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Characterization of crustal-scale structures interpreted from gravity "worms" and their relationships to hydrothermal alteration and mineralization, Granville Province, SW Quebec

Par

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SUMMARY OF PROGRESS

Enhancement of regional gravity and aeromagnetic data, gravity worming, and fault interpretation has been completed for the following sectors of the Grenville Province:

- SW Quebec & N Ontario (Grégory Dufréchou)
- North-central and eastern Quebec (Lyal Harris)
- Area between Montreal and Québec City, with detailed interpretation of the area immediately N of Quebec City (Lyal Harris).

Fieldwork was undertaken to find and examine structures and evidence for hydrothermal alteration in areas of gravity worms and/or other gravity lineaments in the:

- Central Metasedimentary Belt centred on Mt Laurier (Lyal Harris, Grégory Dufréchou, Camille Armengaud, Vladimir Antonoff);
- N and NW Morin Terrane (Lyal Harris);
- Southern Central Metasedimentary Beltin the Outaouais region and S Morin Terrane (Lyal Harris);
- The Mauricie to the Saint-Michel des Saints/Reservoir Taureau area (Lyal Harris, Grégory Dufréchou).
- Quebec City area (Lyal Harris, Camille Armengaud).

The Grenville Province immediately N of Quebec City was used as a test area to determine if a radiometric survey may provide indirect evidence for hydrothermal fluid flow along faults and shear zones in gneiss terranes of the Grenville Province and for training of MSc students Camille Armengaud and Jean-Phillipe Drolet) in the use of instruments that will be used in the Central Metasedimentary Belt of the Grenville Province in the coming summer (see Section 6). Field studies were undertaken in the Lac-Beauport - Lac-Saint Charles area to test whether the radiometric signal, especially elevated uranium content, may be correlated with lineaments reflecting shear and fault zones using both hand-held and vehicle-mounted radiometers. A 10m resolution Digital Elevation Model for the Lac-Beauport - Lac-Saint Charles was enhanced to highlight lineaments for comparison with radiometric data.

Seismic tomographic data were enhanced and a preliminary interpretation for different levels in the crust and mantle compared to gravity lineaments and worms in the Grenville Province and adjacent Superior Craton.

1. INTRODUCTION

1.1. Project objectives

This project integrates structural, geophysical and geochemical studies to characterize and determine mineral exploration implications of deep crustal to potentially lithospheric-scale structures identified from regional Geological survey of Canada gravity data and MIT seismic tomographic data in the Grenville Province in SW Quebec. To ascertain whether interpreted structures represent basement features enhancement and filtering of gravity and aeromagnetic data was also undertaken over the SE Superior craton to determine the relationship between structures interpreted beneath allochthonous terranes in the Grenville Province. Field studies aimed to determine the structural expression, if any, of geophysical lineaments and evidence for localized hydrothermal fluid flow controlled by such structures focus on selected areas of interpreted deep structures in the Central Metasedimentary Belt (CMB) / Mt Laurier Terrain, Morin and Mékinac-Taureau terranes, and the Portneuf-Mauricie and Parc des Laurentides domain (Figs 1, 2).

1.2. Rationale

The Grenville Province is considered as the deep root of a Himalayan-type collisional orogen where 1.8 to 1.24 Ga Andean and/or island arcs were accreted to Laurentia. In younger arcs, deep crustal to sub-crustal lithospheric mantle structures at high angles to the trend of orogenic belts have been identified and interpreted as transfer faults related to reactivated basement discontinuities or the result of changes in subduction zone dip. Such structures have been significant in localizing hydrothermal fluid flow and IOCG, porphyry Cu-Au, skarn, epithermal, sediment-hosted and VHMS deposit styles in Chile and Peru (Sillitoe, 2003), Argentina (Chernicoff et al., 2002), Indonesia (Garwin, 2000), and New Guinea (Hill et al., 2002). This project aims to determine if similar significant transverse structures exist beneath allochthonous terranes of the Grenville Province in Quebec and whether they have exerted controls on deformation, pluton emplacement, and mineralization in the SW Quebec Grenville Province

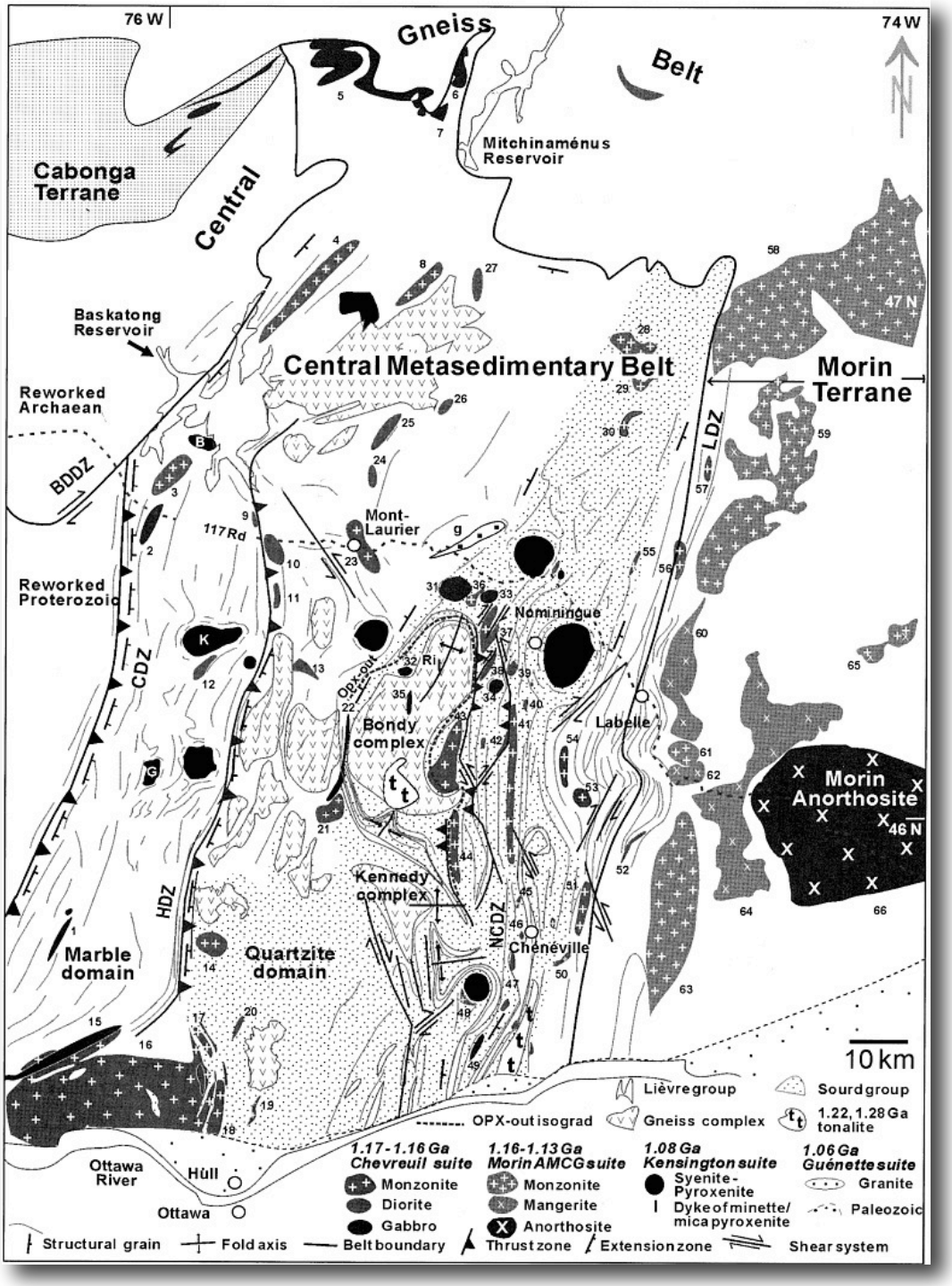

Fig. 1. Simplified map of the Central Metasedimentary Belt and western Morin Terrane (from Corriveau and van Breemen, 2000) covering the main area covered by this project.

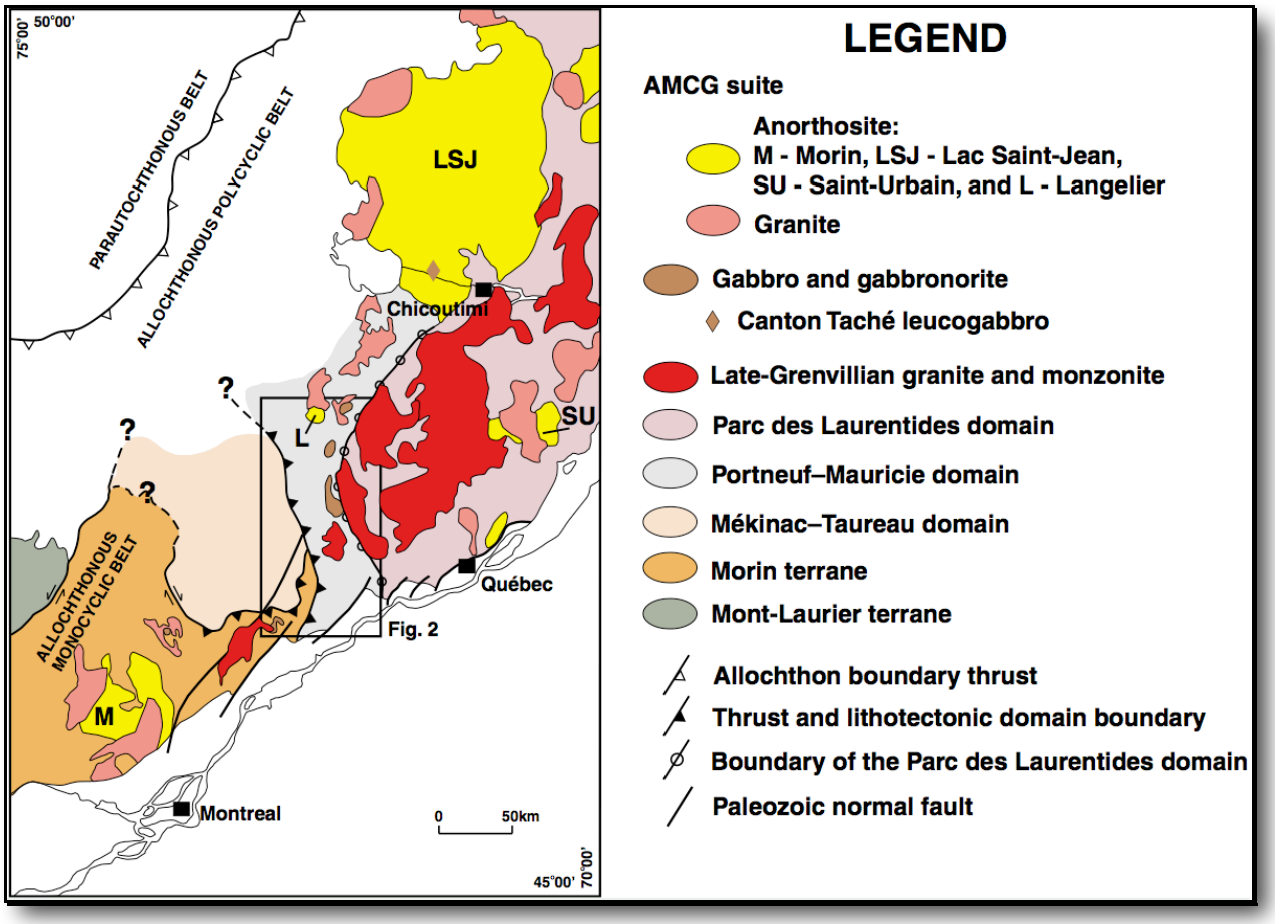

Figure 2. Simplified tectonic subdivision of the Grenville Province of SW Quebec E of the Central Metasedimentary Belt from Nadeau and Van Breemen (2001). This area was also covered by regional geophysical interpretation. A transect was carried out from the Portneuf-Mauricie domain to Morin Terrane. Detailed radiometric studies carried out in the Parc des Laurentides domain N of Quebec City to determine if there is a change in radiometric signature in areas of lineaments interpreted from both geophysical data and a detailed digital elevation model.

1.3. Methodology

1.3.1. Enhancement and structural interpretation of regional GSC gravity data.

The following techniques were used to process regional Geological Survey of Canada (GSC) gravity data (Canadian Geodetic Information System, 2008) to highlight regional-scale structures and provide an estimation of their depth extent and 3D geometry:

(i) Gravity "Worming". 2D or 3D representations of multi-scale edges derived from upwards continued gravity data (Archibald et al., 1999; Holden et al., 2000) are commonly referred to as gravity worm images. Gravity worms highlight crustal- to lithospheric-scale structures that may have controlled circulation of hydrothermal fluids and/or the emplacement of plutons during regional deformation and mineralizing events at Andean margins, orogenic belts and granite-greenstone terrains (Bierlein et al., 2006; Gibson et al., 2006, Austin and Blenkinsop, 2008).

(ii) Upwards continuation of gravity data to depths of 5, 25, and 40 km to identify deep structures.

(iii) In the northern part of the Grenville Province and Chibougamau area of the Superior Province spectral filtering was used to extract short and long wavelength components. Images were further enhanced to aid structural interpretation using vertical

and horizontal derivatives, their ratios, and ternary combinations.

1.3.2. Aeromagnetic data and pseudogravity calculations

Regional GSC aeromagnetic data (Canadian Aeromagnetic Data Base, 2008) was also enhanced to map structures and boundaries within the Grenville Province and adjacent Superior Craton. Poisson's ratio enables an approximation of the gravitational field to be calculated from the total aeromagnetic data reduced to the pole to centre anomalies over their source (Cowan and Cowan, 1991; Blakely, 1996). Pseudogravity images were derived and interpreted and pseudogravity "worms" were calculated. Pseudogravity "worms" compliment gravity worms as they locate structures and contacts across which there is a marked difference in magnetic susceptibility but which are not apparent on gravity worm maps due to low or zero density contrasts across them.

1.3.3. Seismic tomographic data

Seismic tomographic data from the MIT P-wave tomography model for 25 km to 1025 km was used to map structures in the crust and especially in the lithospheric mantle to compare with gravity interpretations of crustal structures.

1.3.4. Field studies

Regional traverses are undertaken in an attempt to find outcrops for detailed structural analysis in areas along key regional geophysical lineaments, especially those marked by gravity "worms". Oriented samples (including blocks extracted using a portable diamond saw) were collected to study fabric development, shear criteria, alteration, and radiometric response. Petrological and geochemical analyses are planned if sufficient funds are available in areas of hydrothermal alteration and mineralization along regional lineaments. A self- contained gamma ray detection system with built-in GPS receiver (RS-700 Mobile Radiation monitoring system) will be used to measure K40 concentrations and U (Bi214) and Th (Tl208) equivalent concentrations on selected transects over identified anomalies. Initial trials have been undertaken in the Grenville Province N of Quebec City.

In addition, subject to need and additional funding:

- Magnetic and electromagnetic profiling may be used in an attempt to locate shear zones corresponding to regional lineaments in areas with little or no outcrop.
- Soil samples may be collected across faults or shear zones interpreted from ground geophysics for geochemical analysis to determine the presence of anomalies suggestive of hydrothermal alteration or mineralization in the bedrock.

2. PRELIMINARY RESULTS[1]

2.1. Interpretation of Deep-Seated Transverse Discontinuities in the SW Quebec Grenville Province

Dufréchou et al. (2009) summarize the main features discovered in the SW Grenville Province. Lithoprobe seismic sections show that Achaean crust extends beneath allochthonous terranes at least as far as the Labelle deformation zone marking the eastern boundary of the Central Metasedimentary Belt (Fig. 1). The crust in this location is 44 km thick on average. Gravity lineaments in the southwestern Grenville Province in Québec show the existence of deep-seated crustal-scale transverse discontinuities. Upward-continued filters corresponding to depths of 5, 25, and 40 km indicate the presence at depth of transverse lineaments trending N140°. The two most significant lineaments are:

(i) The Mont-Laurier lineament. Interpreted on upwards continued gravity imagery to 40 km in depth, this lineament marks the boundary of many deformation zones in the Central Metasedimentary Belt and near the Cabonga terrain, where it also marks the limit between Parautochthonous and Allochthonous terrains. This lineament extends into the Superior Province. This major Achaean structure thus existed along the margin of the Laurentian craton prior to accretionary events and was presumably later reactivated during the Mesoproterozoic, during the construction of the Grenville Province.

(ii) The Portneuf lineament is visible to 25 km in depth. It cuts across the Portneuf-Mauricie terrain, in which Ni-Cu and precious metal-rich magmas were emplaced. It is interpreted as the result of a change in the dip of the slab, attributable to collision between the Laurentian continent and an island arc represented by rocks of the Montauban Group at 1.4

[1] Note that results are still covered by periods of confidentiality and are the subject of several theses so only broad findings can be given at this stage. Full details and maps will be provided in a subsequent final report.

Ga. The absence of this discontinuity in the surface geology may be explained by post-accretionary continental arc plutonism that affected the Portneuf-Mauricie terrain and that presumably masked the presence of this discontinuity, much like the suture zone itself. The presence of this type of structure has already been suggested to explain the presence of Ni-Cu ± PGE mineralization.

2.2. Field studies

Fieldwork was undertaken in areas of gravity worms and/or other gravity lineaments in the:

- Central Metasedimentary Belt centred on Mt Laurier (Fig. 1).
- N and NW Morin Terrane (Fig. 1).
- Southern Central Metasedimentary Belt in the Outaouais region and S Morin Terrane (Fig. 1).
- The Mékinac-Taureau and Portneuf-Mauricie domains (Fig. 2).
- Parc des Laurentides domain N of Quebec City (Fig. 2).

It was extremely difficult in finding outcrop in areas of interpreted structures and areas corresponding to worms were often swamps or low-lying areas of no outcrop. The negative topography may, however, itself suggest that structures may be present and that they have focused erosion. Mylonite zones were found over some worms and gravity lineaments. In the Bondy Gneiss Complex (Fig. 1) a clear association has been documented between the intersection of two regional crustal structures and chalcopyrite, bornite, pyrite, and magnetite mineralization (http://www.richmondminerals.com/projects_bondy_gneiss.php).

The Grenville Province immediately N of Quebec City was used as a test area to determine if a radiometric survey may provide indirect evidence for hydrothermal fluid flow along faults and shear zones in gneiss terranes of the Grenville Province and for instrument testing. Field studies were undertaken in the Lac-Beauport - Lac-Saint Charles area to test whether the radiometric signal, especially elevated uranium content, may be correlated with lineaments reflecting shear and fault zones using both hand-held and vehicle-mounted radiometers. Data analysis is in progress.

3. CONCLUSIONS

Regional gravity data have generally been under-utilized in regional mapping largely because the standard Bouguer images and simple shading and vertical derivatives are insufficient in extracting structures and determining their depth extent. This project has shown that application of additional enhancement and filtering techniques combined with "worming" provides significant additional information for regional structural and tectonic interpretation. Previously unmapped transverse structures of regional significance have been identified in the Grenville Province with potential applications in mineral exploration.

4. ONGOING RESEARCH

Publications and reports on regional interpretation of transverse lineaments in the SW Quebec Grenville Province and adjacent Superior Craton and on the radiometric study N of Quebec are currently in preparation. Final fieldwork in the Grenville Province in the coming spring and summer in the Central Metasedimentary Belt will include structural and petrological studies in areas of gravity lineaments and worms, geochemical sampling, and radiometric traverses using both hand-held (initial reconnaissance) and truck-mounted radiometers.

5. ACKNOWLEDGEMENTS

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