



Critical Minerals in Newfoundland and Labrador

James Conliffe

Mineral Deposits Section

Geological Survey of Newfoundland and Labrador

Prospectors Short Course, Mineral Resources Review 2022

Course Outline

<i>9:00 to 9:40</i>	Critical minerals in Newfoundland and Labrador: An overview	James Conliffe
<i>9:40 to 10:00</i>	A preliminary examination of surficial sampling methods for critical minerals	Heather Campbell
<i>10:00 to 10:30</i>	Coffee Break	
<i>10:30 to 11:00</i>	Fluorite in Newfoundland	Zsuzsanna Magyarosi
<i>11:00 to 11:30</i>	Granite-related critical minerals (Li, Mo, W, Sn, Bi) in Newfoundland	James Conliffe
<i>11:30 to 12:00</i>	Rare earth element mineralization associated with peralkaline complexes in NL	Zsuzsanna Magyarosi
<i>12:00 to 12:15</i>	Discussion	
<i>12:15 to 1:30 PM</i>	Lunch	
<i>1:30 to 2:15</i>	The Kraken Pegmatite Swarm - A Lithium Discovery in Southwestern Newfoundland	Tim Froude
<i>2:15 to 3:00</i>	Peralkaline Volcanic-Hosted REE Mineralization in Labrador: The Foxtrot-like Deposits in the Fox Harbour Volcanic Belt	Randy Miller

Overview

- Introduction to Critical Minerals and how they impact our lives
- Canada's Critical Mineral List
- Critical minerals in Newfoundland and Labrador
 - Inventory of known critical mineral occurrences



Critical Minerals: Definitions

“Critical” means you need it; “strategic” means you don’t have it

- No global definition of critical minerals, but they are typically defined as minerals that play a role in the modern economy including:

- the manufacturing of advanced technologies, such as those needed for the green energy transition

- their supply is limited and/or concentrated to a few countries

- their importance to energy and national security

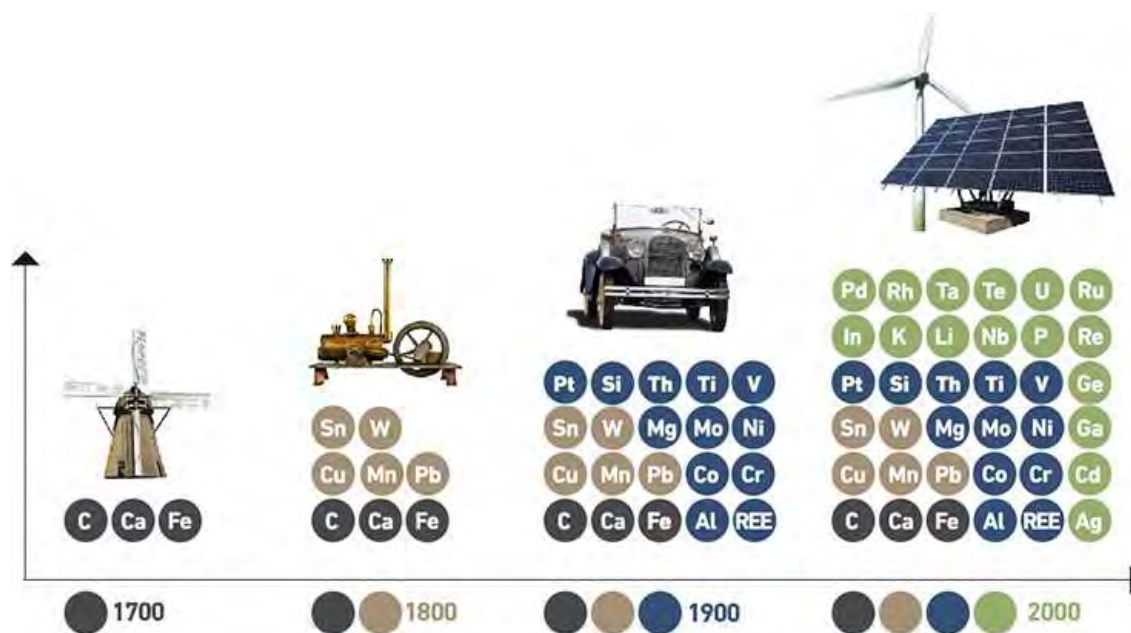
- Canada defines critical minerals as a mineral that must be:

- essential to Canada’s economic security and its supply is threatened

- required for Canada’s transition to a low-carbon economy

- a sustainable source of highly strategic critical minerals for our partners and allies

Critical Mineral through Time



Source: <https://data.geology.gov.yk.ca/Reference/95924>

Critical mineral lists can change over time based on supply and demand, technological development, and shifting societal needs

Critical Minerals: Demand outlook



Increased interest in critical minerals due to transition to green economy

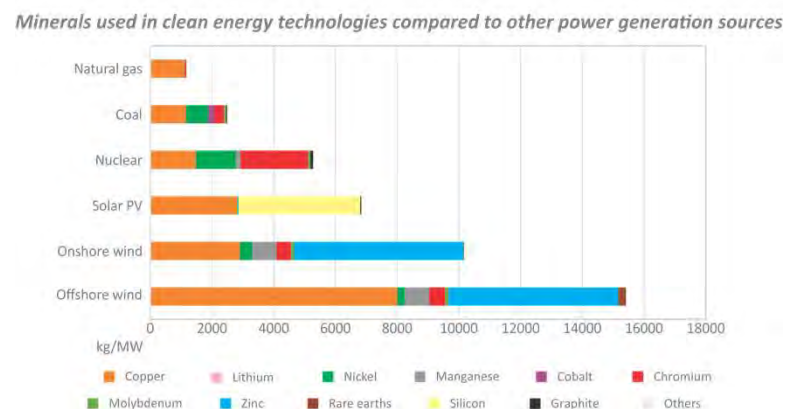
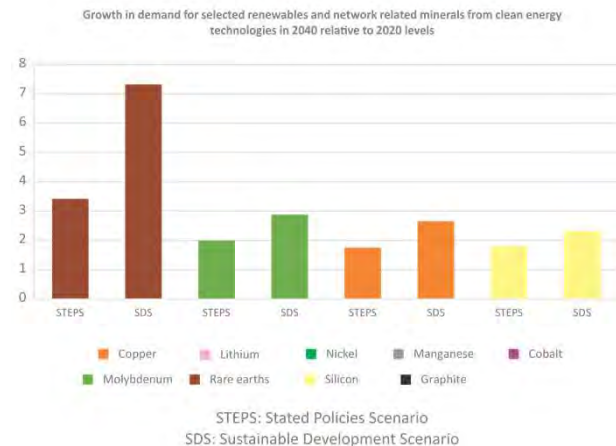
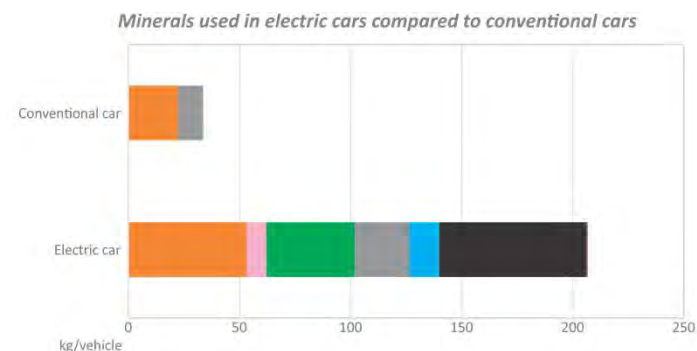
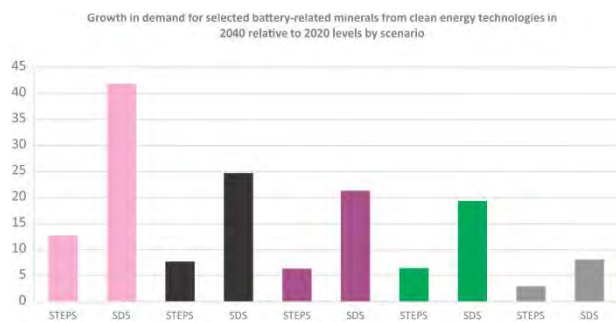


IEA predicts quadrupling of mineral requirements for clean energy technologies by 2040



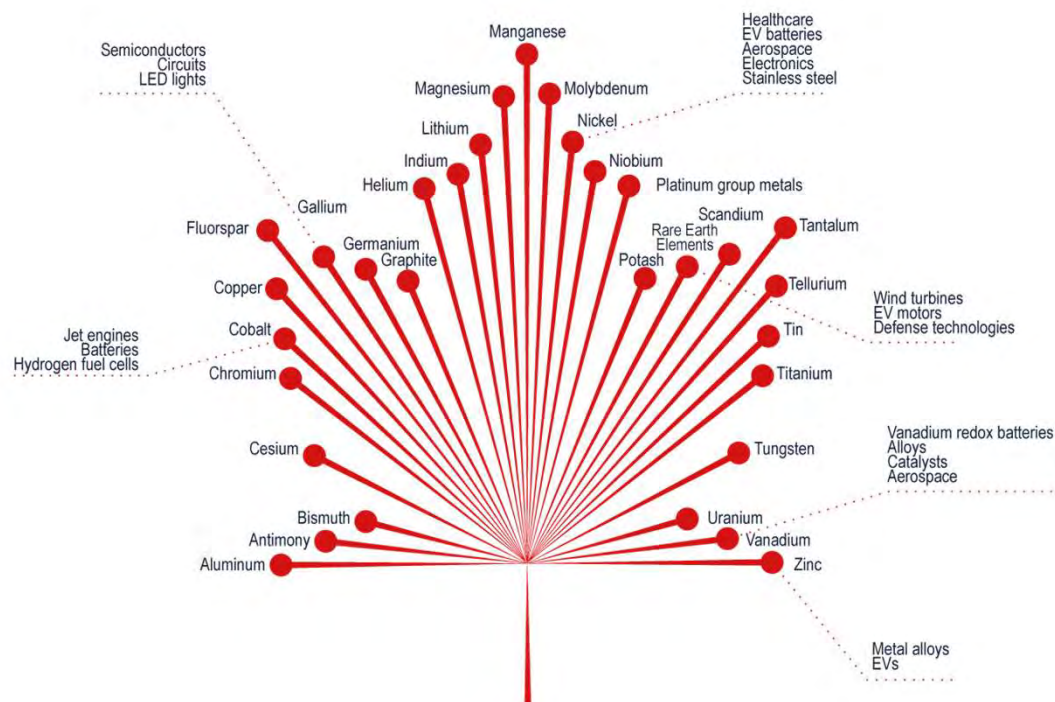
Significant forecasted increases in demand for lithium, graphite, nickel, cobalt, copper, and rare-earth elements

Critical Minerals: Demand outlook



Sources: IEA (2021), The Role of Critical Minerals in Clean Energy Transitions, IEA, Paris <https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>


Canada's Critical Mineral List



- January 2020: Canada–U.S. Joint Action Plan on Critical Minerals Collaboration
- March 2021: Canada unveils official list of 31 critical minerals
- June 2022: Canada launches discussion paper on Canada's critical minerals strategy
- Canada's Critical Minerals Strategy expected to be published by the end of 2022

Sources: <https://www.canada.ca/en/campaign/critical-minerals-in-canada/canada-critical-minerals-strategy-discussion-paper.html>

Global Critical Mineral Lists

Critical Mineral	 1	 2	 3	 4	 5
Aluminum					
Antimony					
Arsenic					
Barite					
Beryllium					
Bismuth					
Borates					
Cesium					
Chromium					
Cobalt					
Coking Coal					
Copper					
Fluorspar					
Gallium					
Germanium					
Graphite					
Hafnium					
Helium					
Indium					
Lithium					
Magnesium					
Manganese					
Molybdenum					

Critical Mineral	 1	 2	 3	 4	 5
Natural Rubber					
Nickel					
Niobium					
Platinum group metals					
Potash					
Rare earth elements					
Rhenium					
Rubidium					
Scandium					
Selenium					
Silicon Metal					
Strontium					
Tantalum					
Tellurium					
Tin					
Titanium					
Tungsten					
Uranium					
Vanadium					
Yttrium					
Zinc					
Zirconium					

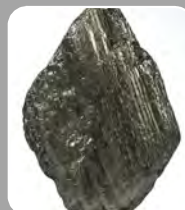
Sources: ¹ <https://www.nrcan.gc.ca/our-natural-resources/minerals-mining/critical-minerals/23414> ² <https://www.ontario.ca/page/critical-minerals> ³ <https://www.iea.org/policies/15271-final-list-of-critical-minerals-2022> ⁴ <https://rmis.jrc.ec.europa.eu/?page=cmm-list-2020-e294f6> ⁵ <https://www.ga.gov.au/scientific-topics/minerals/critical-minerals#heading-2>

Canada's CM List: Early priorities



Lithium

- Uses: Rechargeable batteries
- Use in electric vehicle batteries is a key price driver, demand expected to increase



Graphite

- Uses: Lubricants, batteries, and fuel cells
- Demand expected to grow due to increasing production of electric vehicles and portable electronics



Cobalt

- Uses: Rechargeable batteries and superalloys
- Demand expected to increase as more electric vehicles produced; supply-chain uncertainties and human rights issues



Nickel

- Uses: Stainless steel, superalloys, and rechargeable batteries
- Battery manufacturers replacing cobalt with nickel, leading to increased demand



Copper

- Uses: Electrical and electronics products
- Electric vehicles contain more than three times as much copper as conventional cars



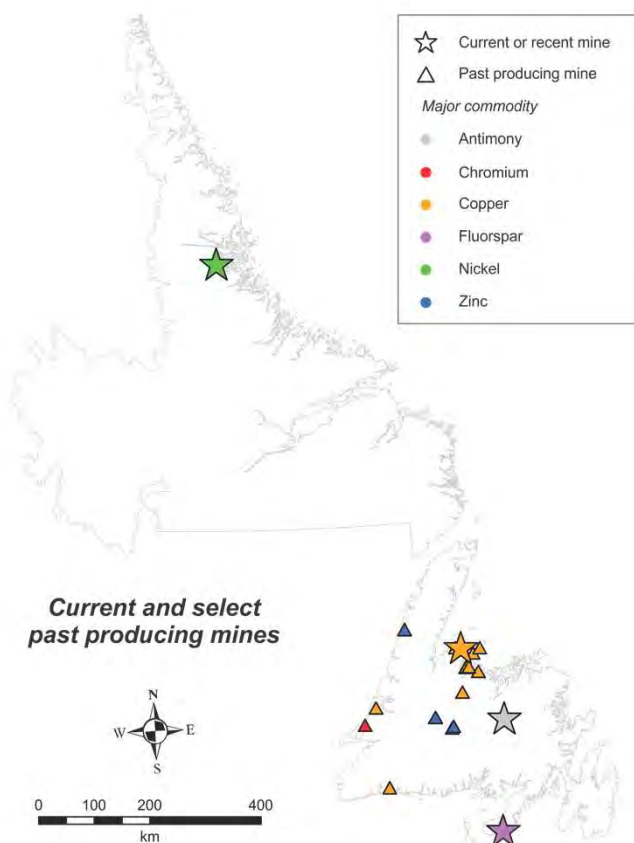
Rare Earth Elements

- Uses: Permanent magnets for electricity generators and motors
- Strong growth in demand due to increased production of EV and wind turbines

Sources: <https://www.canada.ca/en/campaign/critical-minerals-in-canada/canada-critical-minerals-strategy-discussion-paper.html>; <https://www.usgs.gov/news/national-news-release/us-geological-survey-releases-2022-list-critical-minerals>; https://yqsftp.gov.yk.ca/publications/miscellaneous/Reports/MR_23.pdf

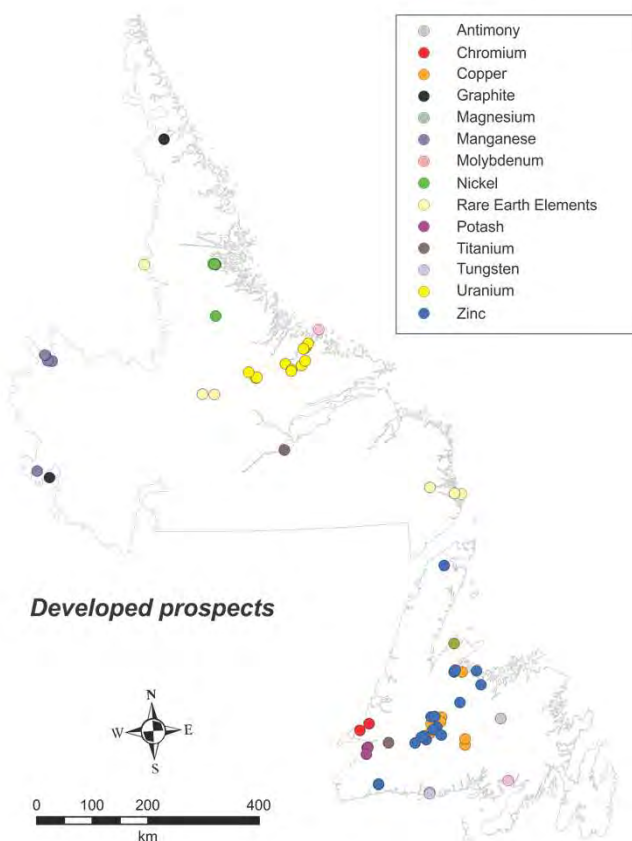
Critical Minerals in Newfoundland and Labrador

Critical Minerals in Newfoundland and Labrador



- Five critical minerals currently or recently mined in Newfoundland and Labrador
 - Antimony (Beaver Brook)
 - Copper (Ming Mine)
 - Fluorspar (St. Lawrence)
 - Nickel, copper and cobalt (Voisey's Bay)
- Historical mining included significant copper and zinc mines (e.g. Buchans, Tilt Cove, Duck Pond, Daniels Harbour) and numerous smaller operations

Critical Minerals in Newfoundland and Labrador



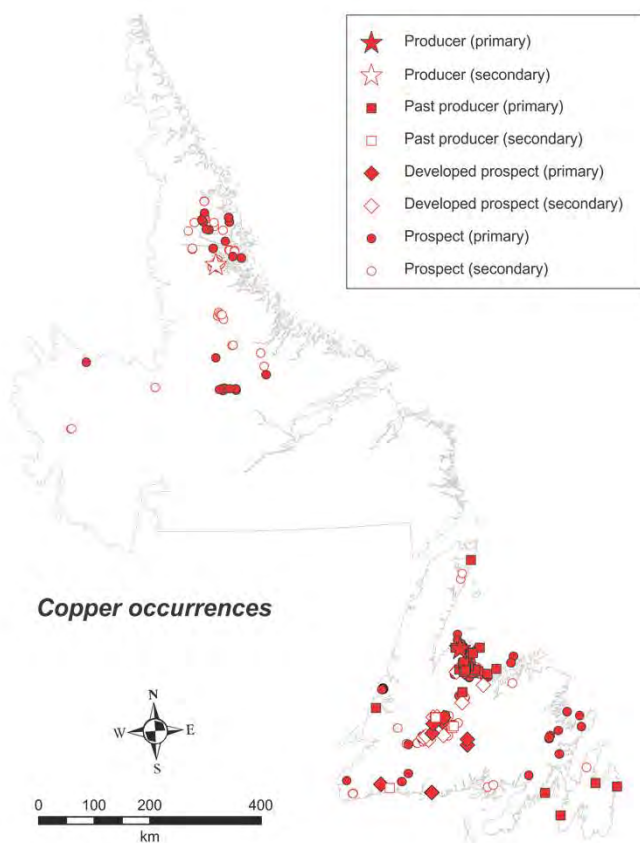
- 18 of the 31 commodities are recorded in advanced exploration projects (i.e. developed prospects) in Newfoundland and Labrador, e.g.
 - REE mineralization in Labrador
 - Zinc and copper in central Newfoundland
 - Nickel, copper, cobalt, PGE mineralization in Labrador
 - Tungsten, molybdenum and lithium in southern Newfoundland
 - Uranium in Central Mineral Belt, Labrador
 - Manganese and graphite in the Labrador Trough

Critical Minerals in Newfoundland and Labrador

Newfoundland and Labrador is home to at least 23 of the 31 critical minerals on Canada's Critical Mineral List

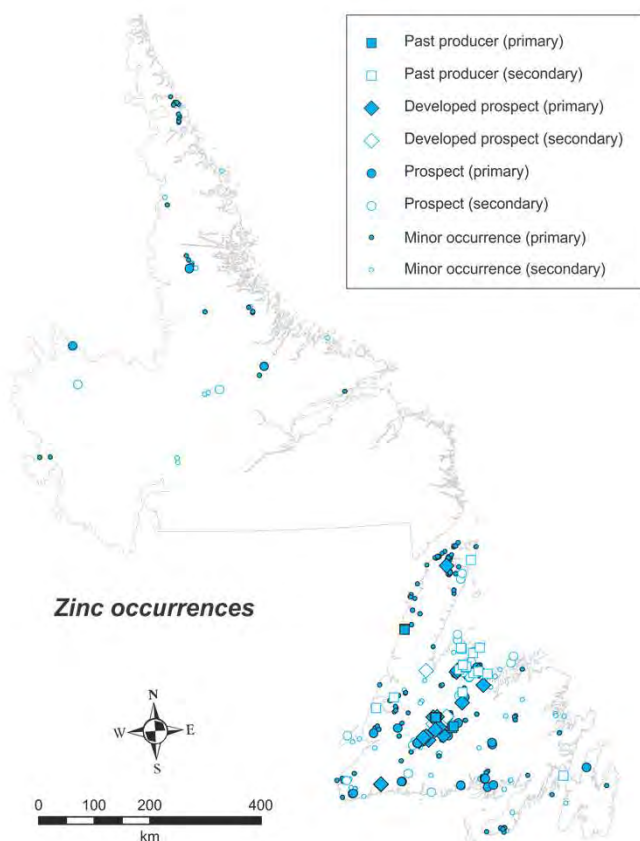
Aluminum	Antimony	Bismuth	Cesium	Chromium	Cobalt	Copper	Fluorspar
Gallium	Germanium	Graphite	Helium	Indium	Lithium	Magnesium	Manganese
Molybdenum	Nickel	Niobium	Platinum group metals	Potash	Rare earth elements	Scandium	Tantalum
Tellurium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zinc	

CM in NL: Copper



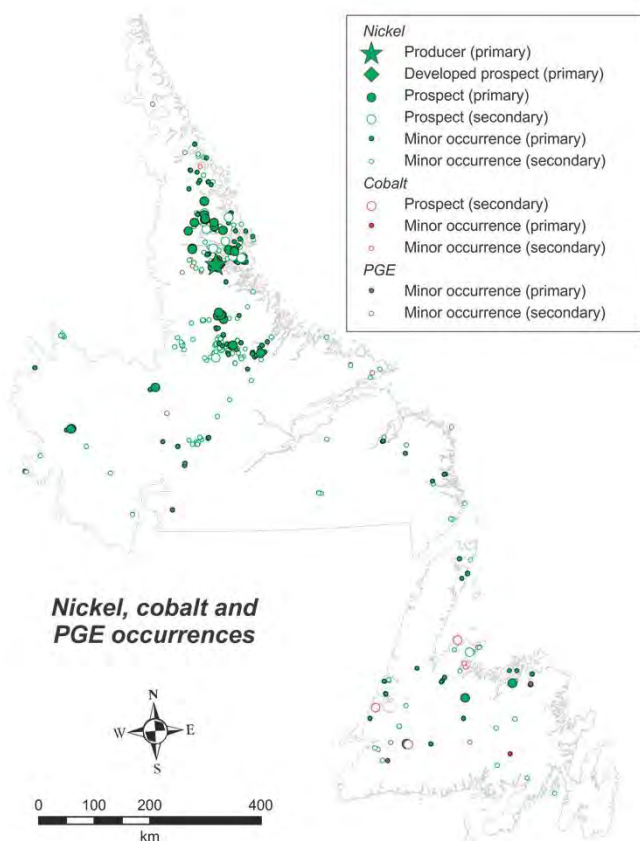
- Newfoundland and Labrador well endowed with copper resources (2418 total entries in MODS system)
 - 2 producing mines, 47 past producing mines
 - 29 developed prospects (most with mineral resources)
- Wide range of deposit types, including:
 - Volcanogenic Massive Sulphide (e.g. Ming Mine, Buchans, Duck Pond, Tilt Cove, Little Deer)
 - Orthomagmatic (e.g. Voisey's Bay)
 - IOCG (e.g. Cross Hills, Montgomery Lake)
 - Porphyry (e.g. Moly Brook)
 - Epithermal (e.g. Hope Brook)
 - Vein hosted (e.g. Cape Ray, Sail Pond)
 - Sedimentary hosted Cu (e.g. Bonavista)

CM in NL: Zinc



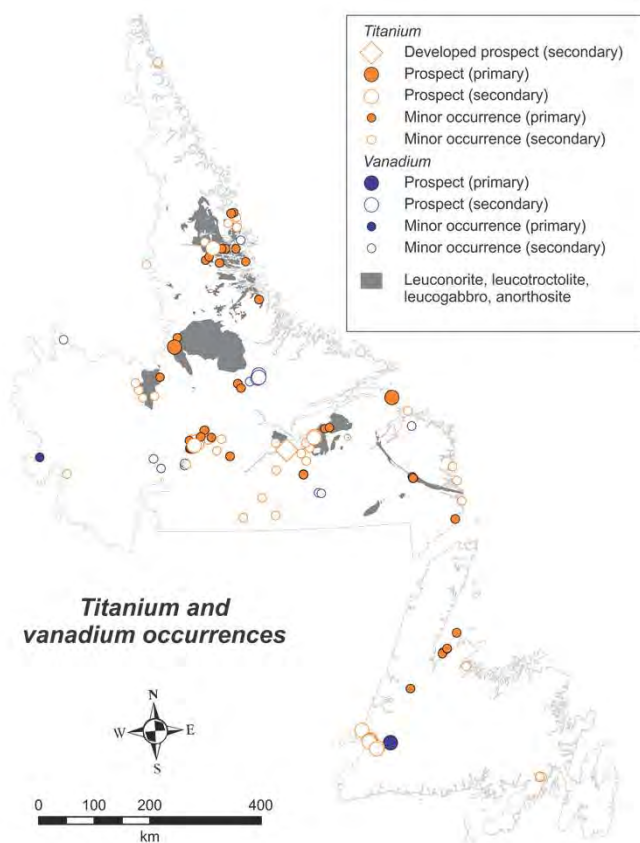
- Long history of zinc mining in Newfoundland, with numerous zinc occurrences across the province (747 total entries in MODS system)
 - 52 past producing deposits, including Buchans and Daniels Harbour mines
 - 37 developed prospects (most with mineral resources)
- Multiple deposit types in NL, including:
 - Mississippi Valley Type (e.g. Daniels Harbour)
 - Volcanogenic Massive Sulphide (e.g. Buchans, Duck Pond, Lemarchant, Bobby's Pond)
 - Vein hosted (e.g. Sail Pond, Cape Ray)

CM in NL: Nickel, Cobalt and PGE



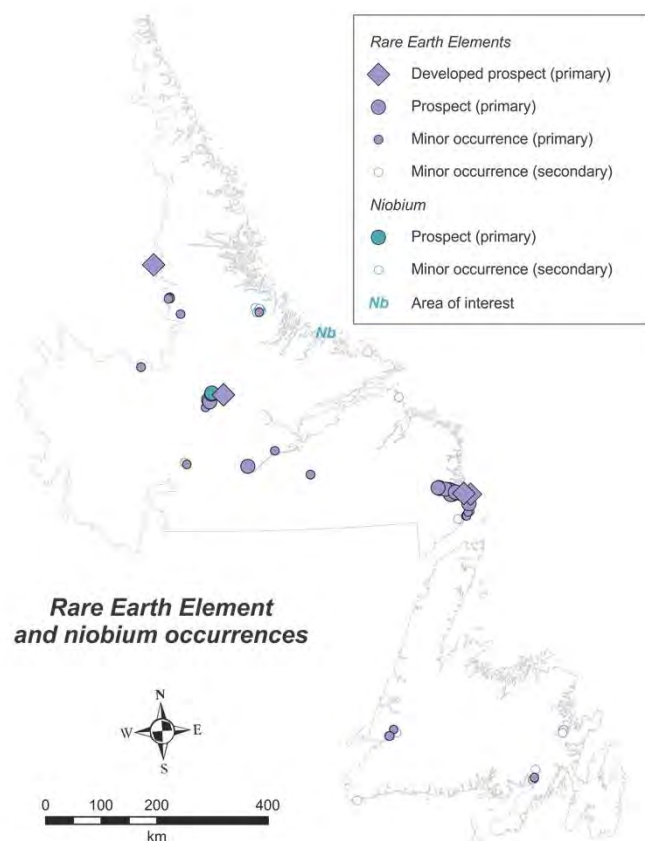
- Nickel, cobalt and copper currently produced from Voisey's Bay mine
 - Deposits at Voisey's Bay include Reid Brook and Eastern Deeps deposits
 - Numerous prospects in Newfoundland and Labrador
 - 429 total entries in MODS system
- Several deposit types with good potential, including:
 - Orthomagmatic (**Ni, Co, PGE**) (e.g. Voisey's Bay, Pants Lake, Taylor Brook, Portage Lake)
 - Volcanogenic Massive Sulphide (**Co**) (e.g. York Harbour)
 - Awaruite in ophiolitic ultramafic complexes (**Ni**) (e.g. Pipestone property)
 - Sedimentary hosted Cu (**Co?**) (e.g. Bonavista)

CM in NL: Titanium and Vanadium



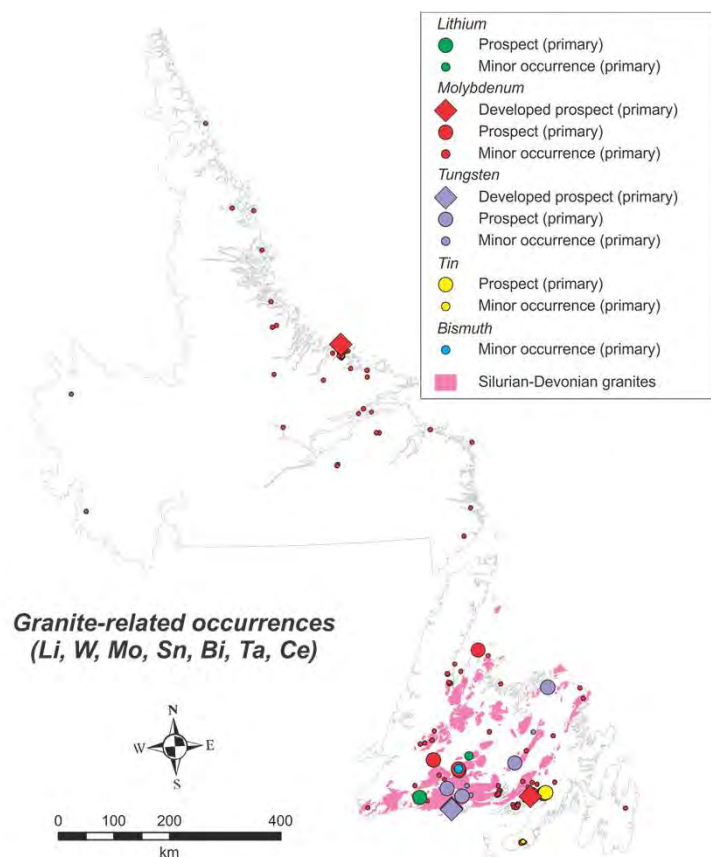
- Advanced exploration projects targeting Ti and V
 - Keating Prospect: 5.08% TiO_2 , 0.116% V_2O_5 over 217 m (French and Mugford, 2010)
 - Moran Lake Upper C Zone: 134 million lbs of V_2O_5 (Wallis et al., 2011)
 - 159 total combined entries in MODS system
- Ti and V mineralization associated with a number of deposit types
 - Fe–Ti oxide accumulations in layered mafic intrusions and large anorthositic complexes (e.g. Keating Prospect, Kiglapait Intrusion)
 - Breccia hosted vanadium mineralization associated with uranium mineralization (e.g. Moran Lake)
 - Placer deposits from weathering of Ti-V oxides (e.g. Churchill River Mineral Sands)

CM in NL: Rare Earth Elements (plus Nb, Ta, Zr, Y)



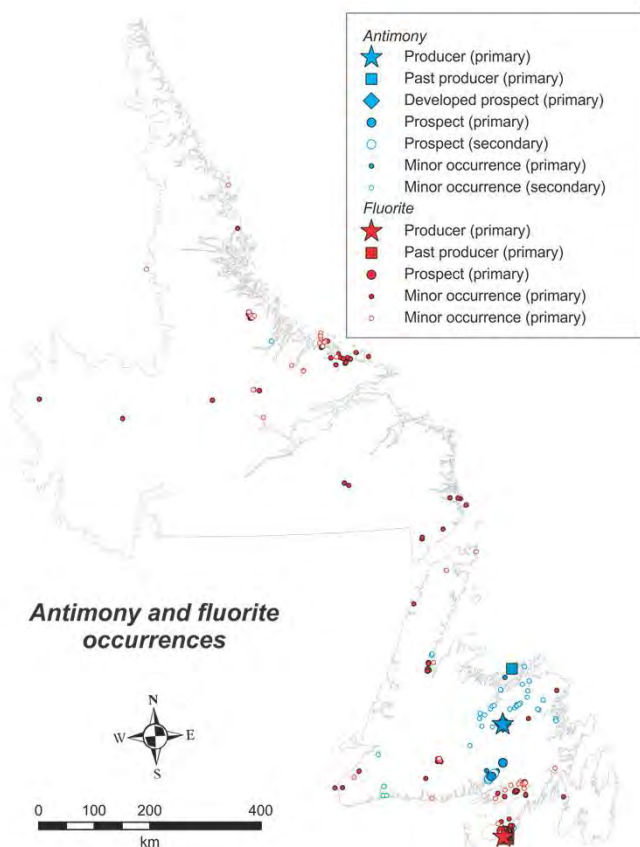
- Most occurrences in Labrador, advanced exploration projects include:
 - Deep Fox and Foxtrot Deposits: 15.1 Mt Indicated Resources (Search Minerals, 2022)
 - Strange Lake Deposit: ~57 Mt at 0.54% TREO, 0.31% Nb₂O₅, 2.93% ZrO₂, and 0.38% Y₂O₃ (IOCC historical estimate)
 - 108 total combined entries in MODS system
- REE and Nb (± Ta) mineralization typically associated with peralkaline igneous complexes (e.g. Foxtrot, Strange Lake, Red Wine District)
 - Potential for Nb and REE mineralization in carbonatites (e.g. Aillik area; Tappe et al., 2006)
 - REE deposits also significantly enriched in Zr, Y (on critical mineral lists of other jurisdictions)

CM in NL: Granite related (Li, W, Mo, Sn, Bi)



- Most significant known occurrences associated with peraluminous granites in southern and central Newfoundland
 - Moly Brook: Indicated resource of 86.8 Mt at 0.065% molybdenum (113 Mlbs Mo)
 - Grey River: Inferred resource of 1.17 Mt at 0.730%WO₃ (18.8 Mlbs WO₃)
 - Kraken Li
- Mineralization associated with peraluminous Silurian and Devonian granites
 - Pegmatites (e.g. Kraken), porphyry veins (e.g. Moly Brook), greisens (e.g. Ackley Sn) and late hydrothermal veins (e.g. Grey River, Granite Lake)
- 285 total combined entries in MODS system

CM in NL: Antimony and Fluorspar



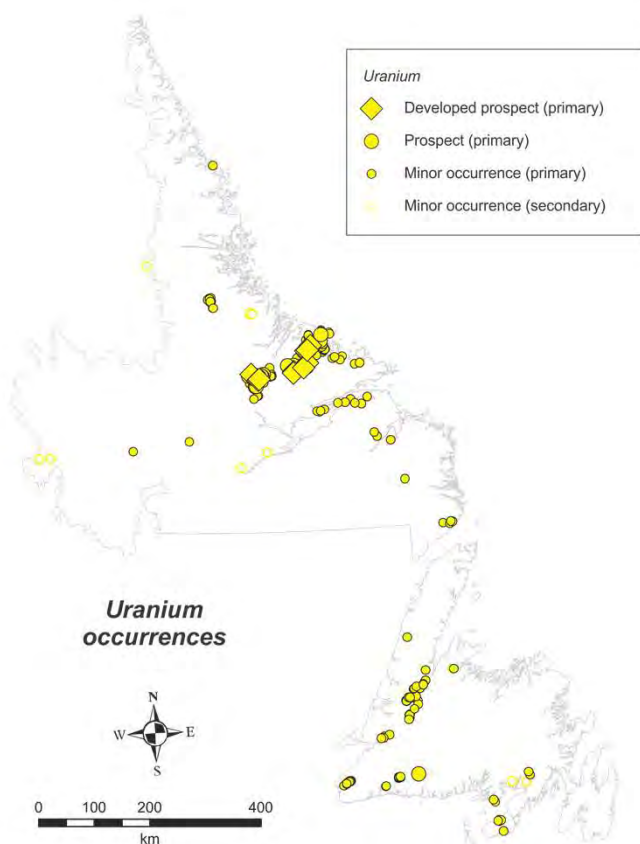
Antimony

- Current production from Beaver Brook mine, other prospects in Conne River area (e.g. Little River Sb-Au Prospect, 0.92 m interval of 30.6% Sb)
- Mineralization in NL hosted in orogenic veins, typically regionally associated with orogenic gold mineralization (common pathfinder for gold mineralization)
 - 78 total entries in MODS system

Fluorspar

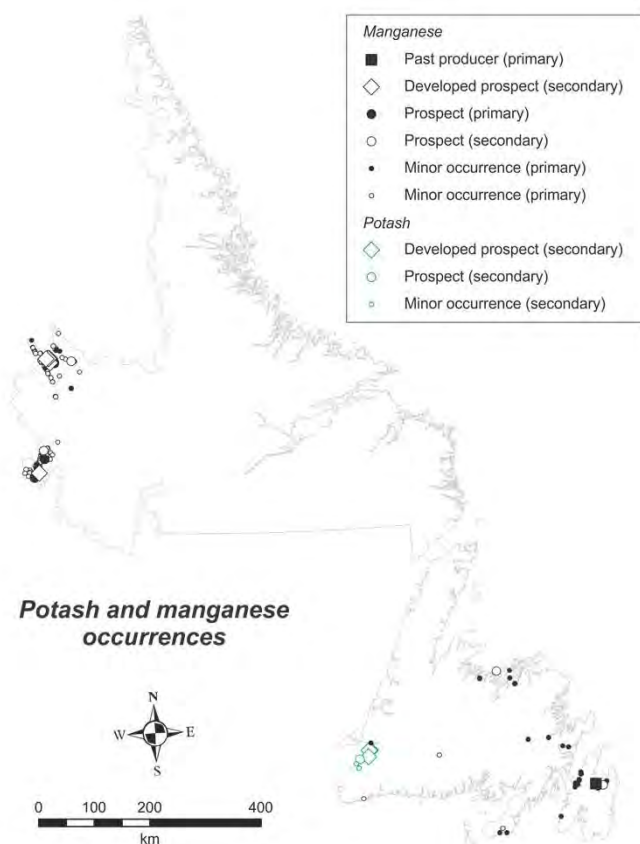
- Recent and historical production from the St Lawrence area
- Mineralization in fluorite veins associated with the Carboniferous St. Lawrence Granite
- Common accessory mineral in other deposit types (e.g. peralkaline granite related REE mineralization)
 - 218 total entries in MODS system

CM in NL: Uranium



- Number of developed prospects in the Central Mineral Belt (CMB) of Labrador (Sparkes, 2017)
 - Michelin: Measured and indicated resource of 84.1 Mlb U_3O_8
 - Jacques Lake: Measured and indicated resource of 11.2 Mlb U_3O_8
 - Moran Lake: Indicated resource of 6.9 Mlbs U_3O_8
- Variety of deposit styles in CMB, including magmatic, metamorphic–metasomatic, iron-oxide-copper-gold (IOCG) and sedimentary environments (Sparkes, 2017)
- Numerous other occurrences in Newfoundland and Labrador (310 total entries in MODS system)

CM in NL: Potash and Manganese



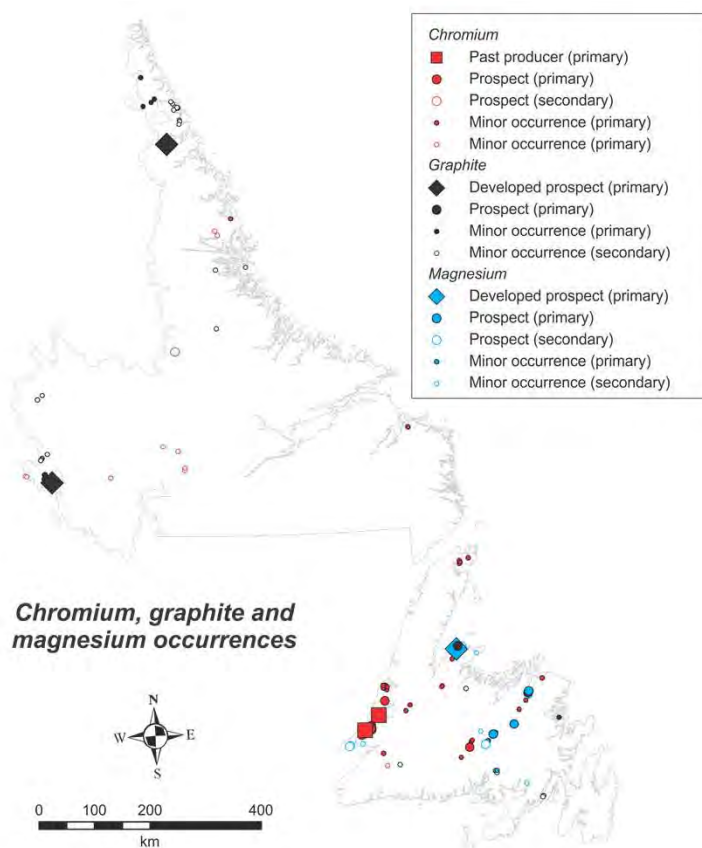
Potash

- Associated with salt deposits in Bay St. George Basin, western Newfoundland (6 total entries in MODS system)

Manganese

- Significant manganese resources associated with altered banded iron formations in Labrador Trough
- Include Mn-rich DSO-type iron ore deposits in Schefferville area, and Mn-rich units in Scully Mine
- Other manganese prospects located on Avalon Peninsula (e.g. Kelligrews River Prospect)
- 177 total entries in MODS system

CM in NL: Chromium, graphite and magnesium



Chromium

- Mineralization associated with ultramafic ophiolite complexes, prospects and past producing mines in the Bay of Islands Complex
- 96 total entries in MODS system

Graphite

- Prospects associated with metamorphosed carbonaceous shales in western and northern Labrador, Baie Verte Peninsula
- 45 total entries in MODS system

Magnesium

- Proposal to extract magnesium from tailings at Baie Vetre Asbestos Mine
- 39 total entries in MODS system

CM in NL: Other minerals

- Potential geological environment identified for critical minerals not currently identified in Newfoundland and Labrador

Gallium, germanium and indium	<ul style="list-style-type: none"> • Found globally as by-product of zinc mining (particularly low temperature MVT and VMS deposits)
Tellurium	<ul style="list-style-type: none"> • By-product in many mineral deposits (VMS, epithermal, porphyry etc.).
Cesium	<ul style="list-style-type: none"> • Typically found associated with lithium bearing pegmatites
Scandium	<ul style="list-style-type: none"> • By-product of Ti, V, U, REE mining, including Lac Tio iron-titanium deposit on North Shore in Quebec
Helium	<ul style="list-style-type: none"> • Found in association with natural gas, potential for offshore NL

Critical Mineral Deposit Models: Summary

- Critical minerals formed in a large number of geological environments in Newfoundland and Labrador

Magmatic deposits

- Magmatic sulfide (Ni, Cu, Co, PGE)
- Magmatic oxide (Ti, V, Sc)
- **Peralkaline igneous hosted (REE, F, Nb, Ta)**
- **Granite-related (Li, Mo, W, Sn, Bi, Ta, Ce)**
- Porphyry (Cu, Mo)
- Ultramafic ophiolite-hosted (Cr, Ni, Mg)
- Carbonatite hosted (REE, Nb, Ta)

Hydrothermal deposits

- Volcanogenic massive sulphides (Cu, Zn, Co, Ga, Ge, In, Te)
- Mississippi Valley Type (Zn, Ga, Ge, In)
- Orogenic vein hosted (Sb, Zn, Cu)
- Iron Oxide Copper Gold (Cu, U, V, Mo, Co, REE etc.)
- Epithermal (Cu, Te)

Other deposits

- Sedimentary uranium deposits (U)
- Sedimentary hosted Cu (Cu, Co)
- Banded iron formation (Mn)
- Evaporite deposits (potash)
- Metamorphosed shales (graphite)
- Placer deposits (Ti, V, Sc)

- Many critical minerals are found as a by-product of existing deposits
 - Not previously assayed for these elements, or previously thought of as deleterious elements

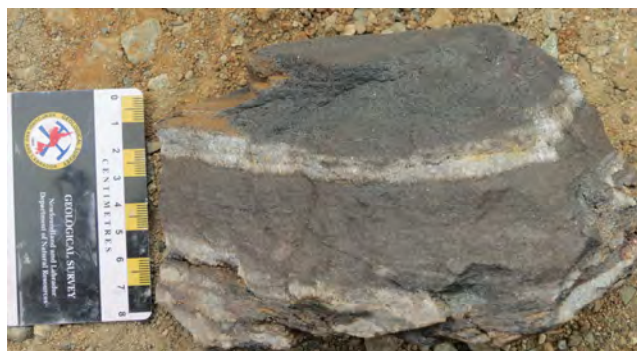
Case Study 1: Scully Mine



- Iron ore mine in Wabush, active from 1965 to 2014
 - Metamorphosed and altered iron formation, with relatively high Mn content (2.58% Mn in Mineral Reserve)

“manganese content in the ore is the primary market limitation to exploiting more of the remaining resources than is currently planned”

Farquharson and Thalenhorst, 2006



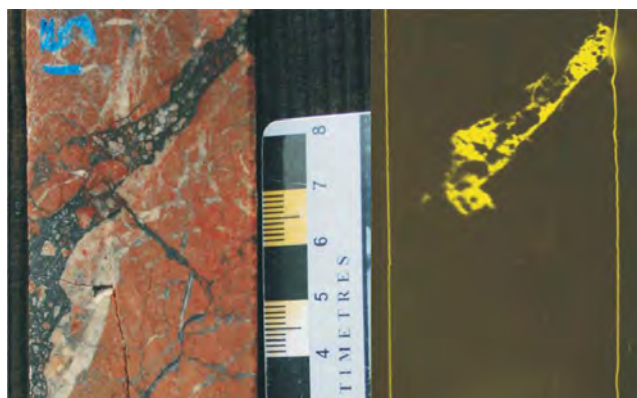
- Tacora Resources restarted mining operations in 2019
 - Additional manganese reduction lines installed
 - Stockpiling high manganese by-product on site
 - Investigating potential to produce manganese for battery metal market

Case Study 2: York Harbour Mine



- Mine active from 1897 to 1913, with further mining activity and exploration from 1950s to 1970s
 - Eleven lenses of Cu-Zn-Ag-Au mineralization reported from close to former mine workings
- Current exploration by York Harbour Metals
- Cobalt enrichment recorded in recent drilling
 - 5.25% Cu, 436.5 g/t Co over 29 m (York Harbour Metals Press Release, March 26, 2022)
- Similar Cyprus-type VMS deposits in Europe with significant Co resources (e.g. Løkken deposit with 30 Mt grading 0.07% Co; Horn et al., 2021)

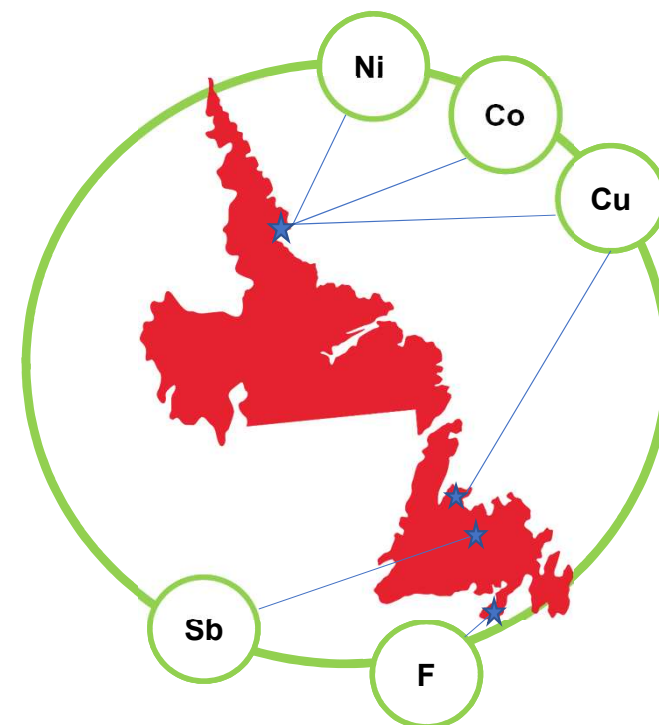
Case Study 3: Moran Lake Upper C Zone



- Uranium mineralization discovered in 1958, hosted in late fractures within brecciated and strongly altered mafic volcanic rocks (Sparkes, 2017)
 - NI 43-101 indicated and inferred resource of ~8 Mlb U_3O_8 (Morgan and Giroux, 2008)
- Significant low-grade vanadium resource also identified, associated with earlier brecciation and hematite alteration (Kerr et al., 2013)
 - NI 43-101 indicated and inferred resource of ~134 Mlbs of V_2O_5 within the Upper C Zone of the deposit (Wallis et al., 2011)

Summary and conclusions

- Identifying and developing new critical mineral resources vital in our transition to a “green economy”
- Canada has created a list of 31 minerals considered “critical”
- Newfoundland and Labrador is home to at least 23 of the 31 critical minerals on the list and 5 of the 31 are currently being mined including: Antimony (Sb), Cobalt (Co), Copper (Cu), Fluorspar (F) and Nickel (Ni)
- Prospecting for critical minerals includes reassessing former known deposits and previously explored geological terranes for critical mineral potential



Links and References

Links to critical mineral resources

<https://www.canada.ca/en/campaign/critical-minerals-in-canada/canada-critical-minerals-strategy-discussion-paper.html>

<https://www.nrcan.gc.ca/our-natural-resources/minerals-mining/critical-minerals/23414>

<https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>

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Tappe, S. Foley, S.F., Jenner, G.A., Heaman, L.M., Kjarsgaard, B., Romer, R.L., Stracke, A., Joyce, N., and Hoefs, J., 2006. Genesis of Ultramafic Lamprophyres and Carbonatites at Aillik Bay, Labrador: a Consequence of Incipient Lithospheric Thinning beneath the North Atlantic Craton. Journal of Petrology, Volume 47, Issue 7, Pages 1261–1315.

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