



An appraisal of Québec's extensive geochemical database

Introduction

Over the last decade, the Province of Québec, in Canada, has remained amongst the world's five most attractive mining jurisdictions, largely due to its policies and mineral potential (McMahon & Cervantes, 2011). The *Ministère des Ressources naturelles et de la Faune* (MRNF), through *Géologie Québec*, is responsible for the development of Québec's geoscientific knowledge over an area exceeding 1.5 million km². Its mandate was reaffirmed and clarified in 2009 within the scope of the Québec's Mineral Strategy (Government of Québec, 2009). *Géologie Québec*'s mission is to acquire, process, and disseminate knowledge on the mineral resources of Québec, in order to assess and promote its mineral potential in a sustainable development perspective. Since 2008, continued and stable funding through the Natural Resources Fund (Mining Heritage Program) provides *Géologie Québec* with the means to ensure the development of Québec's mineral potential.

Québec's territory consists of five geological provinces (Fig. 1) that contain rocks ranging in age from 3 800 to 120

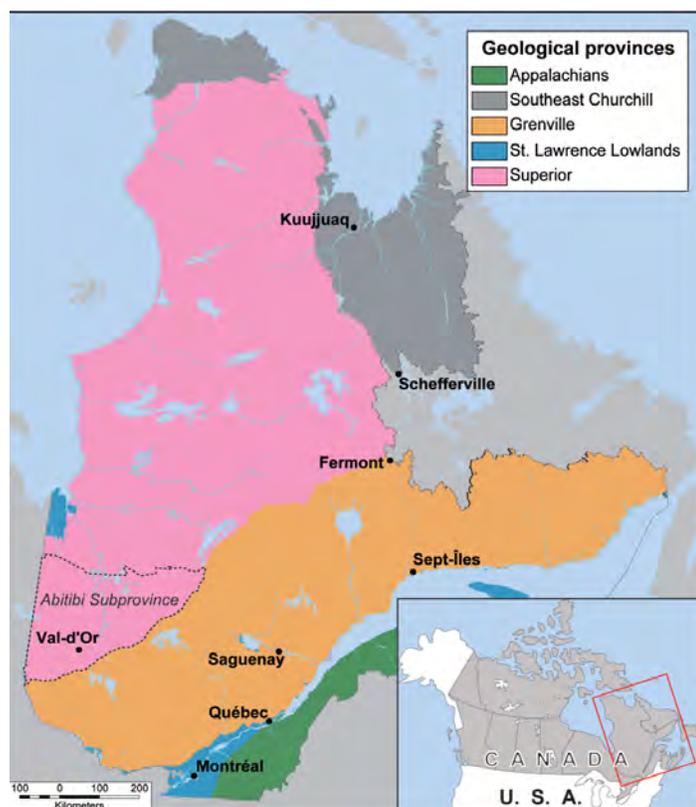


Figure 1. The geological provinces of Québec in Canada.

continued on page 4 –

Note: This EXPLORE article has been extracted from the original EXPLORE Newsletter. Therefore, page numbers may not be continuous and any advertisement has been masked.

An appraisal of Québec's extensive geochemical database ... continued from page 1

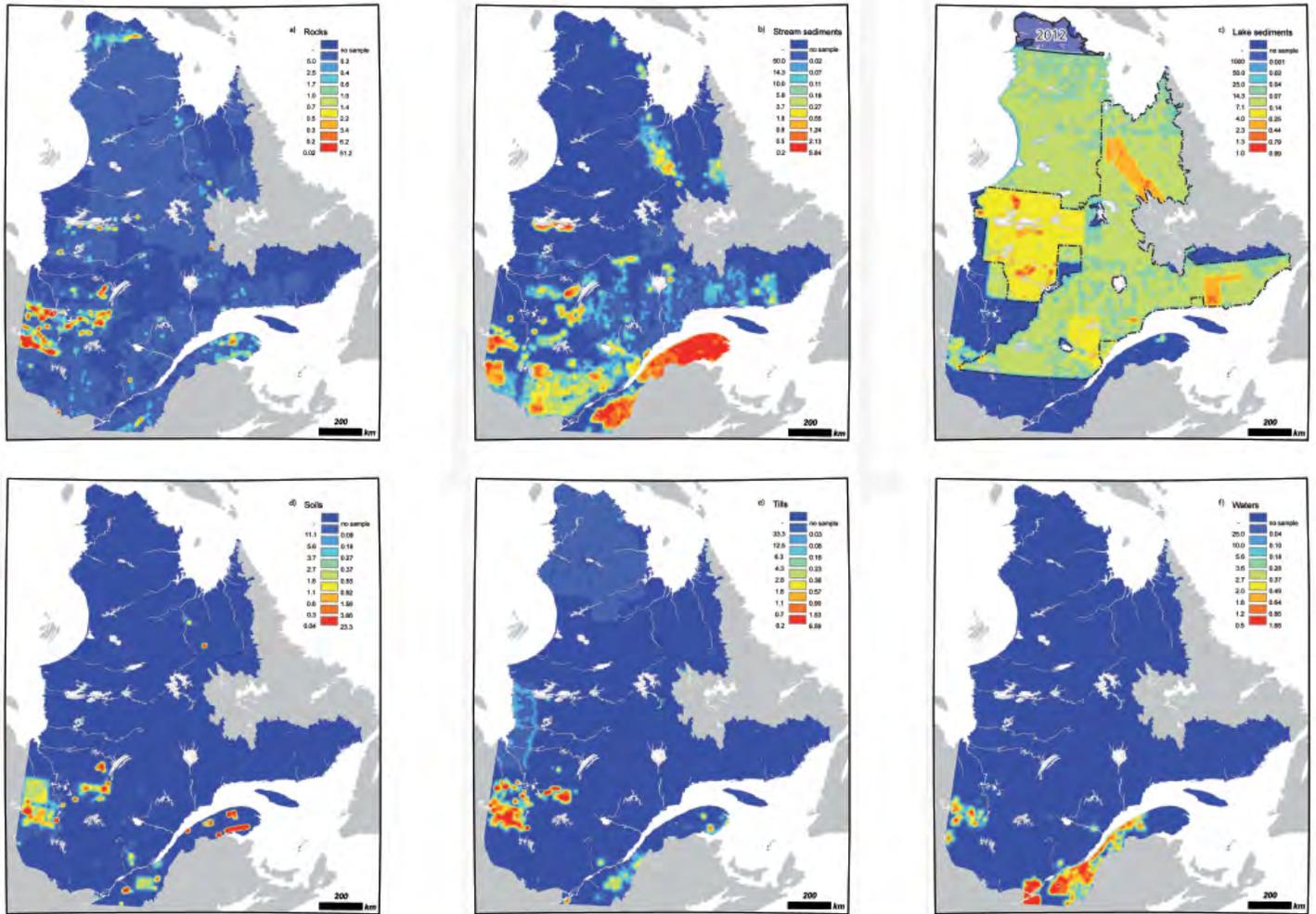


Figure 2. The sample density (or spatial resolution) of geochemical surveys conducted in the Province of Québec, Canada, accordingly to sample media. The images were produced using the Density tool from Spatial Analyst in ArcGIS. Search radii of 15 km and output cell sizes of 1 km² were computed. The color scale for the density plots are based on a division into 10 classes using the quantile method, with the exception of lake sediments for which the geometrical interval method was preferred. The values to the left of the colour chart represent the number of km² covered by a sample. The values to the right reflect the number of samples per km². The dashed line in 2c) outlines the coverage of recent ICP-MS analyses.

million years. Most of the Province is comprised of rocks of Precambrian age that were covered by glaciers during the Quaternary, leading to the deposition of surficial deposits. Lithochemical and surficial geochemical surveys are a key element of mineral discoveries in remote glaciated terrains, and are an important component of *Géologie Québec's* geoscientific programme. The Province maintains a comprehensive geochemical database that includes more than 750,000 analyses for which a replacement cost was estimated in excess of 134 M\$. More than 243,000 samples are rock analyses acquired during geological mapping surveys and exploration programs, and over 510,000 samples were acquired from surficial geochemical surveys (Table 1). However, only 5% of the data for surficial geochemical surveys conducted on Québec's territory are actually included in the compilation of the Geological Survey of Canada (*cf.* the Geoscience Data Repository – GDR: Spirito & Adcock, 2009; Spirito & Adcock, 2010). This article describes the content of Québec's geochemical database to the applied geochemists' community, and reports on the recent advances made by additional coverage of its territory

and the reanalysis of archival samples. More precisely, we will show how the data are being used to enhance geochemical anomalies and produce first order exploration targets.

Québec's gateway to geoscience data: the SIGEOM database

Geoscience data available in the Province are accessible via Québec's Geomining Information System (SIGEOM¹). This system contains geoscientific data derived from work conducted by *Géologie Québec*, exploration and mining companies, and universities. It contains both raw data of a geological (descriptions of outcrops, mineral deposits, drill holes...), geophysical (electromagnetic, magnetic, gravimetric...), or geochemical (rock or surficial sediment) nature, as well as geological data interpreted by geoscientists (contacts, faults, geochronology, etc.). In addition, the documentary database (e-SIGEOM-Examine) provides access to the geoscientific documentation of Québec,

1 http://sigeom.mrnf.gouv.qc.ca/signet/classes/I1102_indexAccueil?l=a

An appraisal of Quebec's extensive geochemical database ... continued from page 4

whether it is derived from the work of *Géologie Québec* (geological reports and studies, geological maps, mineral potential assessment maps), or from exploration work conducted by industry (assessment work reports including results of mapping, drilling, geochemical and geophysical surveys).

Sample media	Number of samples	Comments
<i>Rocks</i>	(243 549)	
Litho geochemistry	199 304	
Assays	44 245	
<i>Surficial - sediments and waters</i>	(510 673)	
Stream	230 362	
Lake sediment	124 651	includes 85 542 samples analyzed by ICP-MS
Soil	76 036	undifferentiated horizons
Till	40 751	fine, heavy and/or light fractions
Water	38 873	ground, surface, spring, well and bore hole waters
Total	754 222	

Table 1. Summary of the content of Québec's geochemical database.

Overview of geochemical data

The SIGEOM database keeps track of over 750,000 analyses collected from different media. As summarized in Table 1, rock samples consist mostly of litho geochemical analyses, whereas surficial samples contain mostly stream and lake sediments. Figure 2a shows the density of rock analyses, a measure that can be employed as a proxy for the extent of geological knowledge in the Province. For instance, areas with no rock samples represent those in which *Géologie Québec* has not yet undertaken mapping programmes or those that were mapped prior to the 1980s, when litho geochemical analyses were uncommon. As a counterpart, the greater density observed in the Abitibi Subprovince and the Cape Smith Belt reflects the large input of analyses from both surface outcrops and exploration drill holes.

Stream sediment surveys have historically been more common in the southern portion of the Province, in part because of easier road access, but coverage exists at different scales and spatial resolutions elsewhere (Fig. 2b). Conversely, lake-bottom sediments were the preferred sample medium in remote northern regions, and a large portion of Québec's territory is now covered at a density of at least ~1 sample per 15 km² (Fig. 2c). The coverage varies according to the sampling density chosen for the various programmes undertaken since the 1970s and is extended

continued on page 6

An appraisal of Quebec's extensive geochemical database ... continued from page 5

Ressources naturelles et Faune Québec

e-sigeom à la carte

español > française > confidentiality policy > Help

To choose a map already carried out by the SIGÉOM.

- **E-Sigeom (Atlas)**

Products from the atlas

E-Sigeom Atlas represents the overall geoscientific products in geomatic format of the sector of energy and mining of the Ministry of natural Resources and Wildlife. Functionalities include queries, viewing maps and online ordering.

To create a map according to your own search criteria starting from the data of the SIGÉOM and of GESTIM.

- + **E-Sigeom (Examine)**
- + **Mining titles**
- + **Geology**
- + **Geochronology**
- + **Geophysics**
- **Geochemistry**
 - Rock sample**

The rock samples designate the rock sampling on the site for the purpose of determining the content of various compounds and/or chemical elements.
 - Sediment sample**

The sediment samples represent the sampling of the site's secondary environment (tills, heavy minerals, brook or lake sediments, etc.) to determine the content of various chemical elements.
- + **Deposits**
- + **Glacial transport**
- + **Quaternary geology**
- + **Drilling**
- + **Hydrogeology**

Québec

© Gouvernement du Québec, 2003

Figure 3. The SIGEOM portal.

by further sampling in the vicinity of specific geochemical anomalies. The nature of surficial deposits in given areas also influences coverage as, for instance, no lake sediment samples exist for a large portion of the Abitibi Subprovince because of the thick cover of glaciolacustrine clay.

Soils and tills have been sampled for a large portion of the Abitibi, and to a lesser extent the Appalachians (Figs. 2d and 2e). The coverage or spatial resolution for soil and till surveys remains restricted for other areas. Finally, analyses of water samples are focussed around the Montréal region, along the southern shore of the St. Lawrence River, and in the Abitibi Subprovince (Fig. 2f).

continued on page 7

An appraisal of Quebec's extensive geochemical database ... continued from page 6

Figure 4. The querying page for surficial samples.

Access to geochemical data

The raw geochemical data are accessed from the SIGEOM portal (Fig. 3) under “Geochemistry”, and then by choosing either “Rock sample” (litho geochemistry and assays) or “Sediment sample” (surficial samples). A click then forwards the users to a querying page (Fig. 4) where their search can be refined by using geographical, physical, descriptive and/or analytical parameters. The available values for coded variables (e.g. NTS map-sheet, sample type, chemical element and analysis method) are accessed by clicking the “Values” button, and then by selecting the appropriate entry from the html popup or Java™ Platform window. The results of the query, including analytical results, may be directly consulted on the screen, and the location of the samples viewed from the Google Earth™ plug-in. Once the user has created an account, the data can be ordered and downloaded in ArcGIS(FGDB) or ArcView(Shape) format through a secured e-payment protocol.

Acquiring new data and improving the database

Maintaining such a large geochemical database obviously presents challenges, as a large number of analytical variables (digestion and instrumental methods, accuracies, detection limits, laboratories...) acquired across many years are brought together (Grunsky, 2007). Successfully integrating analytical data from a collection of geochemical surveys focused on distinct media or size fractions may become puzzling. As such, the improvement of Québec's geochemical database has recently been centered on the rejuvenation of its lake-bottom sediment database. Since 2008, over 85 000 samples were analyzed for a suite of 53 elements from a single laboratory using the ICP-MS method with *aqua regia* digestion (Fig. 2c). From this total number of samples,

12 000 represent newly collected samples and 73 000 are reanalyses from archived samples (Labbé & Moukhsil, 2008; Labbé, 2009; Hurtubise et al., 2009; Maurice & Labbé, 2009; Morin et al., 2010; Labbé, 2011). With the publication in 2012 of the analytical results for ~3 000 new samples from the northern portion of the Ungava Peninsula (Fig. 2c), the entire Province will have a near-complete coverage at a minimum density of 1 sample per 15 km² to the North of latitude 47°15'N.

Geochemical levelling, exploration targets and assessment of mineral potential

Concerned with the need to offer both unprocessed data and integrated products to its customers, *Géologie Québec* publishes thematic projects that use and build upon the geochemical database. One of these projects is aimed at identifying anomalous geochemical zones for eleven metallic elements (Ag, As, Au, Co, Cu, Li, Mo, Ni, U, Y and Zn) from surficial sediment media (lakes, streams, tills and soils) existing in the SIGEOM database (Lamothe, 2009a, Lamothe, 2011a). An ArcGIS ModelBuilder model was built to define the anomalous zones using a natural break method based on populations from geological domains considered to be relatively homogenous. The favourability of these zones for containing metallic concentrations was then calculated using the weights of evidence method from a collection of known metal deposits. The resulting atlas constitutes a land management tool for the under-explored portions of the Province.

Another project has focused on the resolution of the discrepancies arising between lake-bottom sediment

An appraisal of Quebec's extensive geochemical database ... continued from page 7

surveys and produced levelled images from 13 distinct surveys acquired between 1973 and 2009. To this end, a series of maps portraying the backgrounds of 23 elements at the scale of the Province has been produced in Google Earth™ format². A set of 18 elements from this levelled

² The maps were produced using a software designed by CONSOREM (Trépanier, 2007) and are available at <http://www.mrnf.gouv.qc.ca/english/mines/publications/publications-maps.jsp> for the elements Al, As, Ba, Ca, Ce, Cr, Co, Cu, Fe, La, Li, Mg, Mn, Mo, Ni, P, K, Th, Ti, U, V, Y and Zn.

Models	Areas	References
Volcanogenic massive sulphides	Superior Province (Abitibi)	Lamothe et al., 2005; Lamothe, 2011b
Orogenic gold (Abitibi)	Superior Province 2006	Lamothe & Harris, 2006
Cu-Au-Mo porphyries	Superior Province (Abitibi)	Labbé et al., 2007
Orogenic gold	Superior Province (Baie-James)	Lamothe, 2008
Cu-Au-Mo porphyries	Superior Province (Baie-James)	Lamothe, 2009b
Rössing-type U and Iron oxide Cu-Au-U	Grenville Province	Trépanier, 2009

Table 2. List of mineral potential assessments made in the Province of Québec since 2005.

database was then used to define discrete exploration targets (Lamothe, 2011a) using a method of multivariate spatial regression (Trépanier, 2006 and references therein). This method has proven to be effective for determining exploration targets from samples that do not initially yield significant metallic concentrations. It was used to identify targets for five elements (Cu, La, Ni, U, Zn) that are not specifically associated with a geological context, and for three distinct metallogenic models: 1) Cu or Zn associated with volcanogenic massive sulphide (VMS) deposits; 2) Ni or Cu associated with magmatic deposits; and 3) Cu, U or La associated with enriched iron oxide deposits.

Finally, the geochemical data contained in the SIGEOM database are recurrently included into projects assessing the mineral potential for a variety of metallogenic models in given areas of the Province (Table 2). These assessments combine together various data sources (e.g. geology, geophysics, geochemistry) in order to quantify and identify exploration targets that are not currently under examination by mineral exploration companies. The continuous additions and upgrades made to the SIGEOM database help to better define the portrait of Québec's mineral potential, but also pave the way to better address environmental issues in a

world that sees sustained development becoming everyone's concern.

Acknowledgments

J. Moorhead and S. Lacroix reviewed and contributed to the clarity of the message. J. Jobidon and O. Rabeau helped with drafting the figures. The authors also wish to thank B. McClenaghan and W. Spirito for reviewing and improving an earlier version of this article. *Ministère des Ressources naturelles et de la Faune* contribution #BEGQ-8439-2011-2012-06.

References

- GOVERNMENT OF QUÉBEC, 2009. Preparing the future of Québec's mineral sector. Québec mineral strategy. Gouvernement du Québec, Bibliothèque nationale du Québec.
- GRUNSKY, E. C. 2007. The interpretation of regional geochemical survey data. In: MILKEREIT, B. (ed.) *Exploration in the New Millennium. Proceedings of the Fifth Decennial International Conference on Mineral Exploration*, 1, 139-182.
- HURTUBISE, E., MORIN, S.-J. & LABBÉ, J.-Y. 2009. New geochemistry data for lake-bottom sediments in the Minganie and Bass-Côte-Nord areas. *Ministère des Ressources naturelles et de la Faune, Québec report PRO 2009-02*.
- LABBÉ, J.-Y., PILOTE, P. & LAMOTHE, D. 2007. Assessment of the potential for porphyry Cu-Au-Mo deposits in the Abitibi. *Ministère des Ressources naturelles et de la Faune, Québec report EP 2007-01*.
- LABBÉ, J.-Y. & MOUKHSIL, A. 2008. New lake-bottom sediment geochemistry data in the Sept-Rivières MRC (Sept-Îles area). *Ministère des Ressources naturelles et de la Faune, Québec report PRO 2008-08*.
- LABBÉ, J.-Y. 2009. New lake-bottom sediment geochemistry data in the western Grenville province in Québec: areas near Val-d'Or, Chibougamau and La Tuque. *Ministère des Ressources naturelles et de la Faune, Québec report PRO 2009-04*.
- LABBÉ, J.-Y. 2011. New lake-bottom sediment geochemistry data in the Saguenay-Lac-St-Jean region. *Ministère des Ressources naturelles et de la Faune, Québec report PRO 2011-02*.
- LAMOTHE, D., HARRIS, J. R., LABBÉ, J.-Y. et al. 2005. Assessment of the potential for volcanogenic massive sulphide (VMS) deposits in Abitibi. *Ministère des Ressources naturelles, de la Faune et des Parcs, Québec report EP 2005-02*.
- LAMOTHE, D. & HARRIS, J. R., 2006. Assessment of the potential for orogenic gold deposits in the Abitibi. *Ministère des Ressources naturelles et de la Faune, Québec report EP 2006-02*.
- LAMOTHE, D. 2008. Assessment of the potential for orogenic gold deposits in the Baie-James region.

An appraisal of Quebec's extensive geochemical database... continued from page 8

- Ministère des Ressources naturelles et de la Faune, Québec report EP 2008-02.
- LAMOTHE, D. 2009a. Cartes géochimiques ModelBuilder et cibles anormales de l'environnement secondaire pour le Québec. Ministère des Ressources naturelles et de la Faune, Québec report GM 64290.
- LAMOTHE, D. 2009b. Assessment of the potential for porphyry Cu-Au ± Mo deposits in the Baie-James region. Ministère des Ressources naturelles et de la Faune, Québec report EP 2009-02.
- LAMOTHE, D. 2011a. Modelling targets in the secondary environment by the natural break and multivariate spatial regression techniques. Ministère des Ressources naturelles et de la Faune, Québec report EP 2010-02.
- LAMOTHE, D. 2011b. Potentiel en minéralisations de sulfures massifs volcanogènes de l'Abitibi – version 2011. Ministère des Ressources naturelles et de la Faune, Québec report EP 2011-01.
- MAURICE, C. & LABBÉ, J.-Y. 2009. Reanalysis of lake-bottom sediments in Northeastern Québec (Ashuanipi Subprovince, New Québec Orogen, Southeast Churchill Province). Ministère des Ressources naturelles et de la Faune, Québec report PRO 2009-10.
- MCMAHON, F. & CERVANTES, M. 2011. Survey of Mining Companies 2010/2011. Fraser Institute annual report.
- MORIN, S.-J., HURTUBISE, E. & LABBÉ, J.-Y. 2010. New lake-bottom sediment geochemistry data in the Côte-Nord region. Ministère des Ressources naturelles et de la Faune, Québec report PRO 2010-02.
- SPIRITO, W. A. & ADCOCK, S. W. 2009. The Canadian Database of Geochemical Surveys: user manual for the metadata website. Geological Survey of Canada, Open File 5936.
- SPIRITO, W. A. & ADCOCK, S. W. 2010. Canadian geochemical data on the web. EXPLORE, 149, 2–8.
- TRÉPANIÉ, S. 2006. Identification de domaines géochimiques à partir des levés régionaux de sédiments de fond de lac – Phase 2. Ministère des Ressources naturelles et de la Faune, Québec report 65081.
- TRÉPANIÉ, S. 2007. Identification de domaines géochimiques à partir des levés régionaux de sédiments de lac. Ministère des Ressources naturelles et de la Faune, Québec report GM 62922.
- TRÉPANIÉ, S. 2009. Évaluation du potentiel en uranium et en Cu-Au-U et cartographie prévisionnelle d'intrusions mafiques-ultramafiques dans le Grenville. Ministère des Ressources naturelles et de la Faune, Québec report EP 2009-03.

Charles Maurice

*Bureau de l'exploration géologique du Québec
Géologie Québec
Ministère des Ressources naturelles et de la Faune
400 boul. Lamaque, office 1.02
Val d'Or, QC
CANADA J9P 3L4
charles.maurice@mrrnf.gouv.qc.ca*

Daniel Lamothe

*Bureau de l'exploration géologique du Québec
Géologie Québec
Ministère des Ressources naturelles et de la Faune
880 chemin Ste-Foy, 3rd floor
Québec, QC
CANADA G1S 4X4
daniel.lamothe@mrrnf.gouv.qc.ca*

