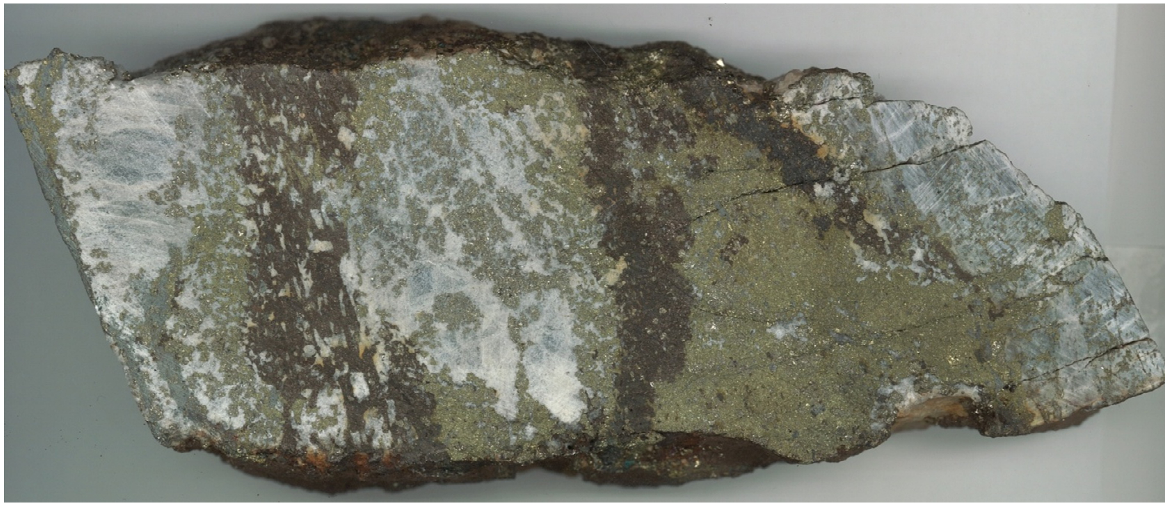
The Mineral Potential of the Labrador Trough for Iron Oxide-Copper-Gold (IOCG) and Affiliated Deposits



James Conliffe (GSNL),

Louise Corriveau (GSC-Québec),

Jean-François Montreuil (MacDonald Mines Exploration Ltd.)

Olivier Blein (BRGM)

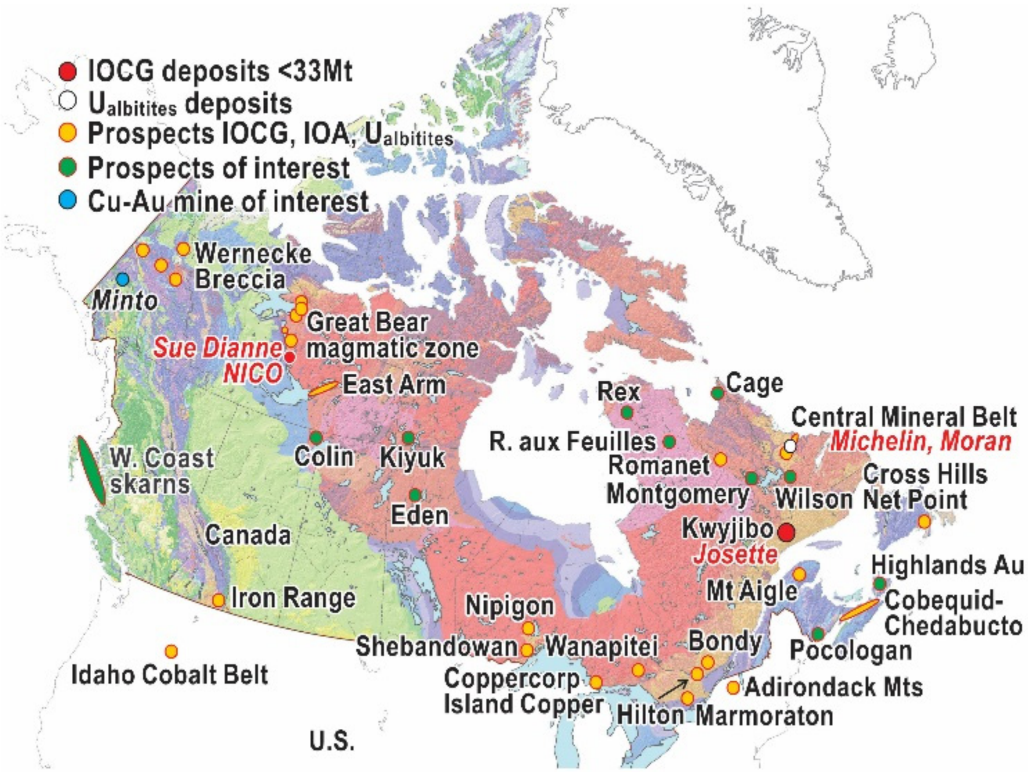
GEOLOGICAL SURVEY
NEWFOUNDLAND AND LABRADOR
Celebrating 150 years

Open File LAB/1760

Newfoundland Labrador
Natural Resources

Overview

- IOCG-type mineralization and associated alteration
- General geology of the Labrador Trough
- IOCG-type mineralization and alteration in the Labrador trough
  - Romanet Horst
  - Montgomery Lake
- Exploration implications, conclusions and possible links to LIP's in the Labrador Trough

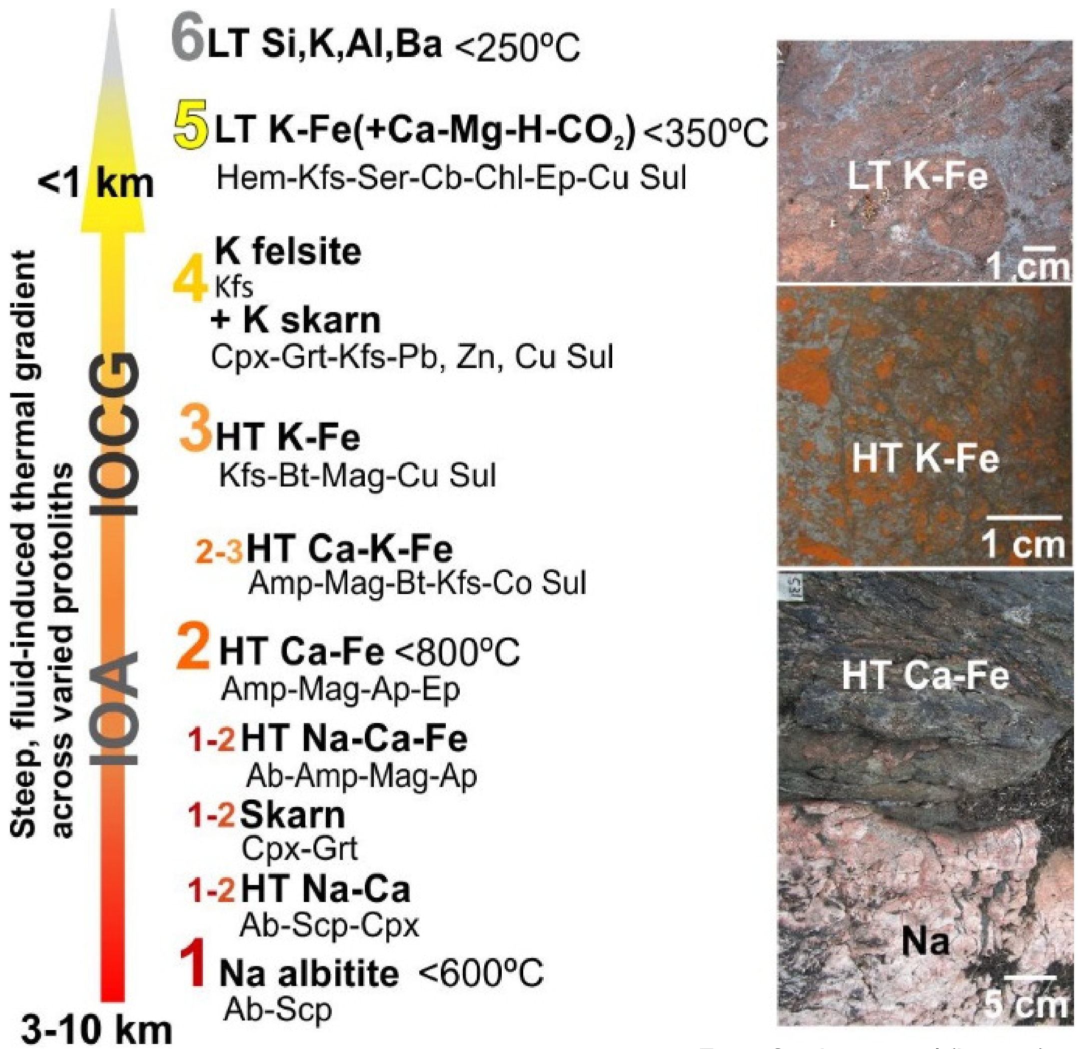


IOCG and affiliated deposits in Canada
(from Corriveau et al., in prep)

IOCG Mineralization

- Iron oxide copper gold (IOCG) deposits and various affiliated deposits are a major global source of Cu, Au and U (e.g. Olympic Dam, Prominent Hill, Ernest Henry)
  - also can contain Ag, Co, Bi, Fe, Mo, Ni, PGE, Pb, REE, V, Zn, etc.
- Found in many geological environments, classification of IOCG deposits based on a number of criteria (Groves et al, 2010; Corriveau and Mumin, 2010; Williams, 2010)
  - Abundant low-Ti Fe-oxides and characteristic alteration patterns
  - Strong structural control, associated with deep seated crustal structures
  - Close temporal (but not always spatial) association with magmatism
- Previous authors have linked generation of IOCG-type deposits and LIPs (Ernst and Jowett, 2013)

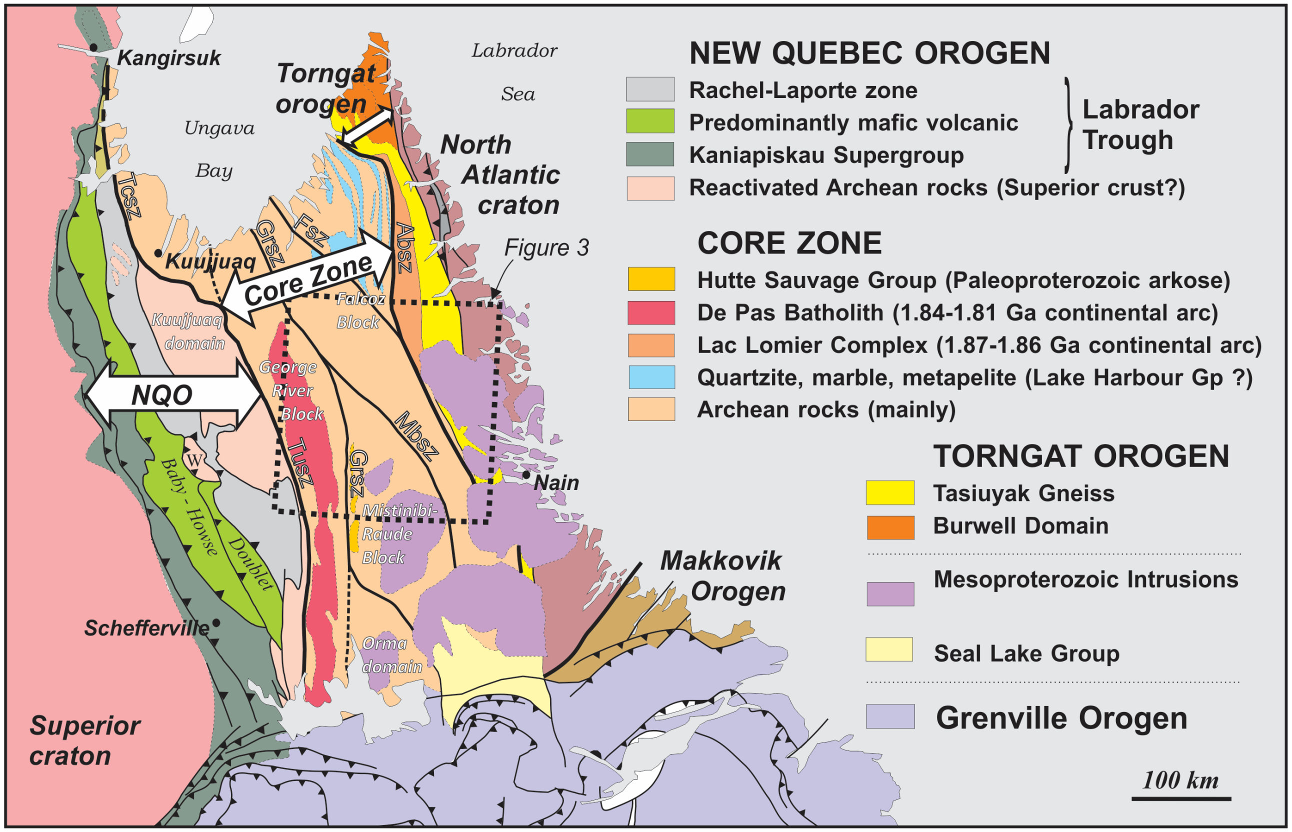
IOCG Mineralization



From Corriveau et al (in prep),
adapted from Corriveau et al. (2016)

- IOCG and affiliated deposits form within distinctive, regional scale iron oxide and alkali-calcic alteration (IOAA) systems (Corriveau et al., 2016)
- When incorporated into ore genetic models and deposit classes may provide effective vectors towards mineralization

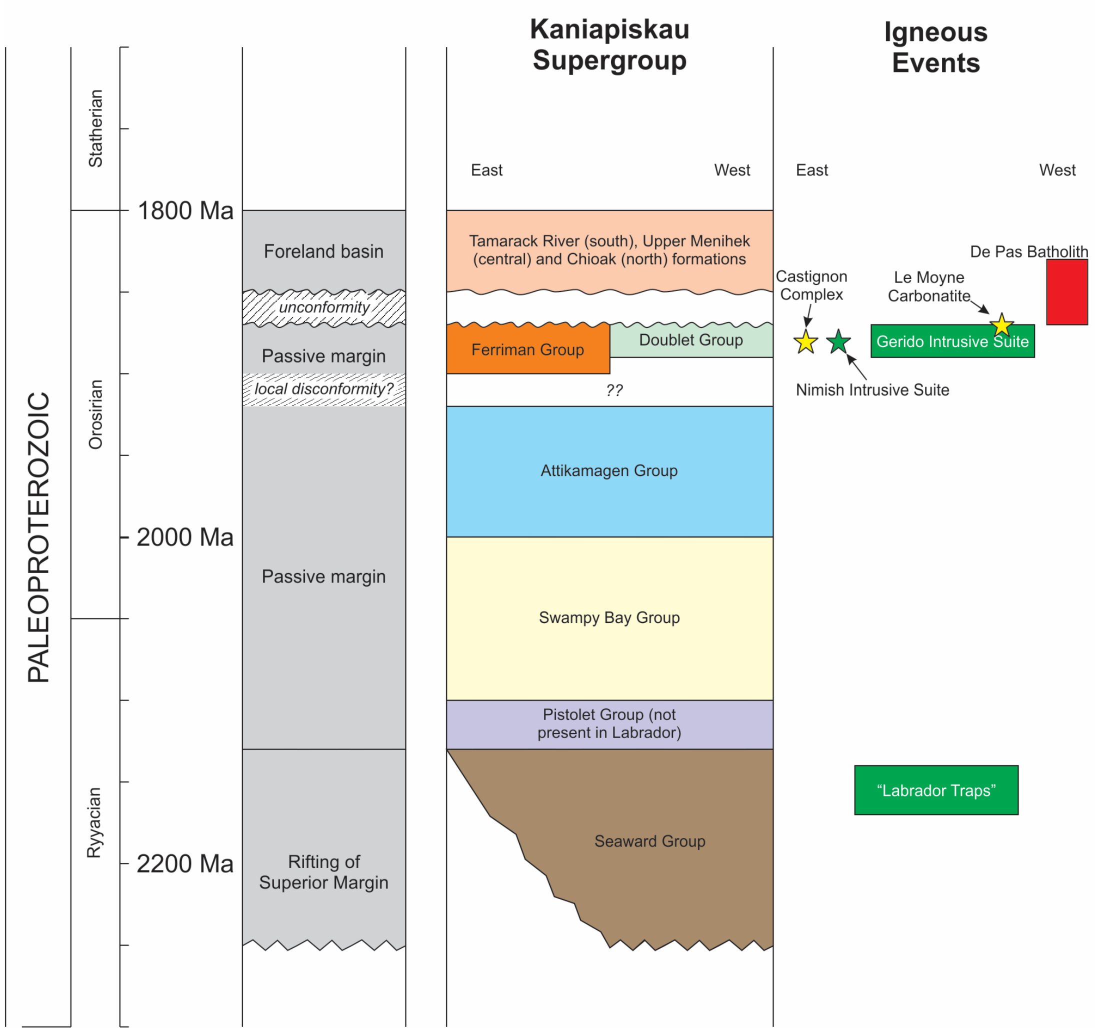
Geological Setting



From Corrigan et al (2018)

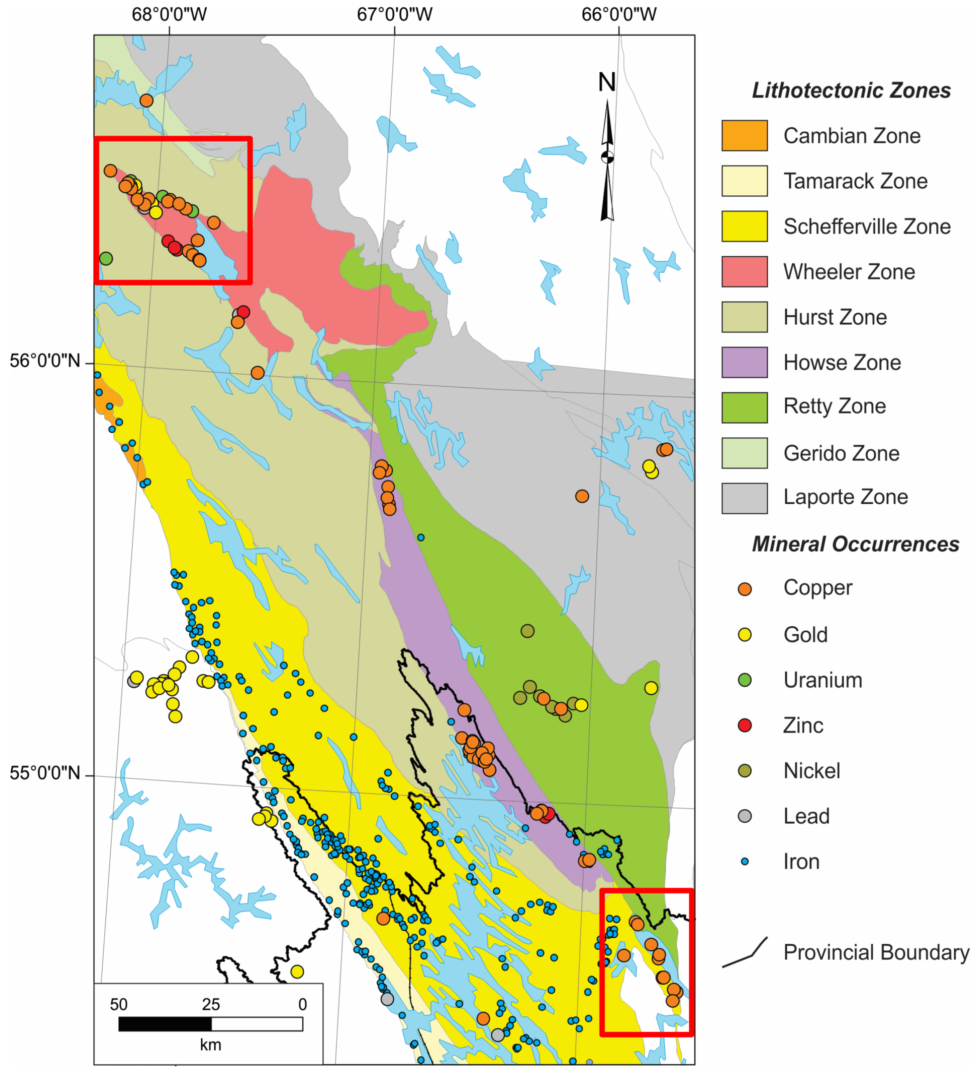
- Labrador Trough located in western Labrador and northeastern Québec
- Forms part of the New Québec Orogeny (NQO)

Geological Setting



- Sequence of Paleoproterozoic (2.2 to 1.8 Ga) sedimentary and igneous rocks
- Record rifting of Superior Margin, development of a passive margin and subsequent collision of Superior with Core Zone (NQO)
- Major igneous events (LIPs) associated with initial rifting and collisions/orogenesis

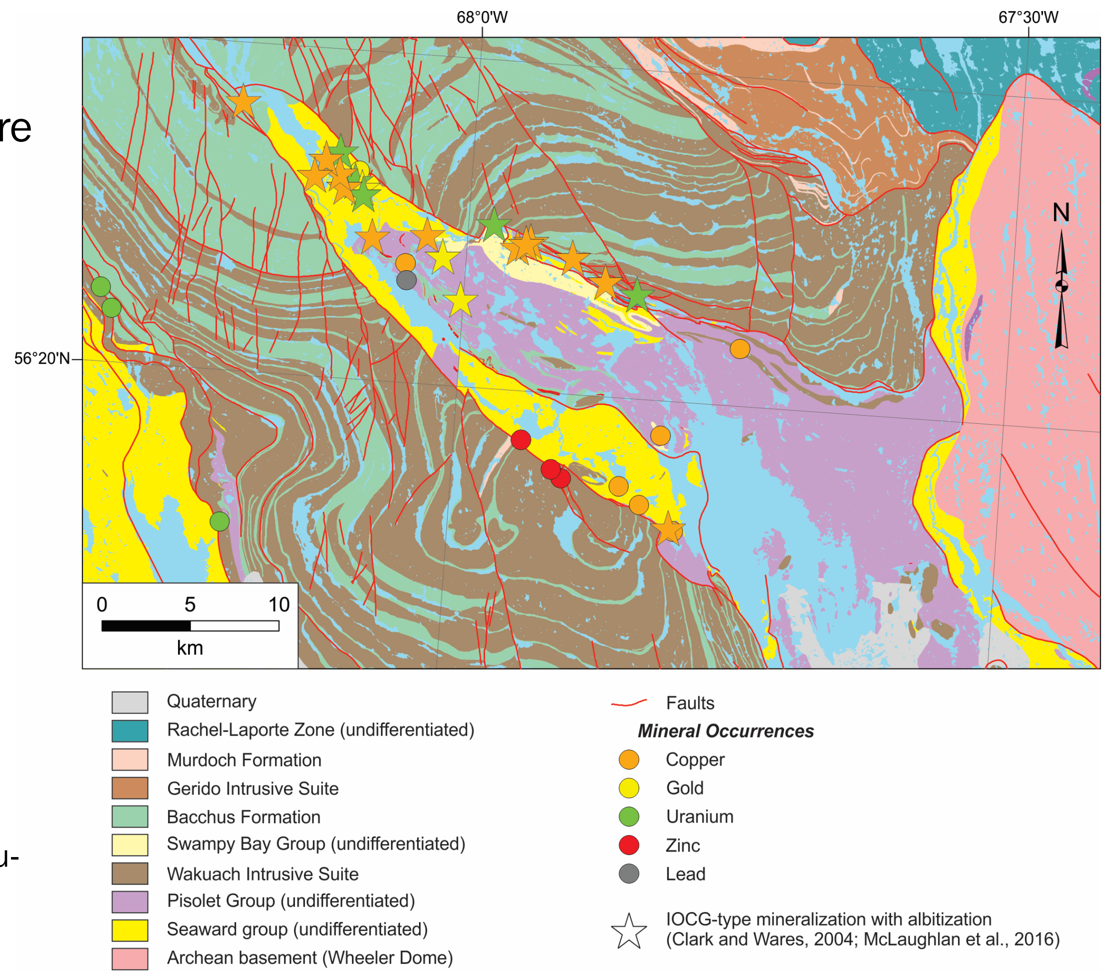
Geological Setting



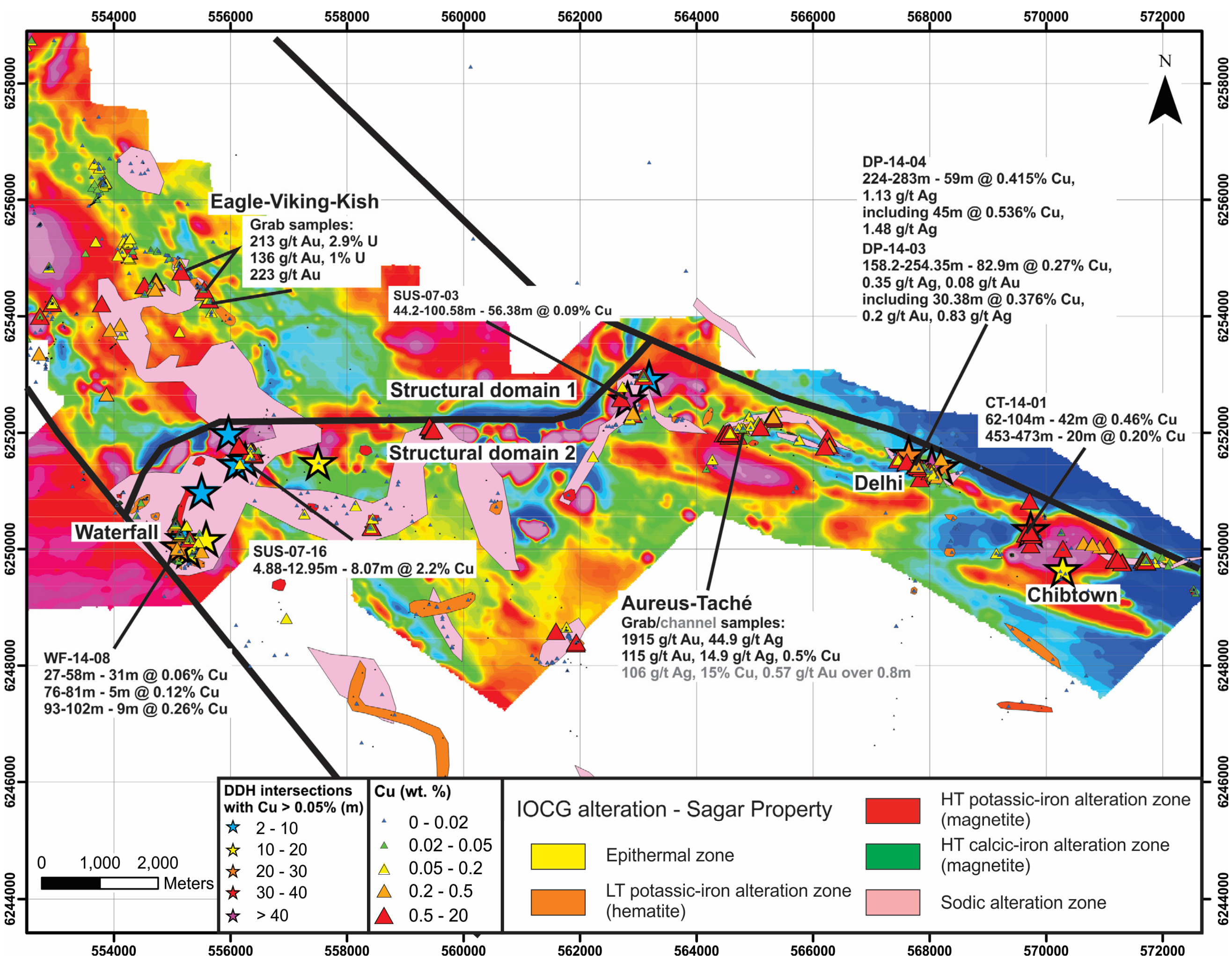
- Subdivided into series of lithotectonic zones (Clark and Wares, 2005)
  - Bounded by major crustal structures and with distinct stratigraphy
- Superior-type iron formations deposited close to continental margin
- Other deposit types present in eastern Labrador Trough (e.g. magmatic sulphides, VMS, orogenic Au etc.)
- IOCG-type mineralization and associated alteration reported from two main areas
  - Romanet Horst
  - Montgomery Lake

Romanet Horst: Geology

- Romanet Horst forms anticlinal structure bounded by major crustal faults (Konstantinovskaya et al., 2019)
- Surrounded by dominantly 2.17 LIP magmatism
- Diversified metallic assemblages in the property showings;
  - e.g. Cu-Co-Au-Ag±REE and Au-U±Mo-Co-Cu-Ni-REE



Romanet Horst: Geology

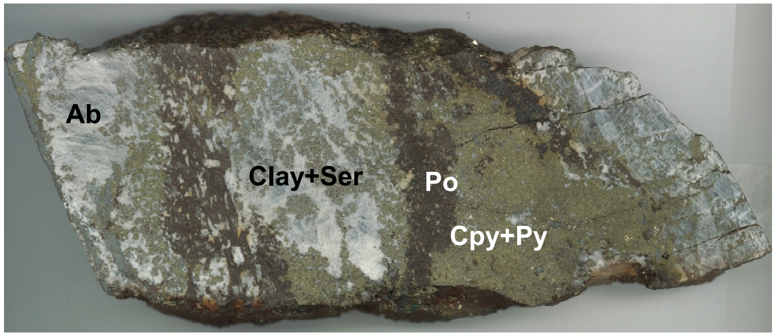


- Regional sodic and sodic-calcic-iron alteration
- Convergence and intersection of numerous and deeply rooted regional structures
- Mineralization zones hosted in albitites

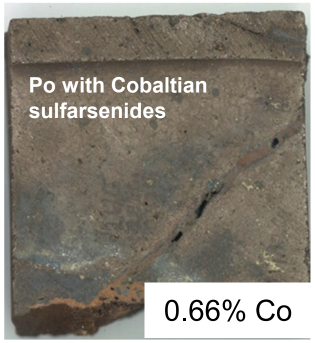
Romanet Horst: Mineralization

- Delhi Pacific – Chibtown Prospects
  - Polymetallic Cu-Ag-Au-(Co-Zn) mineralization
  - Structurally controlled, hosted in albitized shales
  - Recent drilling results include 0.54% Cu over 45 m, 0.38% Cu, 0.2 g/t Au, 0.8 g/t Ag over 30.9 m (DP) and 0.46% Cu over 42 m (CB)
- Taché-Saarberg showings
  - Comprises a series of Co+Cu anomalies (Co > 500 ppm) over 750m along strike
  - Up to 30.8% Cu, 21.2% Cu, 11.3% Cu, 1.92 g/T Au, 0.27% Co, 0.81% Co in grab samples
- Other prospects include
  - Eagle (Up to 213 g/t Au, 2.9% U, 368 ppm La, 0.5% Cu in grab samples).
  - Kish (up to 1% U and 136 g/t Au in grab samples).
  - Viking (up to 0.1% U, 6.1% Cu, 1.6% Ni, 5.7% Se and 223 g/t Au in grab samples).
  - Lac Mistamik (up to 43 g/t Au, 601 ppm La, 20.7 g/t Ag, 1.8% U, 0.1% Cu in grab samples)

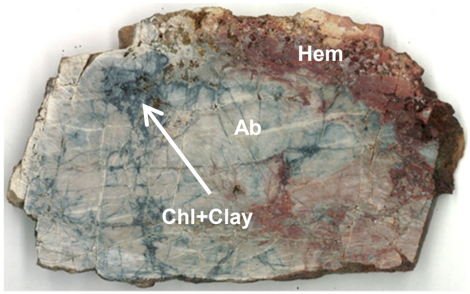
Delhi Pacific Showing



Delhi Pacific Mineralization

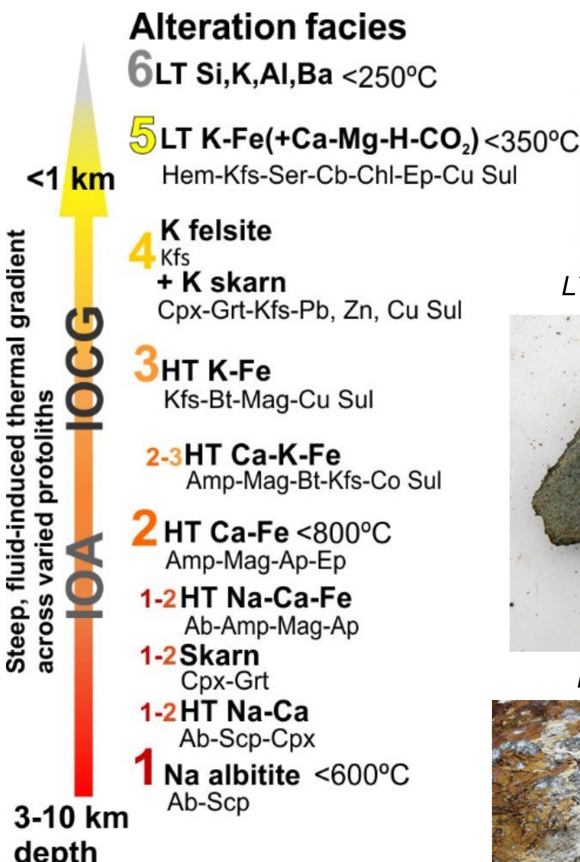


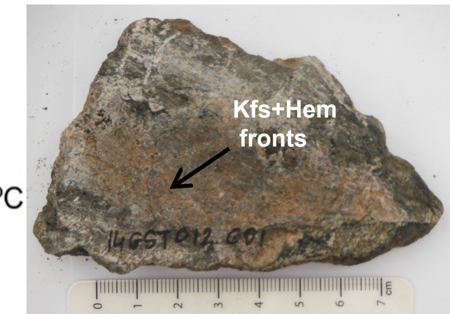
Taché-Saarberg Mineralization



Viking Mineralization

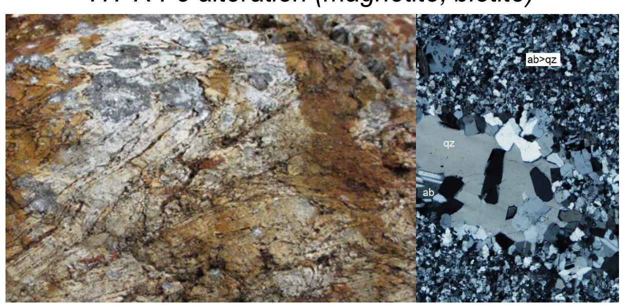
Romanet Horst: Alteration





LT K-Fe alteration (K-feldspar, hematite)

HT K-Fe alteration (magnetite, biotite)

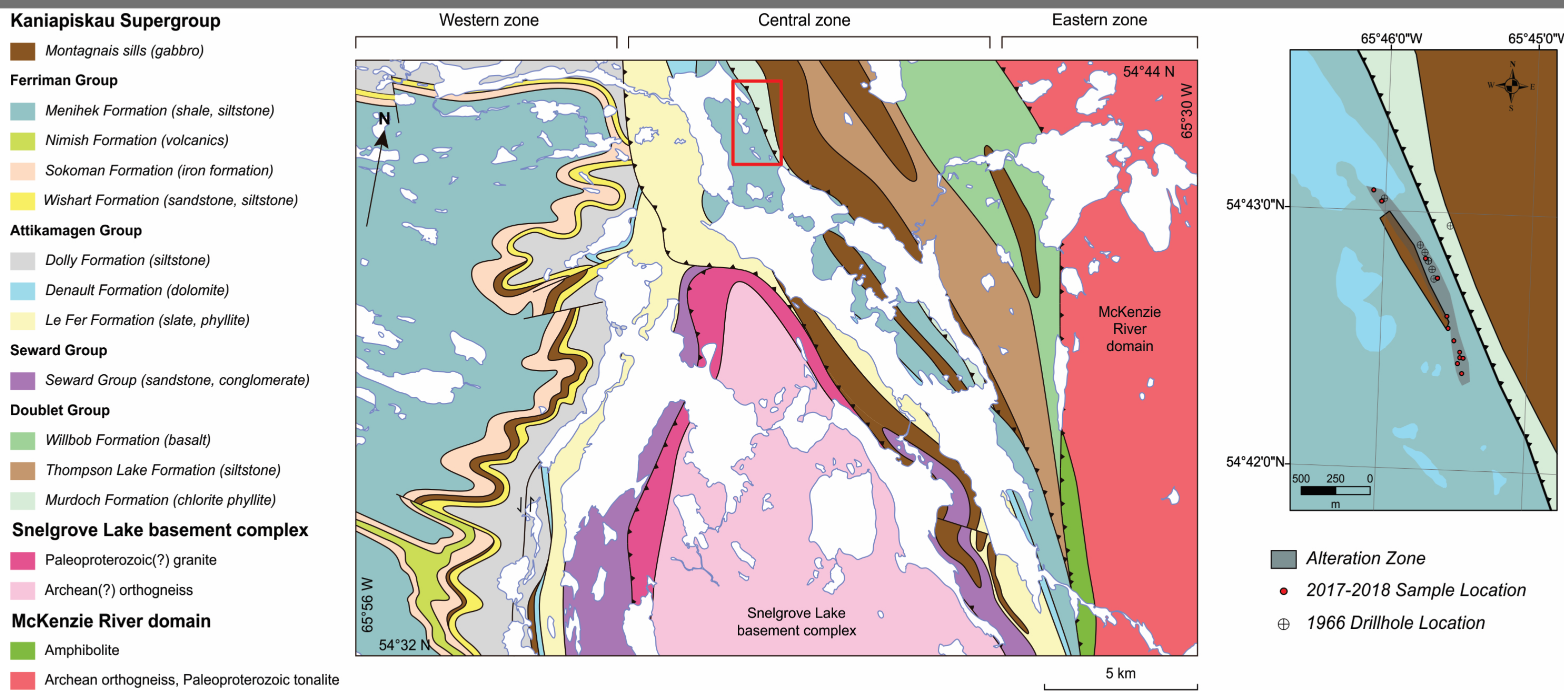


Regional Na (albitite) alteration

Corriveau et al. (2014) recognized alteration facies typical of IOCG style mineralization

- Regional Na±Ca alteration (albitite)
- High temperature Ca-Fe (amphibole-dominant)
- High temperature K-Fe alteration (magnetite and biotite dominant)
- Low temperature K-Fe (hematite and sericite dominant); distinctive of IOCG deposits and locally host copper-sulphide mineralization

Montgomery Lake: Geology

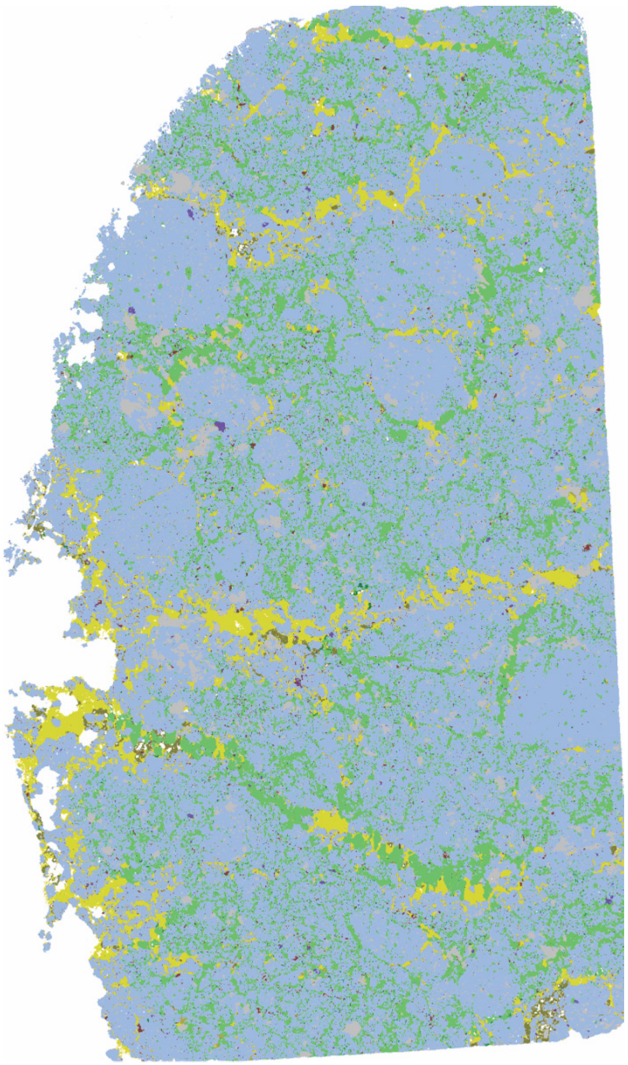


- Structurally complex area, with numerous large crustal scale faults and exposed basement in core of north plunging anticline (similar to Romanet Horst?)
- Numerous gabbro sills and possible Paleoproterozoic granite at margin of basement complex (Wardle, 1979; Butler, 2019)
- Strong alteration zone parallel to Walsh Lake Fault traced for more than 1.5 km

Montgomery Lake: Mineralization

- Intensely altered units, commonly brecciated with rounded to sub-angular clasts in fine-grained grey matrix
- Historical exploration from 1942 to 1966 includes trenching, diamond drilling, geophysical (EM, mag, gravity) and geochemical surveys
  - 0.31% Cu over 14.5m, 0.17% Cu over 25.5m, 0.12% Cu over 36.1m, 1.0g/t Au over 1.5m, 9.2 g/t Ag over 1.5m
  - Grab samples from main trench up to 5.48% Cu, 424 ppb Au
- Anomalous Cu (> 0.1% Cu) and Au (> 100 ppb) grades in grab samples over 1.4 km strike length
- Also enrichment in LREE and Ag (up to 1.7 g/t Ag)

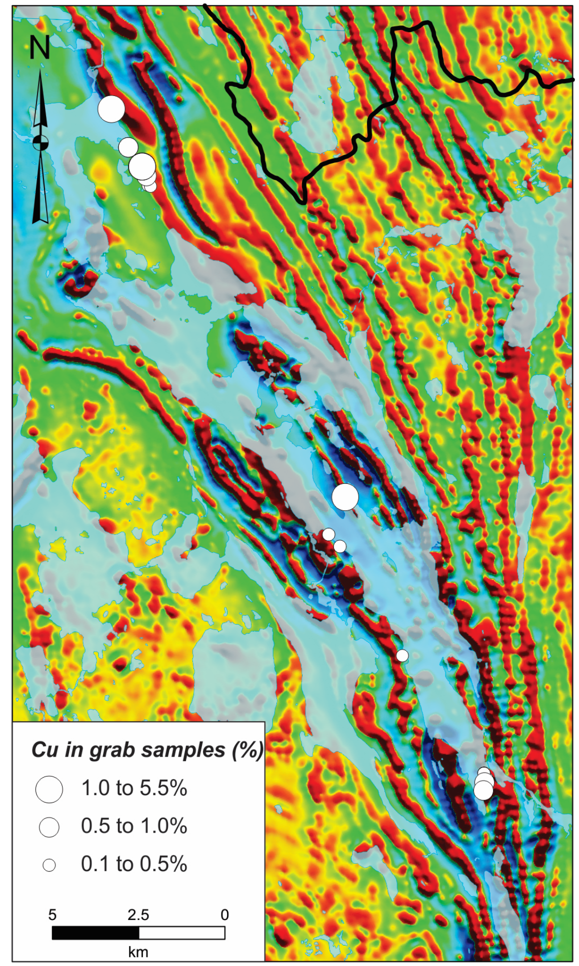
Montgomery Lake: Genetic Model



- Two main phases of alteration
  - Early Na alteration consisting primarily of albite and quartz with < 10% carbonate – "Albitite"
  - Later Ca-Na-Fe brecciation (hydraulic breccia) associated with chalcopyrite, minor pyrrhotite and pyrite
- IOCG affiliated deposit (Iron Sulphide Copper Gold deposit)
  - Strong structural control near major crustal structure
  - Hosted in graphitic sedimentary sequence (reducing) under conditions too reduced to stabilize Fe-oxides
  - Early sodic alteration (regional)
  - Late chalcopyrite and pyrrhotite mineralization and brecciation (minor magnetite, apatite)
  - Presence of hypersaline fluids (preliminary fluid inclusion study)
- Similar global examples include Eloise, Lady Clayre (Cloncurry), Delhi-Pacific (Romanet Horst, Labrador Trough)

Montgomery Lake: Regional Implications

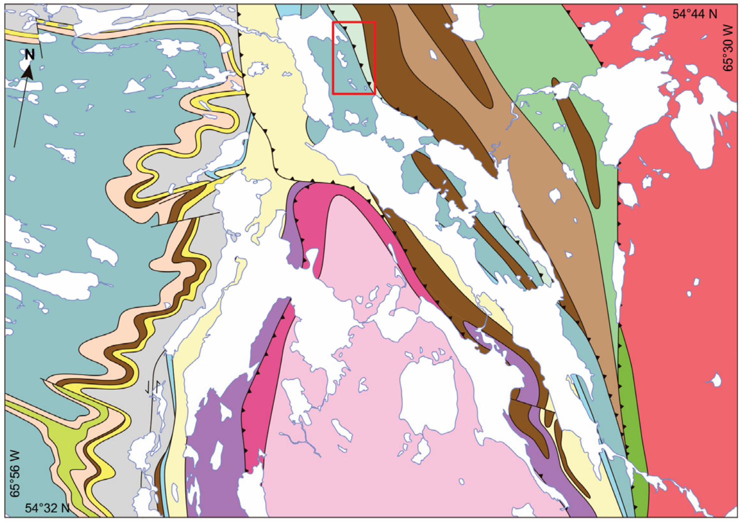
- Potential for further exploration in eastern Labrador Trough using IOCG exploration model
  - Similar tectonic setting to Romanet Horst
  - Prospecting has identified anomalous Cu over > 23 km strike length (Labonte et al., 2009; this study)
  - Possible similar alteration to Montgomery Lake reported from southern end of Andre Lake (Kozela, 1960)
  - Numerous unexplained magnetic and radiometric anomalies in Andre Lake area (Labonte and Kieley, 2009)
  - Diamond drilling on Andre Island area in 1960s encountered potassic (biotite) alteration, brecciation and intervals of pyrrhotite and magnetite rich units with trace chalcopyrite
- Future work planned following up on previous prospecting results and magnetic anomalies, and aims to place alteration in framework developed by Corriveau et al. (2010, 2016)



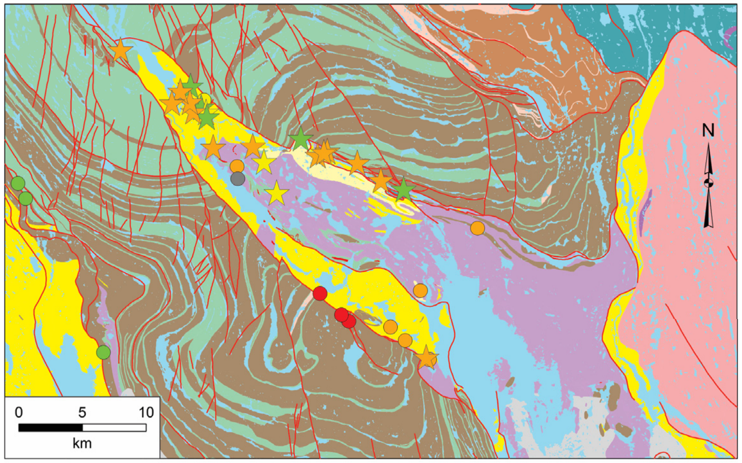
IOCG in the Labrador Trough: Overview

Newfoundland Labrador

- Similarities in tectonic setting of Romanet Horst and Montgomery Lake areas
  - Strong structural control, located close to major crustal structures
  - Proximal to basement domes (Superior affinity)
  - Importance of early (rift related) sediments and former evaporite horizons (brines?)
- Regional sodic alteration associated with polymetallic mineral occurrences (Cu, Au, Ag, U, REE, Co)
  - Common brecciation, evidence of hypersaline fluids (Montgomery Lake)
- Alteration studies in Romanet Horst indicate other IOAA facies typical of IOCG and affiliated deposits

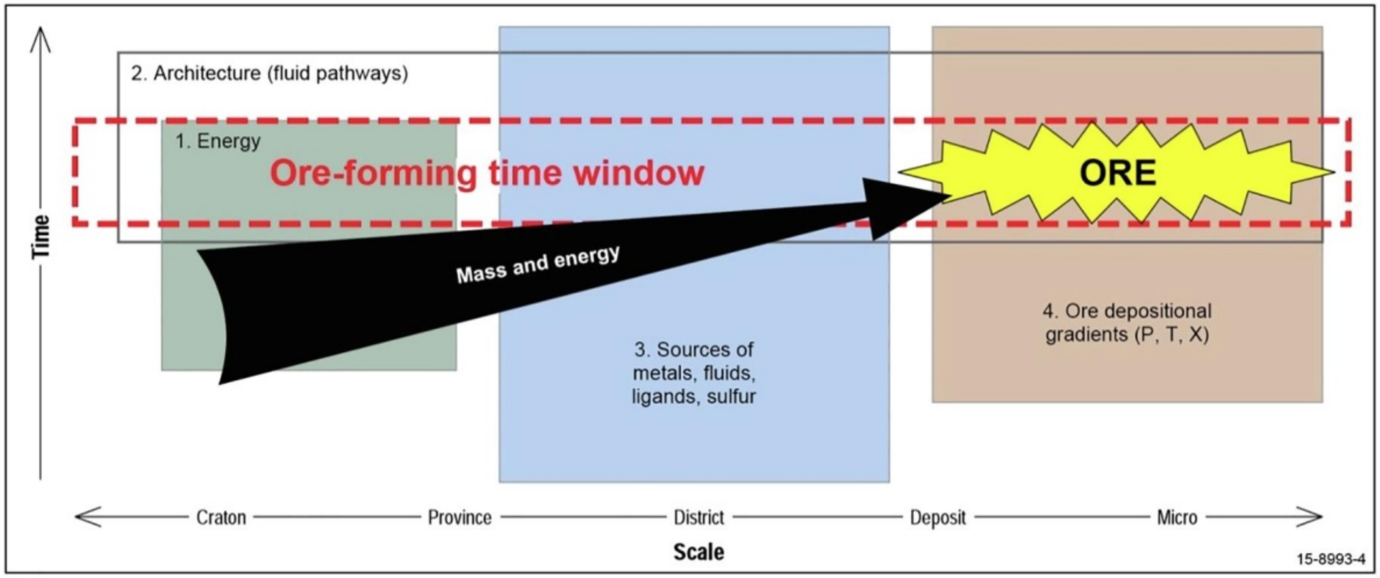


Montgomery Lake/Andre Lake



Romanet Horst

IOCG in the Labrador Trough: Mineral Systems Based Approach



- Potential of a region to host IOCG-type mineralization can be determined using mineral systems based approach (Skirrow et al., 2019)
- Focusses on critical geological processes necessary to form mineral deposits, especially important in greenfield exploration
- Areas of the Labrador Trough displays many mappable criteria indicative of IOCG potential
  - More baseline geological, geochemical and geophysical studies required

IOCG in the Labrador Trough: Possible links to LIPs

(mappable criteria from Skirrow et al., 2019)

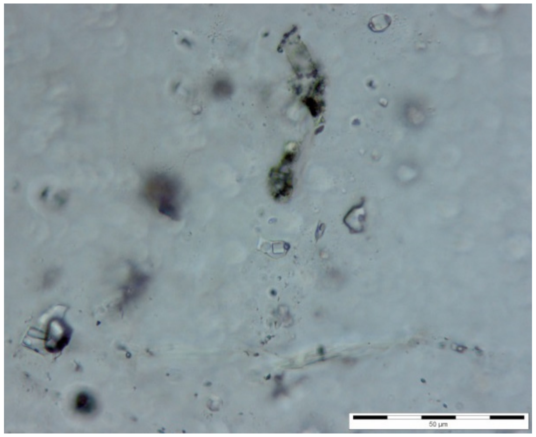
Drivers and source of energy

- IOCG and affiliated deposits commonly have temporal links to large scale I- and A-type magmatism
  - Possible energy sources in Labrador Trough include 1.85 Ga De Pas Batholith (bimodal) and other potential Paleoproterozoic granites and carbonatite complexes

Sources of metals, fluids, ligands and sulphur

- Possible magmatic or mixed magmatic hydrothermal fluid sources for IOCG and affiliated deposits
  - ~1.85 Ga magmatism in Labrador Trough
- Metals may be leached along fluid flow path
  - Leaching of metals from ~2.17-2.14 Ga LIP

De Pas Batholith megacrystic granite (image from Corrigan et al., 2019)



Halite-bearing "hypersaline" fluid inclusions Montgomery Lake showing

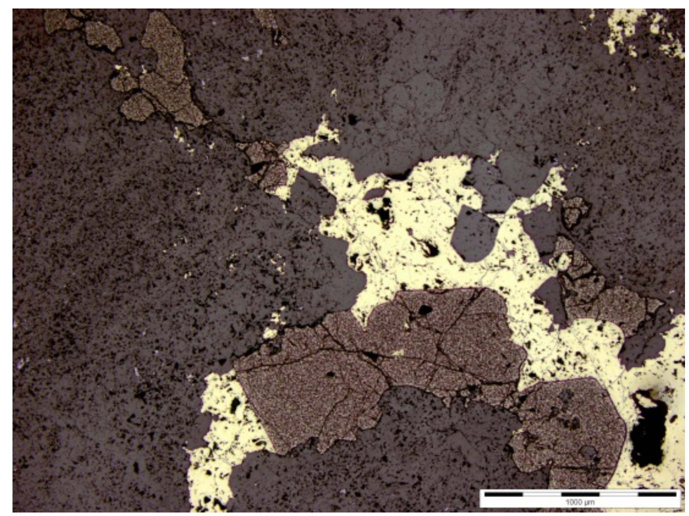
IOCG in the Labrador Trough: Conclusions and Exploration Potential

Newfoundland Labrador

- IOCG and affiliated deposits (including albitite hosted U and ISCG Cu-Au deposits) have been recorded in the Romanet Horst and Montgomery Lake areas

- Significant exploration potential remains, with poor outcrop and limited previous work in most areas
  - Evidence of extensive albite alteration associated with the De Pas batholith (Lafrance et al., 2015)

- Further geological (e.g. bedrock mapping, structural), geochemical (e.g. alteration mapping, isotope studies) and geophysical (e.g. gravity, magneto-telluric data) studies required to fully assess the mineral potential of the Labrador Trough



References

Butler, J P (2019) New observations from the Andre Lake area (NTS 23I/12), western Labrador: Tectonic relationships in the Hinterlands of the New Québec Orogen. In Current Research, Compiled and Edited by C. P. G. Pereira and D. G. Walsh, Government of Newfoundland and Labrador, Department of Natural Resources, Geological Survey, Report 19-1, pages 131-146.

Clark, T and Wares, M (2005) Lithotectonic and metallogenic synthesis of the New Québec Orogen (Labrador Trough). Ministère des Ressources naturelles, Québec, MM 2005-01, 175 pages.

Corrigan, D, Wodicka, N, McFarlane, C, Lafrance, I, van Rooyen, D, Bandyayera, D and Bilodeau, C (2018) Lithotectonic Framework of the Core Zone, Southeastern Churchill Province, Canada. Geoscience Canada, Volumer 45(1), pages 1-24.

Corrigan, D, Rayner, N, and van Rooyen, D (2019) Detrital zircon provenance and tectonostratigraphic evolution of the mid- to southern Labrador Trough. GAC-MAC-IAH Annual Meeting (Quebec City), Abstract Volume 42, page 74.

Corriveau, L, and Mumin, A H (2010) Exploring for iron oxide copper–gold deposits: the need for case studies, classifications and exploration vectors, in Corriveau, L. and Mumin, A.H., eds., Exploring for iron oxide copper-gold deposits: Canada and global analogues: Geological Association of Canada, Short Course Notes 20, p 1-12.

Corriveau, L, Williams, P J, and Mumin, H (2010) Alteration vectors to IOCG mineralization – from uncharted terranes to deposits, in Corriveau, L. and Mumin, A.H., eds., Exploring for iron oxide copper-gold deposits: Canada and global analogues: Geological Association of Canada, Short Course Notes, No. 20, p. 89-110.

Corriveau, L, Nadeau, O, Montreuil, J –F, and Desrochers, J -P (2014) Report of activities for the Core Zone: Strategic geomapping and geoscience to assess the mineral potential of the Labrador Trough for multiple metals IOCG and affiliated deposits, Canada. Geological Survey of Canada, Open File 7714, 12 pages.

Corriveau, L, Montreuil, J-F, and Potter, E G (2016) Alteration facies linkages among IOCG, IOA and affiliated deposits in the Great Bear magmatic zone, Canada, in Slack, J., Corriveau, L. and Hitzman, M., eds., Proterozoic iron oxide-apatite (± REE) and iron oxide-copper-gold and affiliated deposits of Southeast Missouri, USA, and the Great Bear magmatic zone, Northwest Territories, Canada: Economic Geology, v. 111, p. 2045-2072.

Ernst R E, and Jowett, S (2013) Large Igneous Provinces (LIPs) and Metallogeny. Society of Economic Geologists Special Publication Volume 17, pages 17–51.

Groves, D I, Bierlein, F P, Meinert, L D, and Hitzman, M W (2010) Iron oxide copper-gold (IOCG) deposits through Earth history. Implications for origin, lithospheric setting, and distinction from other epigenetic iron oxide deposits: Economic Geology, v. 105, p. 641-654.

Konstantinovskaya, E, Ivanov, G, Feybesse, J-L and Lescuyer, J-L (2019). Structural Features of the Central Labrador Trough: A Model for Strain Partitioning, Differential Exhumation and Late Normal Faulting in a Thrust Wedge under Oblique Shortening. Geoscience Canada, Volume 46(1), pages 5-30.

Labonte, J and Kieley, J W (2009) Second and sixth year assessment report on compilation, geophysical interpretation, prospecting and geochemical exploration for licences 9559M-9560M, 13522M-13533M, 13538M, 13542M, 13785M, 13793M-13794M, 13850M-13853M, 13855M-13858M, 14596M, 15146M-15148M, 15893M-15898M, 16366M-16369M and 16535M-16544M on claims in the Howse Lake to Wet Lake area, western Labrador, 2 reports. Altius Resources Incorporated, Cornerstone Resources Incorporated and Turpin, A J. Newfoundland and Labrador Geological Survey, Assessment File LAB/1531, 113 pages.

Labonte, J, Kieley, J W and Wilton, D (2009) First and second year assessment report on geological, geochemical and geophysical exploration for licences 9559M-9560M, 13522M-13533M, 13538M, 13542M, 13785M, 13793M-13794M, 13848M-13858M, 14319M-14323M, 14589M-14597M and 15142M-15148M on claims in the Howse Lake to Wet Lake area, western Labrador, 3 reports. Cornerstone Resources Incorporated and Altius Minerals Corporation. Newfoundland and Labrador Geological Survey, Assessment File LAB/1483, 308 pages.

Lafrance, I, Bandyayera, D, Charette, B, Bilodeau, C and David, J (2015) Géologie de la région du lac Brisson (SNRC 24A). Ministère de l'Énergie et des Ressources naturelles, Québec, RG 2015-05, 64 pages.

Skirrow, R G, Murr J, Schofield A, Huston D L, van der Wielen S, Czarnota K, Coghlan R, Highet L M, Connolly D, Doublier M, and Duan J (2019) Mapping iron oxide Cu-Au (IOCG) mineral potential in Australia using a knowledge-driven mineral systems-based approach. Ore Geology Reviews, Volume 113.

Wardle, R J (1979) Geology of the eastern margin of the Labrador Trough. Government of Newfoundland and Labrador, Department of Mines and Energy, Mineral Development Division, Report 78-09, 27 pages.

Williams P J (2010) Classifying IOCG Deposits. Geological Association of Canada Short Course Notes, vol. 20, pages 23–38.

Newfoundland Labrador

Natural Resources

Thanks to

- Jared Butler, Andrew Smith, John Hinchey, and Ben MacDougall
- Wayne Tuttle (logistics)
- McGill Sub-Arctic Research Centre
- Canadian Helicopters
- Chris Finch (geochemistry) and Gabriel Sindol (SEM-MLA)

GEOLOGICAL SURVEY
NEWFOUNDLAND AND LABRADOR
Celebrating 150 years