gold deposits such as Olympic Dam. Secondary REE deposits include monazite-rich beach and fluvial placers, and residual (lateritic) placers that are generally derived by deep weathering of primary carbonatites. "Ion-adsorption clays" are residual deposits developed by weathering of enriched granites, and are important sources for Chinese heavy REE production. There is currently great interest in finding and developing REE deposits outside China, with most emphasis on those that are enriched in heavy REE. There are presently several advanced exploration projects of this type across Canada and North America.

Geochronology of the Moly Brook Mo-Cu deposit, southern Newfoundland: implications for local and regional granite-related metallogeny

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The Moly Brook deposit, located near Grey River on the south coast of Newfoundland, is hosted within deformed granitoid rocks of the Siluro-Devonian Burgeo Intrusive Suite. The deposit consists of a broadly linear zone of N-S-trending, steeply-dipping, sheeted to locally stockwork-style hydrothermal veinlets. Molybdenite and other sulphides occur as disseminated and stringer mineralization within quartz veins and adjacent wall rocks. Undeformed granitic and aplitic dykes and veins appear both spatially and temporally coincident with the mineralization. The results of Re-Os molybdenite and U-Pb (SHRIMP) zircon geochronology constrain the age of the host rock, sulphide mineralization and cogenetic felsic magmatism. The data also suggest a link between the Mo-Cu mineralization and nearby tungsten deposits.

Re-Os molybdenite ages from four molybdenite-bearing quartz veins at Moly Brook yield a weighted mean model age of 380.9 ± 0.8 Ma, or an ^{187}Re-^{187}Os isochron age of 381.2 ± 1.8 Ma. Two samples from the Grey River deposit, in which molybdenite is paragenetically associated with lode tungsten mineralization, yield a weighted mean Re-Os model age of 381.4 ± 1.2 Ma. Both ages are identical within uncertainty and are within the range of previously determined K-Ar ages on hydrothermal muscovite (~ 370–390 Ma). U-Pb (SHRIMP) zircon data from a molybdenite-bearing granite dyke at Moly Brook yields a ^{206}Pb/^{238}U weighted average zircon age of 378 ± 3 Ma. The foliated granitoid host rock to the mineralization yields a ^{206}Pb/^{238}U weighted average zircon age of 411 ± 3 Ma, which agrees with an earlier Rb-Sr whole-rock date of 412 ± 5 Ma.

The Re-Os and U-Pb data show that Mo-Cu mineralization at Moly Brook was contemporaneous with the formation of W-bearing quartz veins at Grey River and suggest that both are cogenetic with a phase of evolved granitoid magmatism at ca. 380 Ma. The age of the granite dyke is identical to the age of the nearby François Granite (378 ± 2 Ma), while the timing of mineral deposition in the Moly Brook area agrees with Re-Os ages determined for granophile mineralization within the Ackley Granite (380 ± 2 Ma), some 140 km to the east. These results add to evidence for a regionally significant and geologically concentrated episode of Upper Devonian granitic magmatism and related mineralization in this part of the northern Appalachians.

Geoscientific knowledge, exploration targets and advanced rare-metal projects in Québec

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Géologie Québec's mandate consists in acquiring, processing and distributing geoscientific knowledge on Québec's mineral resources, in order to assess and promote its mineral potential. With the establishment of the Fonds du patrimoine minier (mining heritage Fund), the Bureau de l'exploration géologique (BEGQ) now disposes of roughly 12 M$/year to acquire new data in the province. For instance, seventeen projects were conducted in 2010–2011 into four large geoscience fields: bedrock geology, Quaternary geology, geophysics, and geochemistry.

Bedrock geology surveys engage most human resources and keep on being BEGQ's top expertise. Six projects were accomplished at scales ranging from 1/250 000 to 1/20 000 in the Superior, Grenville and Churchill provinces. An innovative bedrock and Quaternary survey is actually being conducted in the Abitibi Clay Belt, which is covered by thick Quaternary deposits. This project aims to drill and study both surficial deposits and basement rocks to gain a better knowledge in an area that retain high gold mineralization potential. Traditional Quaternary geology surveys are also a significant part of BEGQ activities, as maps of surficial deposits are produced to gain insights on aquifers of municipalized areas. Geophysical and geochemical surveys did occupy important financial resources in the recent years. Following an ambitious airborne geophysical program initiated in 2007, the James Bay territory continues to be the object of broad high-definition aeromagnetic surveys (some including spectrometry data), where a complete coverage is expected within the next two years. Furthermore, the Geological Survey of Canada carried out an aeromagnetic survey to the West of Kuujjuaq within the framework of the GEM program. This survey is aimed at supporting the next geological surveys planned to begin in the summer of 2011. The update of the lake-bottom sediments database, launched in 2007, goes forward with a regional survey that now completes the coverage of the Grenville Province North of latitude 47°22'30". With the recent reanalysis of archived samples from the James Bay territory and Churchill Province, the lake-bottom sediments database now holds more than 65% of its samples being analysed by ICP-MS for a suite of 53 elements. A major outcome of BEGQ activities is the yearly proposal of new exploration targets. For instance, 46 of the 91 targets proposed in 2010 were designated by mining exploration companies for further investigations. In addition, the statistical treatment of lake-bottom sediment data, and the assessment of the mineral potential for given commodities, further enlightens the mineral potential of Québec in delivering close to 3000 possible targets to include in exploration programs.

Finally, Québec holds several favourable geological environments for the discovery of rare metal mineralization (Nb, Ta, Li, Be, Zr, Hf, rare earths, Y, and Sc). The renewed interest for these commodities has triggered an updated compilation of showings, prospects and deposits at the scale of the province. Advanced projects have calculated resources compliant with the National Instrument 43-101, which makes Québec amongst the next potential producers for some of these strategic substances.

Late Ordovician–Early Silurian migration of basin-and-range volcanism across Laurentia to Gondwana and the transition from transtensional to transpressional tectonics in the Badger Basin of central Newfoundland

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In the westernmost parts of the Notre Dame and Dashwoods subzones of the Dunnage Zone, mylonitized Late Ordovician cover sequences composed of mixed subaerial and shallow marine strata accumulated above Taconic Arc basement near the Baie Verte ocean-continent suture and the Cape Ray arc-arc suture. Continental arc-related volcanism and epiclastic sedimentation began in the late Sandbian (ca. 457 Ma; Black Creek group) and early Katian (ca. 453 Ma; Windsor Point Group) and probably continued into the Early Silurian (ca. 441 Ma; earliest Llandovery; lower Micmac Lake Group and ca. 440 Ma; top Rhuddanian; basal Sops Arm Group). An Early to Middle Silurian phase of dominantly within-plate bimodal volcanism and terrestrial sedimentation was more widely developed between White Bay and Halls Bay, especially toward the southeast of this region, where the transtensive cover basins opened near the margins of the youngest ophiolite belt within the Taconic Arc. This volcanic pulse began in the late Llandovery (ca. 432 Ma; lower Springdale Group and top Telychian; basal Natlins Cove Formation–upper Sops Arm Group) and continued throughout the early Wenlock (ca. 426 Ma; Cape St. John Group and ca. 425 Ma; King's Point Complex).

Within these linear rift zones, renewed pulses of magmatism formed progressively younger Late Ordovician or Early Silurian ignimbrite eruptions that, in places, directly onlapped basement to unconformably overlie the newer, ever more juvenile, parts of the remobilized peri-Laurentian arc. This was accomplished by episodically uplifting the mountainous ranges of the Notre Dame Subzone and denuding the local arc basement, at a time immediately preceding the terrestrial felsic volcanism represented by the basal ignimbrite or subsequently during the synvolcanic oblique extension phase that governed the particular rift zone.

The deep-marine turbidites of the Late Ordovician–Early Silurian Badger Group occur in the northwestern part of the peri-Gondwanan Exploits Subzone of central Newfoundland. On a regional scale, the sub-Silurian unconformity between Notre Dame Subzone basement and its volcanic cover is now tectonically situated within a southeast-dipping Early Devonian tectonic wedge that also contains the dormant Red Indian Line and the structurally underlying, northwest-dipping Silurian boundary thrusts of the Badger Basin. Prior to the eruption of the oldest dated ignimbrite in the terrestrial Botwood Basin (ca. 429 Ma; Charles Lake Volcanics), an early phase of thrusting locally affected Llandovery and older marine strata in the Badger Basin and, in some localities, the stratigraphically underlying arc-related rocks and limestones of the Exploits Subzone may possibly have also been involved in this event. These particular northwest-dipping structures result from orogen-parallel displacement during sinistral transpression.

In some places, these foliation-parallel thrust faults are interpreted to have reactivated the margins of syndepositional graben that had formed, in part, during a Late Ordovician phase of intrabasinal extension and related subsidence. Katian debris flows developed in Pushgillian strata around ca. 453 Ma, in Cauteleyan strata around ca. 449 Ma and in Rawtheyan strata around ca. 447 Ma. Interstratified with unbroken Katian successions of graptolite-bearing distal turbidites, these debrites contain early Sandbian (ca. 460 Ma) extraclasts and large Darriwilian (ca. 468 Ma) olistoliths that were exhumed from horsts underlain by the once buried substrate of the Exploits back arc basin. Moreover, Hirnantian canyon-fill limestone conglomerates (ca. 446 Ma; Point Leamington Formation) and partially broken slump sheets of Aeronian calc flysch (ca. 437 Ma; Upper Black Island greywacke) contain coeval and older blocks of the reefal carbonates that typify many of the peri-Gondwanan terranes. However, during the late Early Silurian (ca. 436–430

Ma; Telychian or Llandovery C4-C6; upper Goldson conglomerate), some of the coarse detritus seen in the upward-thickening polymictic lenticles may have been sourced from uplifts in the peri-Laurentian Taconic Arc, including those within the easternmost and youngest tract of the Notre Dame Subzone.

It is postulated that a Mid Paleozoic slab of sub-continental Appalachian lithosphere dipped beneath the fossilized Iapetan suture in the Dunnage Zone and that an affiliated upper plate arc migrated southeastward toward the Rheic Ocean between the Late Ordovician and Early Silurian. Thus, in this way, the basin-and-range province of peri-Laurentia is thought to be geodynamically related to the peri-Gondwanan Badger retro-arc foreland basin. Subsequent transpressional collision of the Badger Basin with the southeasterly adjacent Botwood Basin occurred after the detachment of the retreating slab, although it is unknown if the encroaching oceanic lithosphere lay to the west or east of Penobscot-sutured Ganderia.

Present-day serpentinization of ultramafic mantle rocks by meteoric groundwater, Bay of Islands Ophiolite Complex, Newfoundland

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The Bay of Islands Ophiolite Complex is a well preserved ophiolite complex comprising rocks of the oceanic crust and mantle located in western Newfoundland. The mantle peridotite from the complex exposed on the mountains of the Tablelands is composed largely of the minerals olivine [$(Mg,Fe)_2SiO_4$] and pyroxene [$(Ca,Mg,Fe)_2Si2O_6$] which are unstable near the Earth's surface and react with H_2O and CO_2 (serpentinization) in near surface environments producing Mg–HCO_3-type waters. Reaction of Mg–silicate and these Mg–HCO_3-waters out of contact with the atmosphere consumes H+ and leads to the precipitation of magnesite and dolomite. The waters formed from these reactions are progressively richer in Ca and OH^-, are supersaturated with respect to brucite, serpentine and diopside, and have a high pH of c. 12. When these Ca–OH-type waters flow near the surface and mix with Mg–HCO_3-waters and the atmosphere, they precipitate calcite and dolomite in near surface veins and carbonate cement in unconsolidated sediments and travertine. The Ca–OH-type waters are incompatible with minerals in adjacent country rocks and form a Ca–rich metasomatic zone or rodingite assemblage along the contact.

The metamorphic change from olivine (Fe^{2+}) to magnetite (Fe^{3+}) during serpentinization occurs at temperatures <200°C and creates a highly reducing environment leading to the reduction of water to H_2 and abiotic production of hydrocarbons (graphite & methane). Similar elevated abiotic hydrocarbon concentrations have been reported from submarine ultramafic hosted systems in which geological, chemical and biological processes are intimately interlinked and support dense microbial communities. The conditions associated with serpentinization of ultramafic rocks by meteoric waters may be similar to those present during early Earth (and other telluric planet) formation and could be a common means for producing precursors of anaerobic organisms that may represent the earliest life forms on Earth.

Possible applications for visible/infrared reflectance spectroscopy (VIRS) in exploration for rare-earth elements

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Visible-Infrared Reflectance Spectroscopy (VIRS) uses absorption responses to electromagnetic radiation of 350–2500 nm wavelengths to characterize natural materials and identify minerals that have distinct absorption spectra. Its principal application in exploration geoscience is in the study of hydrothermal alteration assemblages, but the current interest in exploration for rare-earth element (REE) deposits awakened our interest in possible applications to this type of mineralization. Some interesting possibilities emerged from pilot studies.

Individual REE oxides have unusual absorption responses in the visible region (390 nm–750 nm) and notably in the near infrared (NIR; 750 nm to 1300 nm), which is normally a relatively "quiet" region for natural minerals. REE-bearing minerals (e.g., monazite, bastnaesite, betafite and xenotime) also produce these unusual NIR absorption features. This behaviour is related to the unique electron shell configurations of the lanthanide elements, and the absorption patterns are highly specific. However, there are presently few spectra from REE-bearing minerals in the available reference databases, and such minerals typically show wide variations in composition, including REE distributions. Notwithstanding these complications, VIRS data acquired from mineralized samples in several areas of Labrador reveal distinctive spectral responses indicative of REE, even though their exact mineralogical sources are not yet readily identifiable. This implies that VIRS analysis could be used to test for potential REE mineralization in samples identified on the basis of other criteria such as anomalous radioactivity. However, the threshold for such detection is as yet unknown. The diverse styles of REE mineralization now identified in Labrador afford us an opportunity to gather and distribute VIRS absorption spectra for unusual minerals, which may be useful to explorationists elsewhere. As an example, the first reference spectra for the Na-Ca-Fe-Zr-REE silicate eudialyte (from the Red Wine Mountains area) are presented and discussed.

The VIRS method may also be of use as a first-order tool for recognizing favourable host rocks to REE mineralization. This type of mineralization is commonly associated with peralkaline igneous suites. Peralkalinity is a geochemical characteristic that can be discerned through whole-rock analyses, but it is also manifested by primary Na-Fe-rich chain silicates such as aegirine (a pyroxene) and arfvedsonite or reibeckite (amphiboles). These minerals are similar to common igneous pyroxenes and amphiboles, but can be identified through their short-wave infrared (SWIR; 1300 nm to 2500 nm) absorption responses. Thus, VIRS methods may be able to confirm compositionally suitable host rocks from hand samples, without making thin sections or obtaining analyses.

The setting of Au-Ag-Te mineralization at the Aucoin prospect (NTS 13N/06) Hopedale Block, Labrador

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The Aucoin gold prospect is located 70 km west of Hopedale in the Archean Hopedale Block of Labrador (NTS 13N/06). Remarkably, it represents one of only two examples of gold mineralization in Labrador that have been tested by drilling. It was discovered in 1995 via ground prospecting in the vicinity of a single gold-in-lake sediment geochemistry anomaly, obtained from a regional government survey. Trenching and grab sampling have yielded assays of up to 478 g/t Au with >100 g/t Ag and, diamond drilling has yielded intercepts of up to 12.4 g/t Au with 14 g/t Ag over 1.05 m.

The mineralization occurs within an array of anastamosing, discontinuous, northeast- and northwest-trending white quartz veins (typically <20 cm wide) that are associated with a northwest-southeast-trending, strongly chlorite-ankerite-epidote-talc ± sericite altered and sheared curviplanar contact zone between massive to weakly foliated syenite and cogenetic monzodiorite. The weak foliation is interpreted as primary magmatic layering. High gold assays correlate with elevated silver and tellurium, reflected by the presence of argentiferous electrum and Ag-Au telluride (petzite?) occurring as inclusions in pyrite, chalcopyrite and in association with rutile replacing ilmenite. Rare wire gold has been reported at the margins of the veins.

The Aucoin mineralization was previously inferred to be hosted by Archean granitoid gneisses. These are cut by 2235 Ma, vertical diabase dykes with chill margins that were inferred to correlate with the regionally extensive Kikkertavak dyke swarm. Based on the presence of mineralized "diabase dykes" the mineralization was inferred to be younger than the Kikkertavak dykes but likely Paleoproterozoic in age. The fresh igneous nature of the unaltered syenite and monzodiorite host rocks to the mineralized quartz veins, along with their alkaline character, however, suggests an alternate interpretation. The alkaline host rocks are herein inferred to correlate with either the ca. 1500–1420 Ma, intermediate rocks of the Harp Lake Complex or, alternatively, those of the 1350–1290 Ma Nain Plutonic Suite. If this inference is correct, then precious metal mineralization at Aucoin is likely Mesoproterozoic or younger in age and may have a direct magmatic connection with the alkaline plutonic host rocks. Further geoscientific data acquisition, including U-Pb geochronology of the syenite and $^{40}Ar/^{39}Ar$ thermochronological investigations of alteration are currently underway.

The reconstruction of the Pleistocene-Holocene turbidite sand delivery in Gulf of Papua aided by SEM-MLA provenance analysis

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An integrated provenance, textural and chronostratigraphic analysis of Pleistocene-Holocene turbidite sand in the Gulf of Papua (NSF Source to Sink Focus Area) has been undertaken to elucidate glacioeustatic influences on sedimentary behaviour in a modern deepwater depositional system. Sands were sampled in seven jumbo piston cores from the slope and basin floor, yielding 53 samples. A quantitative modal mineralogy analysis was conducted using scanning electron microscopy (SEM) and mineral liberation analysis (MLA) of ~15,000 individual grains per sample. Tests using the Gazzi-Dickinson ternary diagram show a lack of differentiation among samples. Although free from grain-size effects, use of this diagram is strongly affected by the detailed mineralogical classification that results from automated MLA. MLA does allow sample differentiation using heavy minerals sensitive ratio and multivariate analysis such as non metric multidimensional scaling (nMDS) and principal component analysis (PCA).

Time-sliced provenance based on our C-14 age model shows three major pathways: (1) long-distance northwest-southeast sediment transport of quartzofeldspathic sand sourced from the Papuan Mainland, delivered from the Fly-Strickland fluvial system through Pandora shelf and slope (core MV-54), Pandora basin floor (cores MV-23, 33) and Moresby Channel (MV-25, 29), characterized by low m/f and pumice content and decreasing of l/h-hm and unstable/tourmaline (uti) ratio basinward; (2) short-distance NNE-SSW transport of felsic-mafic volcanic sand apparently from the collision margin of the Papuan Peninsula, delivered via small rivers narrow shelf, and deep-sea canyons (MV-22) characterized by high m/f ratio without distinct pattern of heavy minerals ratio and (3) intermediate-distance delivery from the Fly-Strickland and Papuan Peninsula along coastal pathways to the Moresby Trough (MV-22) characterized by high pumice contents, overall low in uti and l/h-hm. The vertical provenance pattern shows that the Pandora Trough samples (MV 23, 33, 54) were entirely pathway 1 during the time period 44–17 Ka, while Moresby Trough received sediment via pathway 1 (MV-25, 29) and pathway 2 (MV-22), gradually shifting to pathway 3 from late Pleistocene to the middle Holocene. We also suggest that the Gazzi Dickinson scheme be re-evaluated in light of powerful new automated MLA techniques, to allow better sample discrimination in fine-grained lithic and felsic sands typical of our study area, and many other deep-water basins.

The application of CR-39 autoradiographs in the textural analysis of uranium-bearing samples and thin sections

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The search for uranium mineralization is often aided by specialized instrumentation such as a scintillometer, which enables you to locate exposures of anomalous radioactivity; however, determining the actual distribution of the mineralization within geological samples is often somewhat more problematic. The use of CR-39 as a solid state nuclear track detector (SSNTD) in the textural analysis of radioactive minerals in geological samples was first described by I.R Basham in 1981. CR-39 autoradiographs provide a detailed, high-resolution picture of the in-situ distribution of the radioactive minerals within geological samples on both the macroscopic and microscopic scales. The procedure for developing these radiographic images requires no specialized laboratory facilities and can be carried out in the field during active exploration. The resultant images provide a relatively cheap and effective means of obtaining detailed textural information that provides insight into the style of mineralization, its relationship to primary and secondary structures in the host rock, and its association with particular geological features or mineral phases. Although this technique does not provide any information as to the identity of the minerals responsible for the radioactivity, the resultant autoradiographs can be used to select regions for further detailed study such as petrography, microprobe analysis, or SEM imaging.

Geochemistry of ultrabasic reducing waters at a continental site of present-day serpentinization in the Tablelands, Gros Morne National Park, Newfoundland

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Abiogenic hydrocarbons (produced geologically by the reduction of oxidized forms of carbon) have been hypothesized to be possible precursor compounds from which life originated. Apart from being geologically synthesized hydrocarbons can also form through microbial processes or by thermally induced decomposition of once living organic matter. These hydrocarbons are known as biogenic hydrocarbons. Understanding the reaction pathways by which abiogenic hydrocarbons form on Earth and differentiating between abiogenic and biogenic hydrocarbons can help better understand the processes that are responsible for past and present life.

Serpentinization – a reaction between water and ultramafic rock (derived from the mantle) – is suspected to be a source of hydrocarbons on early Earth and potentially on other ultramafic planetary bodies. Through the hydration of ultramafic rock, this reaction produces hydrogen gas (H_2) and reducing conditions necessary for abiogenic hydrocarbon synthesis, while also producing conditions amendable for the production of methane through microbial chemoautotrophic pathways.

Today, exposed rocks from the Earth's mantle can be found in few rare continental locations that exhibit present-day serpentinization. One such location is found in the Tablelands Ophiolite, in Gros Morne National Park, Newfoundland. Present-day serpentinization at the Tablelands is evidenced by fluid seeps characterized by their high alkalinity (~pH 11–12), highly reducing conditions (as low as −820 mV), high Ca^{2+} /Mg^{2+} ratios, and the presence of dissolved methane and other lower molecular weight hydrocarbon gases. These fluids contain high concentrations of Ca^{2+} (~5.00×10^4 ppb) compared to freshwater inputs (~ 1.00×10^3 ppb) and react at the surface with atmospheric CO_2 producing travertine deposits (as $CaCO_3$ precipitate), which is also characteristic of serpentinization localities. Isotopic and geochemical analysis of the fluids, dissolved hydrocarbon gases, and carbonates will be discussed to help understand how methane and other low molecular weight hydrocarbons are produced in the serpentinized fluid seeps at the Tablelands Ophiolite; and how the information can be useful in our understanding of the past and present carbon cycle, prebiotic chemistry, and the evolution of chemolithotrophy on early earth and other ultramafic planetary bodies.

Drilling challenges in the direct shipping iron ores of the Labrador Trough (Schefferville area)

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Labrador Iron Mines Limited (LIM) is currently in the process of defining Direct Shipping Iron Ore Resources in the Western Labrador / Schefferville area of the Labrador Trough ahead of the start-up of mining at the James and Redmond deposits in the spring of 2011. The Iron Ore Company of Canada (IOC) previously mined approximately 150 Mt of Direct Shipping Iron Ore (DSO) from the area during the period 1954 to 1982.

The hematite (DSO) is often very soft and friable and often occurs as alternating layers of hard and soft mineralization. Moisture content of the ores can reach as high as 14% and porosity can be as high as 45%. LIM initiated drilling in 2006 using a diamond drill coring rig. Recovery using a coring rig in the soft iron ores proved to be very unsuccessful and the drilling process had to be re-evaluated. In 2008, LIM adopted the Reverse Circulation (RC) method of drilling the soft iron ores. This method was further refined in the 2009 and 2010 field seasons. RC Drilling uses a water and air injecting tricone drill bit and double tube drill rods to remove the drill cuttings and bring them to surface. The drill cuttings / chips then pass through a cyclone, rotary wet splitter and finally a "knife splitter" to produce a sample in three fractions: the sample itself, a witness sample and a discard sample. This method requires a sampling crew composed of one rig geologist, a senior sampler and a junior sampler to be present at the drill rig at all times. All drill chip logging is carried out simultaneously as the hole is being drilled. In addition, an extensive QA/QC program has been implemented to test sampling at all stages.

A. P. Low's 1893–1894 expedition through the Labrador Peninsula: a tale of iron and irony

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Albert Peter Low (1861–1942) was a geologist with the Geological Survey of Canada (GSC) who made a pioneering trek through Québec and Labrador in 1893–1894, travelling the major rivers of northeastern Québec and central and western Labrador and documenting the geology exposed therein. In June 1893, Low's party set off from Lac St. Jean canoeing to Lake Mistassini thence to the headwaters of the East Main River then over to the headwaters of the Koksoak River and finally downstream into Ungava Bay. By steamship from there, they arrived in Rigolet in October 1893 and proceeded to North West River. Staring in the late winter of 1894, the crew travelled up the Hamilton (Churchill River) portaging around Grand (Churchill) Falls and into Lake Michikamau and then along the Ashuanipi and Attikonak rivers. During their travels through western Labrador, Low documented the vast iron ore resources of the region. The crew then proceeded by difficult portages along the Romaine to St. John rivers to Mingan on the north shore of the St. Lawrence River; 16 months after they started from Lac St. Jean. Low estimated the expedition covered a total of 8736 km as in canoe, 4736 km; on vessel, 1600 km; with dog-teams, 800 km; and on foot, 1600 km. The Low expedition provided a veritable cornucopia of data on what was, at the time, a last great unexplored wilderness of North America.

