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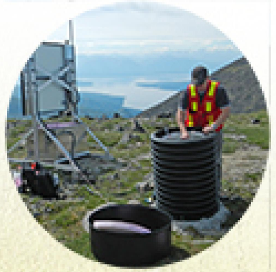


Geological Survey of Canada
Scientific Presentation 143

Evidence for a Neoarchean to earliest-Paleoproterozoic mantle metasomatic event prior to formation of the Mesoproterozoic-age Strange Lake REE deposit, Newfoundland and Labrador, and Quebec, Canada

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Publications in this series have not been edited; they are released as submitted by the author.

Abstract

A complete suite of bulk major- and trace-elements measurements combined with macroscopic/microscopic observations and mineralogy guided by scanning electron microscope-energy dispersive spectrometry (SEM-EDS) analyses were applied on Nekuashu (2.55 Ga) and Pelland (2.32 Ga) intrusions in northern Canada, near the Strange Lake rare earth elements (REE) deposit, to evaluate their magmatic evolution and possible relations to the Mesoproterozoic Strange Lake Peralkaline Complex (SLPC). These Neoarchean to earliest-Paleoproterozoic intrusions, part of the Core Zone in southeastern Churchill Province, comprise mainly hypersolvus suites, including hornblendite, gabbro, monzogabbro/monzodiorite, monzonite, syenite/augite-syenite, granodiorite, and mafic diabase/dyke. However, the linkage of the suites and their petrogenesis are poorly understood.

Geochemical evidence suggests a combination of ‘intra-crustal multi-stage differentiation’, mainly controlled by fractional crystallization (to generate mafic to felsic suites), and ‘accumulation’ (to form hornblendite suite) was involved in the evolution history of this system. Our model proposes that hornblendite and mafic to felsic intrusive rocks of both intrusions share a similar basaltic parent magma, generated from melting of a hydrous metasomatized mantle source that triggered an initial REE and incompatible element enrichment that prepared the ground for the subsequent enrichment in the SLPC.

Geochemical signature of the hornblendite suite is consistent with a cumulate origin and its formation during the early stages of the magma evolution, however, the remaining suites were mainly controlled by ‘continued fractional crystallization’ processes, producing more evolved suites: gabbronorite/hornblende-gabbro → monzogabbro/monzodiorite → monzonite → syenite/augite-syenite.

In this proposed model, the hydrous mantle-derived basaltic magma was partly solidified to form the mafic suites (gabbronorite/hornblende-gabbro) by early-stage plagioclase-pyroxene-amphibole fractionation in the deep crust while settling of the early crystallized hornblende (+pyroxene) led to the formation of the hornblendite cumulates. The subsequent fractionation of plagioclase, pyroxene, and amphibole from the residual melt produced the more intermediate suites of monzogabbro/monzodiorite. The evolved magma ascended upward into the shallow crust to form monzonite by K-feldspar fractionation. The residual melt then intruded at shallower depth to form syenite/augite-syenite with abundant microcline crystals. The granodiorite suite was probably generated from lower crustal melts associated with the mafic end members. Later mafic diabase/dykes were likely generated by further partial melting of the same source at depth that were injected into the other suites.

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Funding

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Natural Resources Canada's Targeted Geoscience Initiative Program (TGI) and
Geo-Mapping for Energy & Minerals_GEM Hudson-Ungava

TGI Ore Systems

Magmatic Ore Systems Project's 'Sub-Activity':

"Critical minerals within carbonatite, syenite, and allied peralkaline-alkaline rocks in the central and eastern parts of the Canadian Shield: where, when and how were they formed"

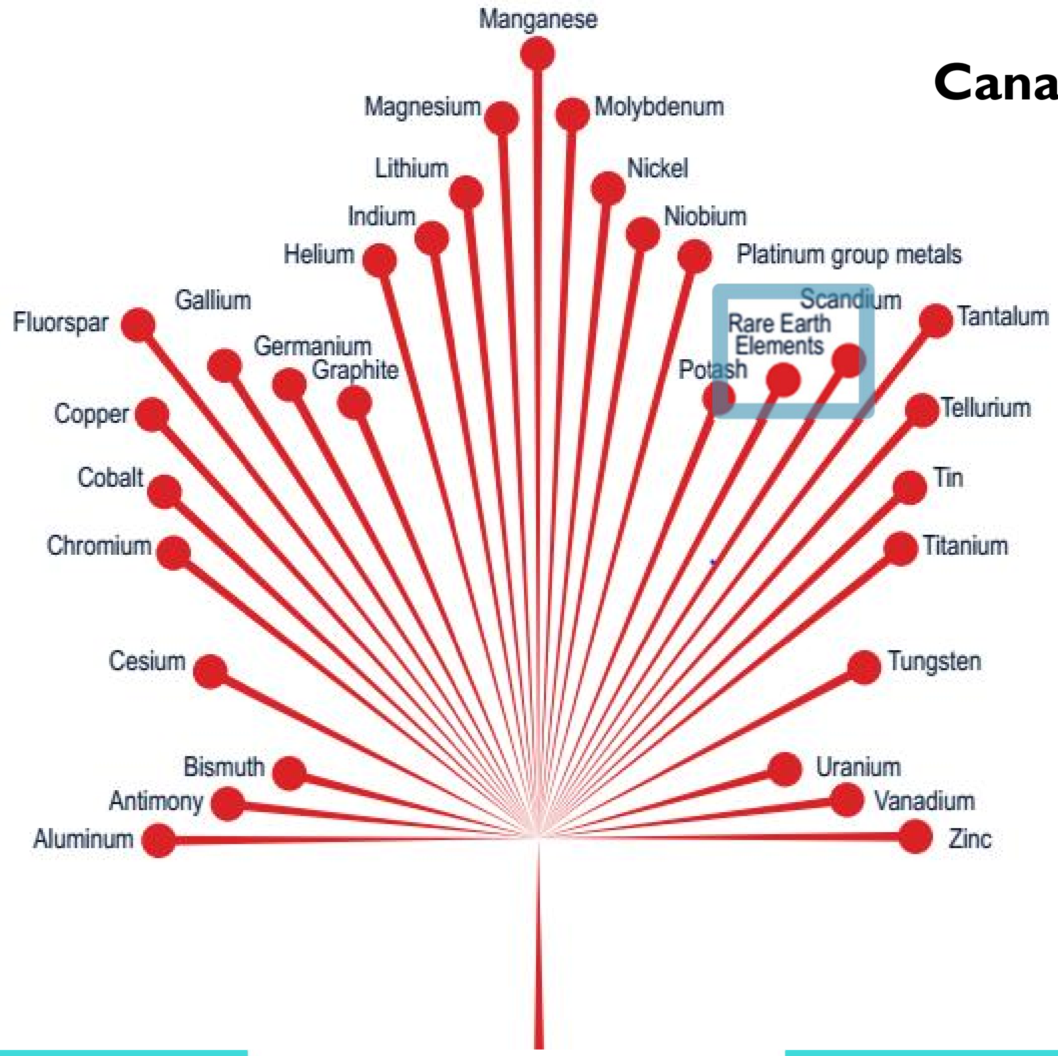
Led by Dr. Anne-Aurelie Sappin

In collaboration with the Ministère des Ressources Naturelles du Québec and the Geological Survey of Newfoundland & Labrador

Photo by Dr. David Corrigan

CANADA'S CRITICAL MINERALS LIST 2021

REE-bearing Minerals:
Monazite, Bastnasite, Xenotime,
Zircon, Apatite, Allanite, Titanit



Canada–U.S. Joint Action Plan

REEs

Monazite (LREE): (Ce, La, Nd, Th)P

Bastnasite: (La, Ce, Y)CO_3F

Xenotime: (HREE)Y

Apatite (LREE): $Ca_5(PO_4)_3(OH,F,Cl)$

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Rare Earth Metals & Our Daily Life

REEs are key components in many electronic devices that we use in our daily lives, as well as in a variety of industrial applications, clean energy, aerospace, and defence.

More valuable than gold & oil

Health

Clean Technology

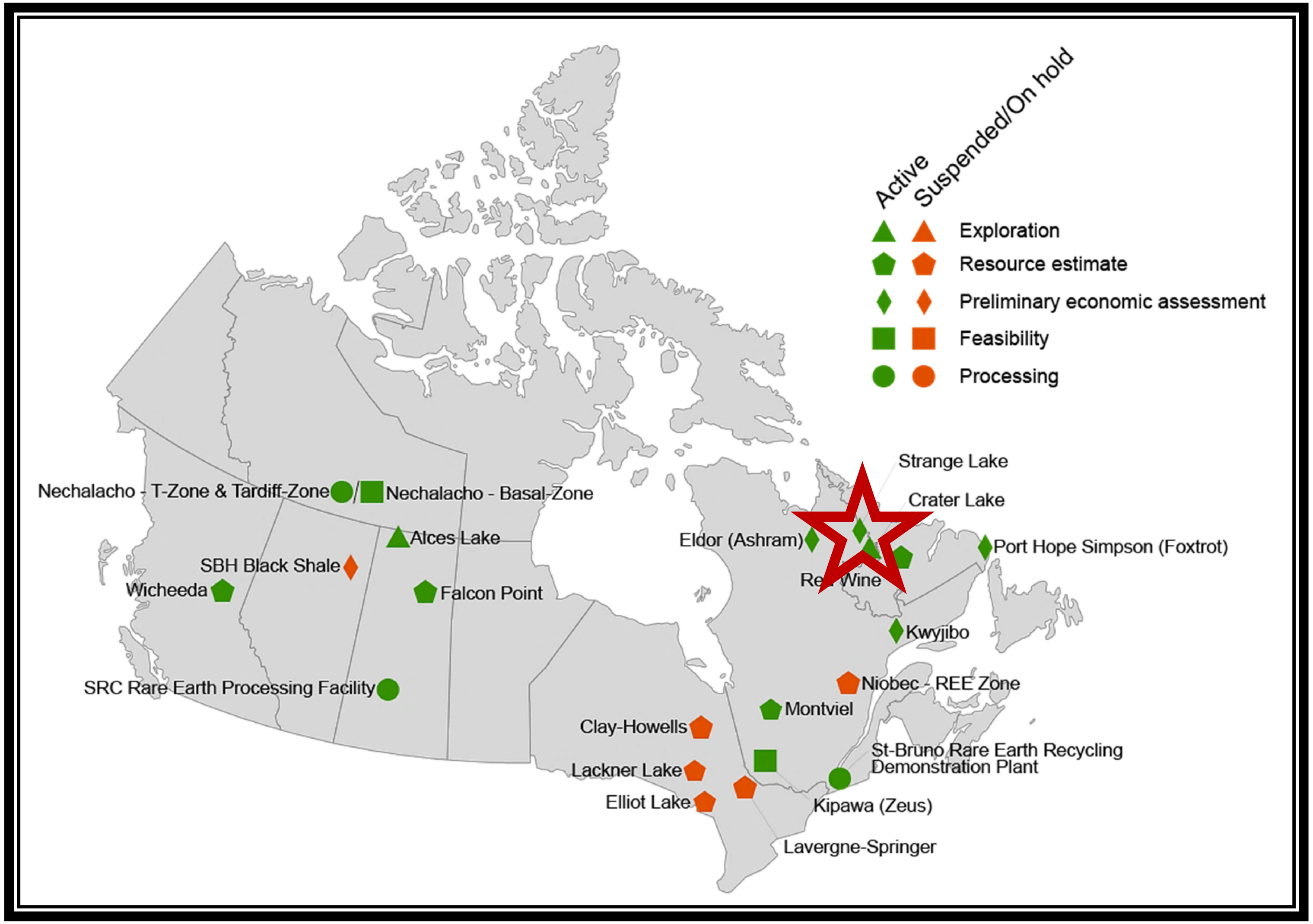
Computing, Mobile, & Entertainment

Advanced Communications

National Defence

REE Resources in Canada

Rare Earth Projects: Potential Future Mines in Canada



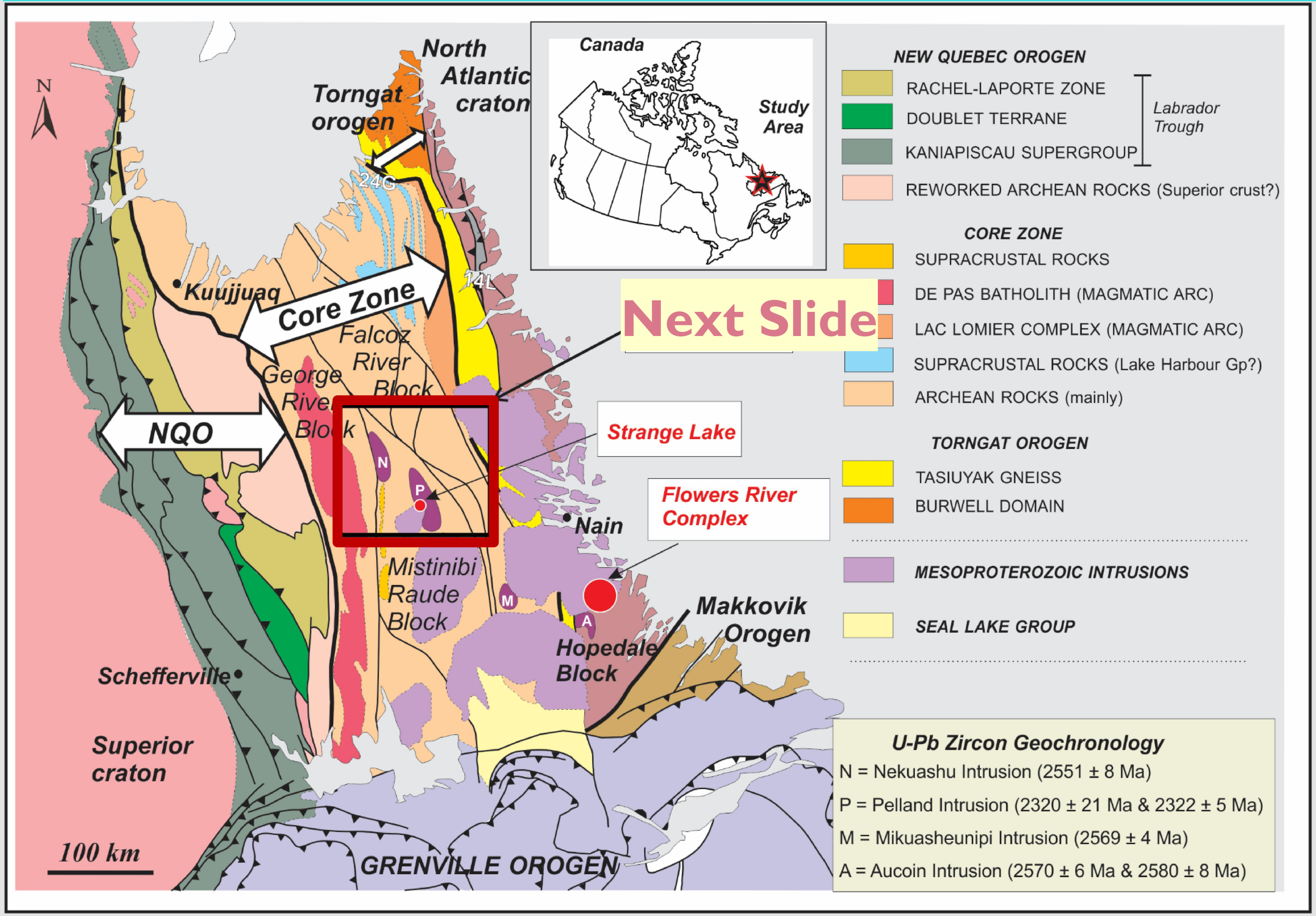
Natural Resources Canada (2021)

Most Recent Updates in 2021

Canada is host to a number of advanced exploration projects and some of the largest reserves and resources (measured and indicated) of these metals. **These reserves and resources are estimated at over 14 million tonnes in 2021 (NRCan).**

Strange Lake Deposit (REE, Nb, Zr)

Southeastern Churchill Province: Quebec-Labrador



Simplified geological map of the Southeastern Churchill Province (SECP) and location of the Core Zone (modified after James and Dunning, 2000 and Corrigan et al., 2018). NQO = New Quebec Orogen

Strange Lake Deposit

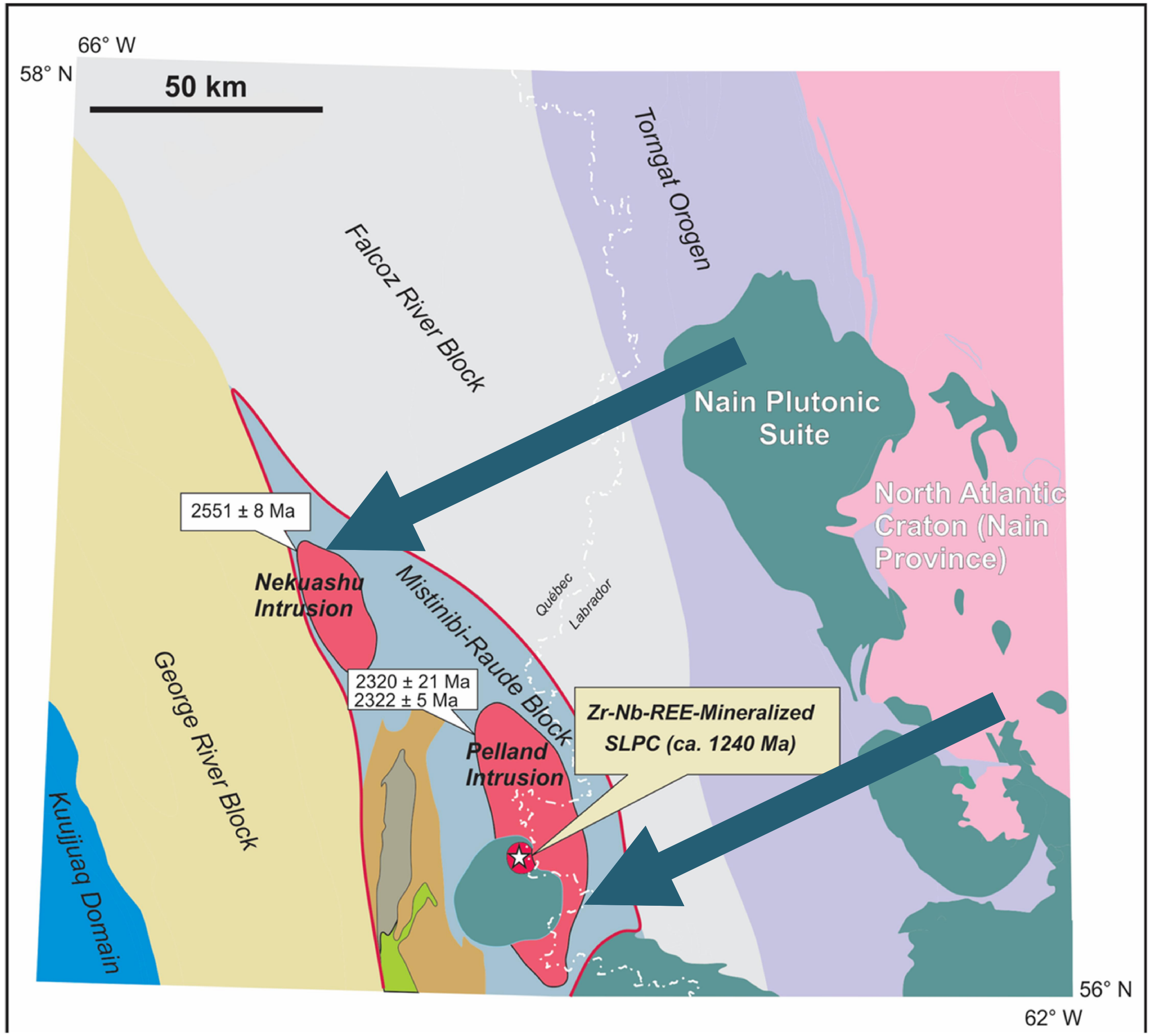
One of the richest rare-metal deposits in the world

A peralkaline A-type granite that is hyper-enriched in

REE, Zr, and Nb

with an indicated resource of 20 Mt grading 1.44 wt.% REE_2O_3, of which ~50% are heavy rare-earth oxides (e.g., Siegel et al., 2018; Vasyukova and Williams-Jones, 2020).

Core Zone: *Mistinibi-Raude Block*



Neoarchean to Earliest-Paleoproterozoic Intrusions

Nekuashu Intrusion (ca. 2.55 Ga)

Pelland Intrusion (ca. 2.3 Ga)

Mesoproterozoic Intrusion

Zr-Nb-REE Strange Lake (1.24 Ga)

Mistinibi-Raude Block
- < 1.99 Ga Hutte Sauvage clastics
- ca. 2.32 - 2.55 Ga alkalic intrusions
- Mistinibi complex (migmatitic paragneiss)
- ca. 2.37 Ga Ntshuku volcanic belt
- ca. 2.3 - 2.6 Ga orthogneiss (Pallatin Suite; 2.33 Ga)

Nain Plutonic Complex
- Strange Lake Peralkaline Complex (SLPC)
- Monzonite, granite, monzogranite, gabbro, norite, and anorthosite

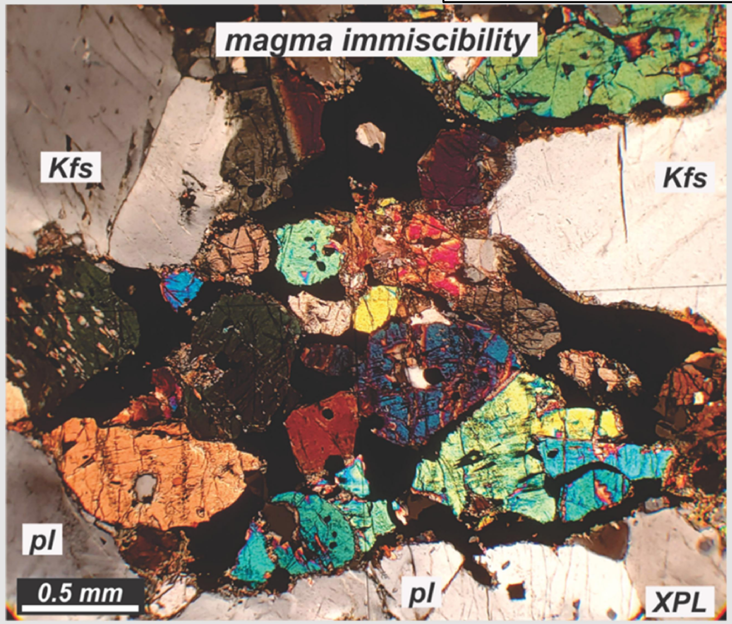
Simplified geological map of the central part of the Core Zone in the Southeastern Churchill Province (modified after Corrigan et al., 2018).

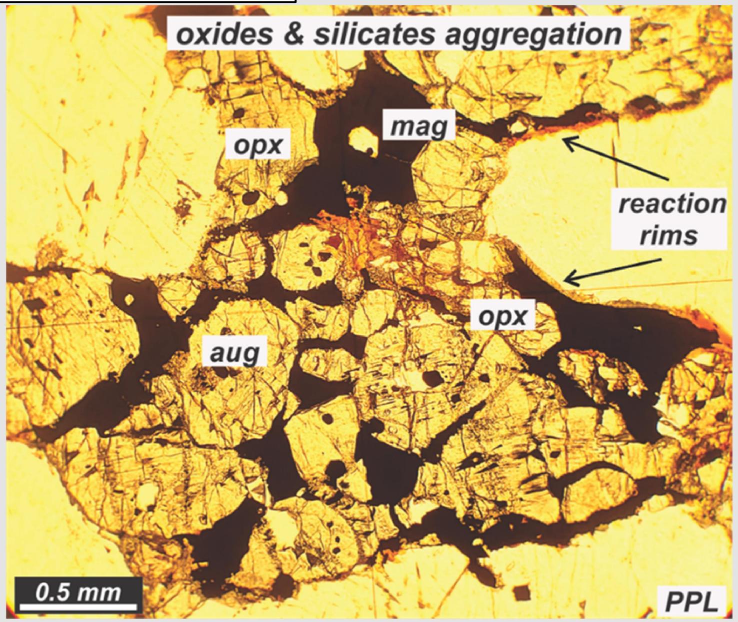
Nekuashu & Pelland Intrusions (Lithology)

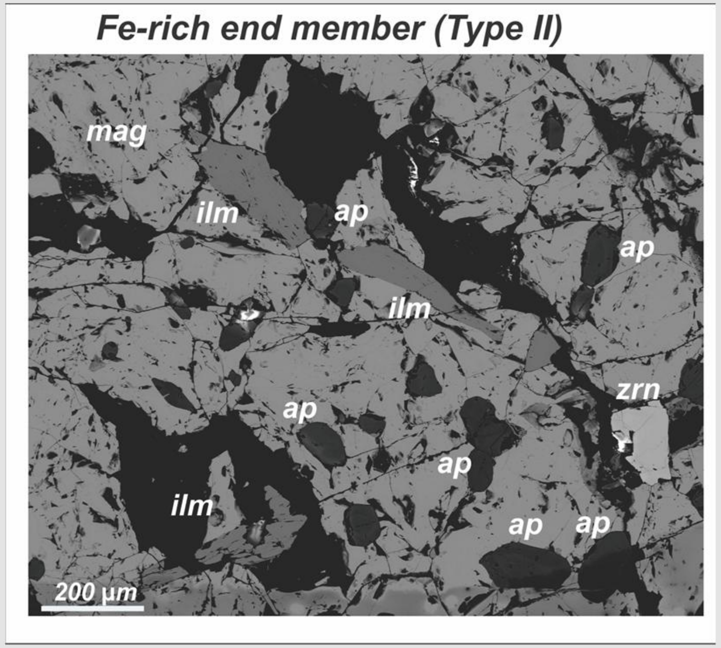
They are composed of granodiorite, syenite, monzonite, monzogabbro/monzodiorite, gabbro, hornblendite, & mafic dykes.

Monzonite, Micro-Scale Fe-rich Globules

Fe-rich end member (Type I)







Irregular to rounded-shaped textures (a few mm to cm)

Fe-rich globule Type I (magnetite, ilmenite, augite, orthopyroxene)

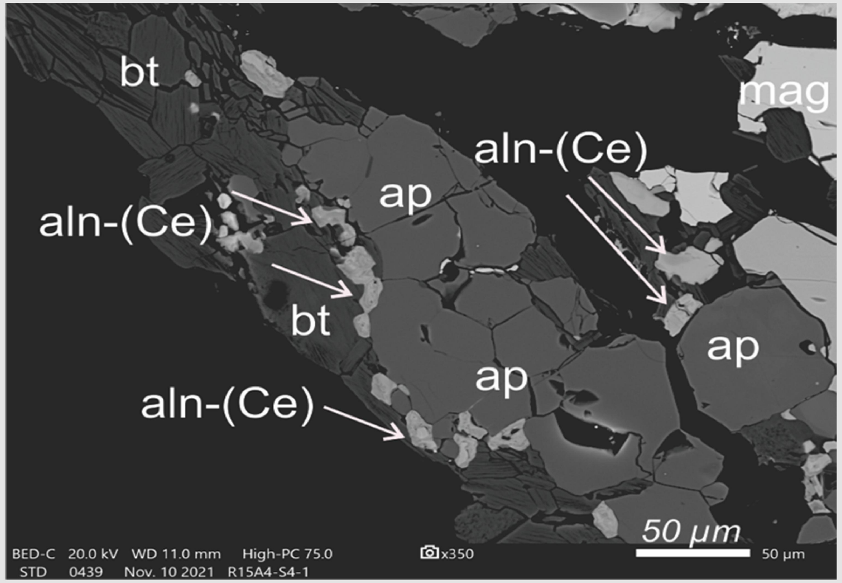
apatite, zircon, allanite-(Ce) ± sulphides

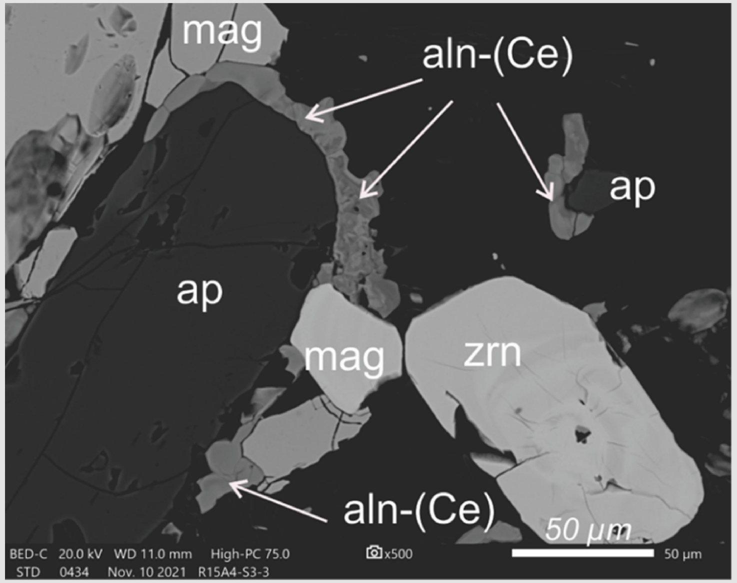
Fe-rich globule Type II (magnetite, ilmenite, apatite, REE)

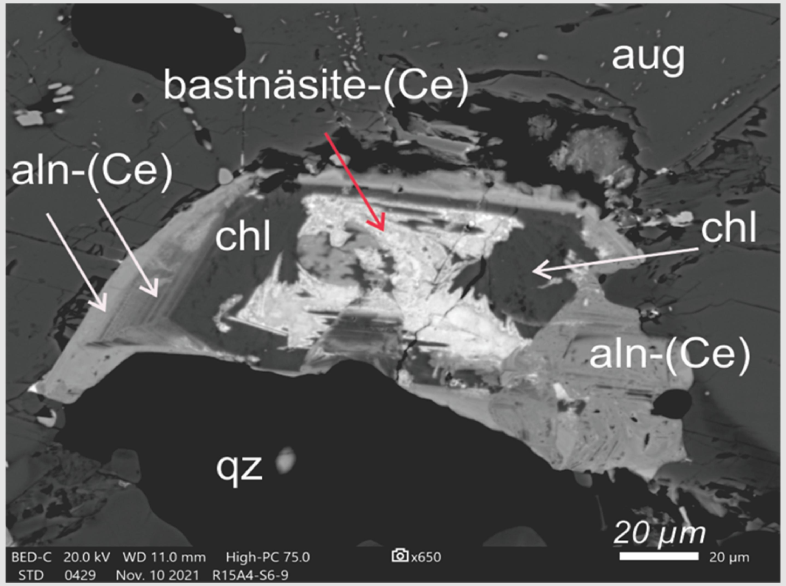
bastnäsite-(Ce), allanite-(Ce), zircon, titanite ± sulphides

Monzonite, Micro-Scale Fe-rich Globules

Fe-rich end member (Type II)







Irregular to rounded-shaped textures (a few mm to cm)

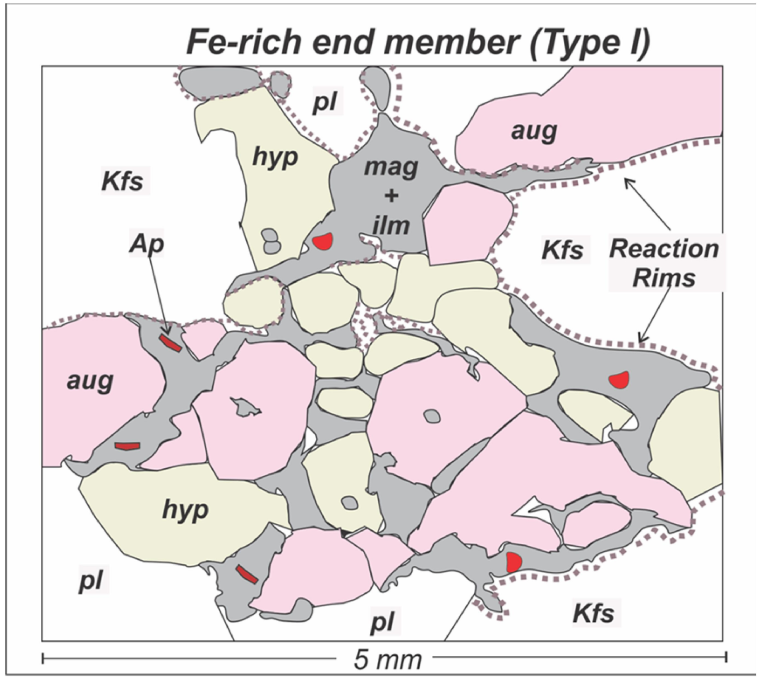
Fe-rich globule Type I (magnetite, ilmenite, augite, orthopyroxene)

apatite, zircon, allanite-(Ce) ± sulphides

Fe-rich globule Type II (magnetite, ilmenite, apatite, REE)

bastnäsite-(Ce), allanite-(Ce), zircon, titanite ± sulphides

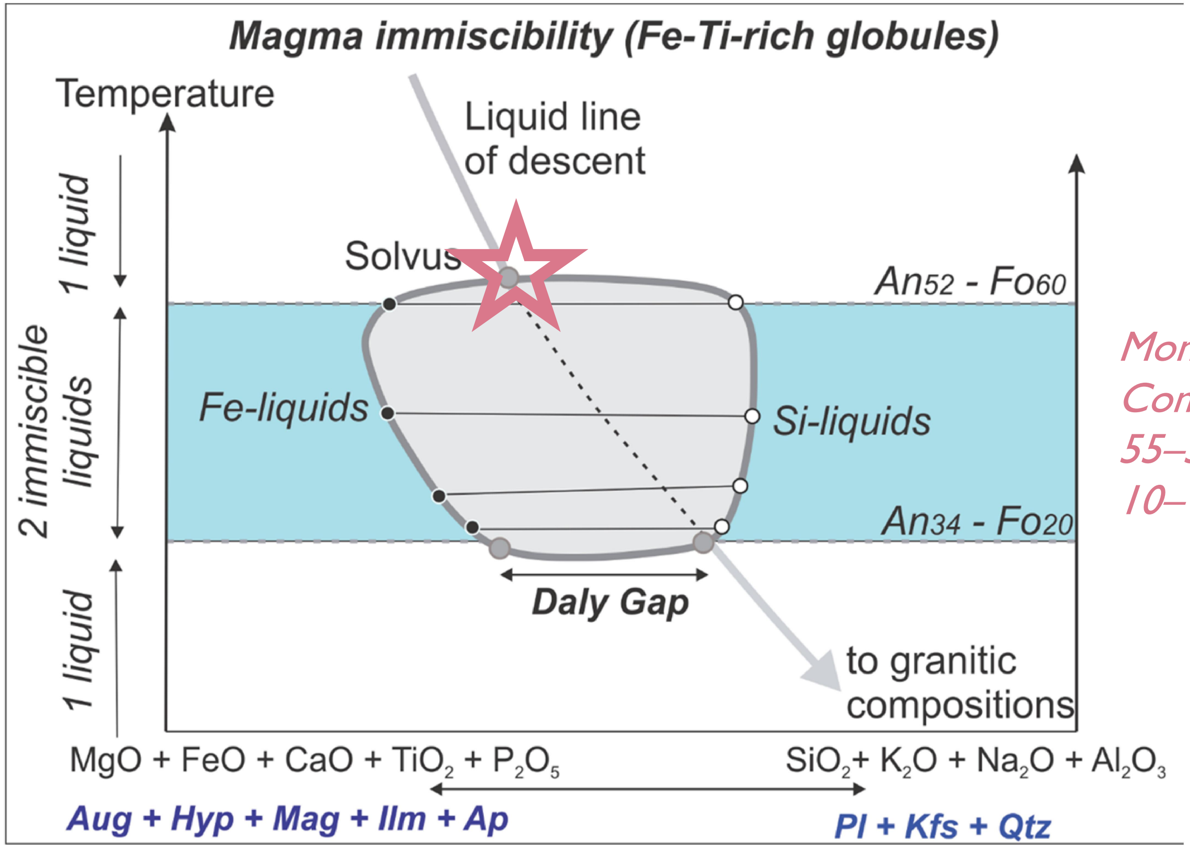
Micro-Scale Magma Immiscibility



($FeO + MgO + CaO + TiO_2 + P_2O_5$)

magnetite + ilmenite + cpx + opx

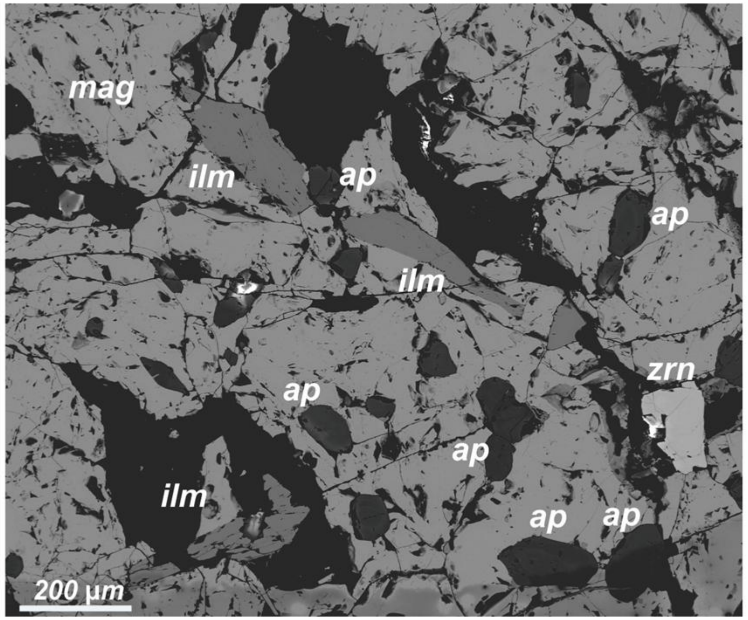
apatite + zircon + allanite-(Ce)



Monzonitic Composition:
55–57 wt. % SiO_2
10–11 wt. % FeO

Schematic diagram modified after Charlier et al. (2011): A model for Sept Iles intrusion (Quebec, Canada), one of the largest layered plutonic bodies on Earth.

Fe-rich end member (Type II)



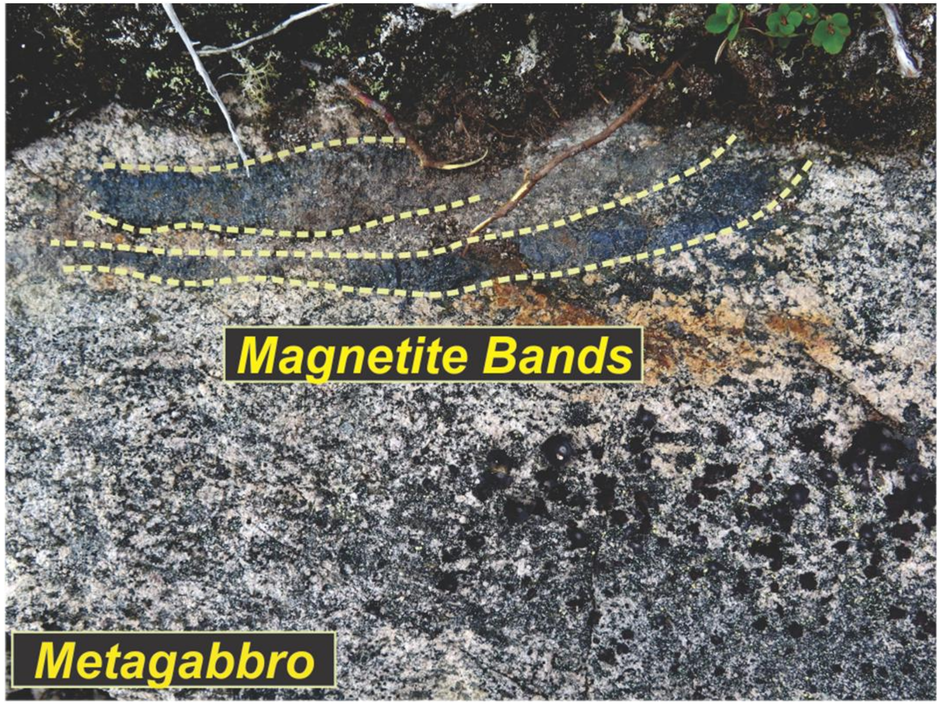
($FeO + TiO_2 + CaO + P_2O_5$ + REE)

magnetite + ilmenite + apatite

REE: *[bastnäsite-(Ce) and allanite-(Ce)]*

zircon + titanite ± sulphides

Gabbro, Magnetite Bands (REE Mineralization?) & Macro-Scale Magma Immiscibility (?)



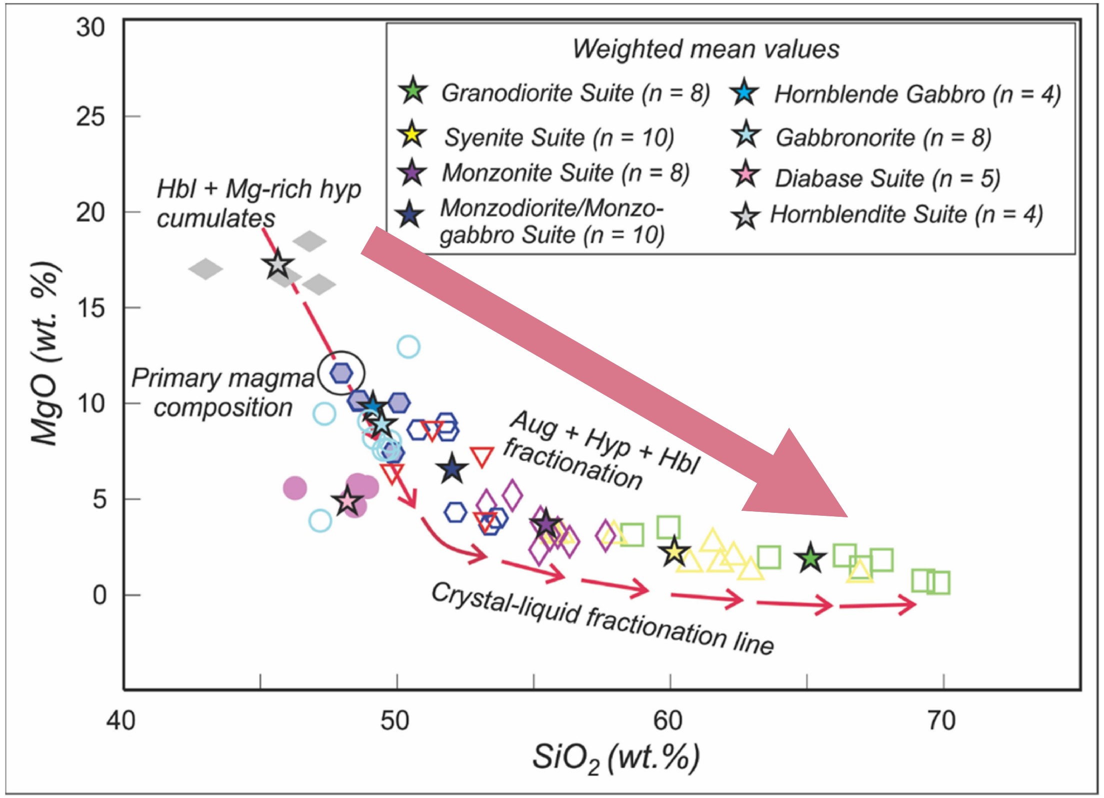
Whole rock geochemistry: ∑REE is very high (~ 600 ppm), similar to REE-mineralized monzonite

Nekuashu & Pelland Intrusions (Geochemistry & Magmatic Evolution)

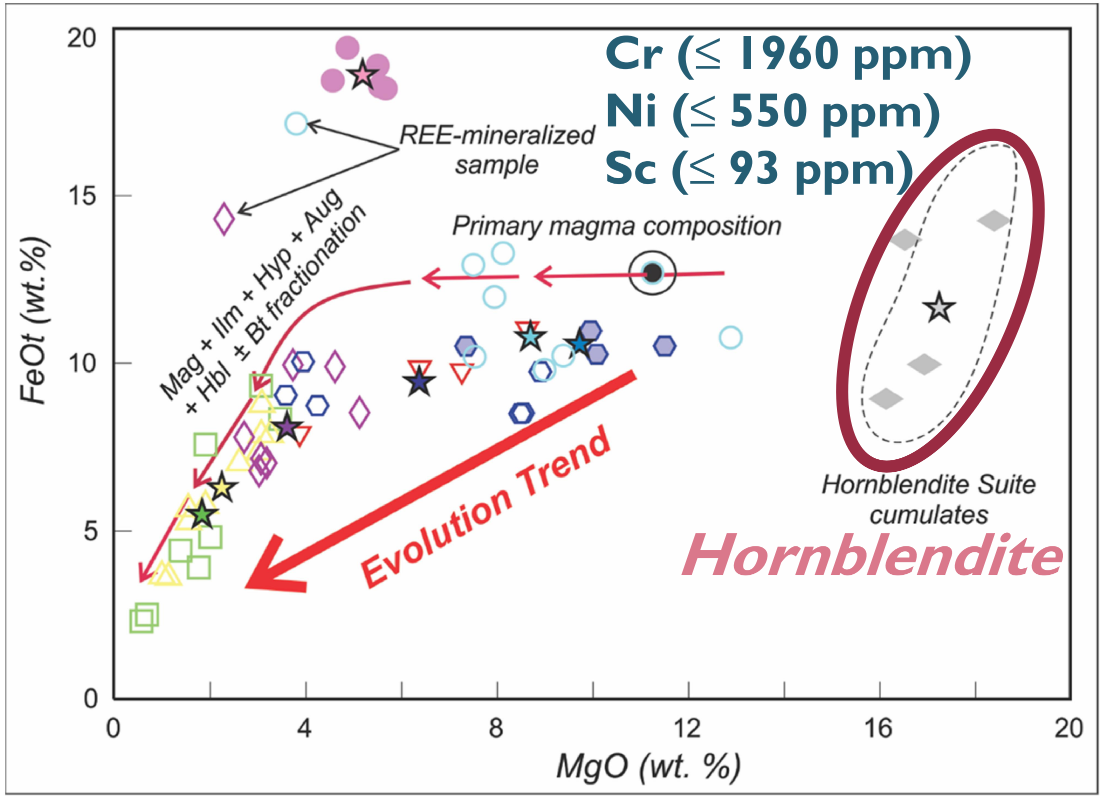
‘Intra-crustal multi-stage differentiation’ mainly controlled by fractional crystallization- to generate mafic to felsic suites:

gabbronorite/hbl-gabbro→monzogabbro/monzodiorite →monzonite→augite-syenite

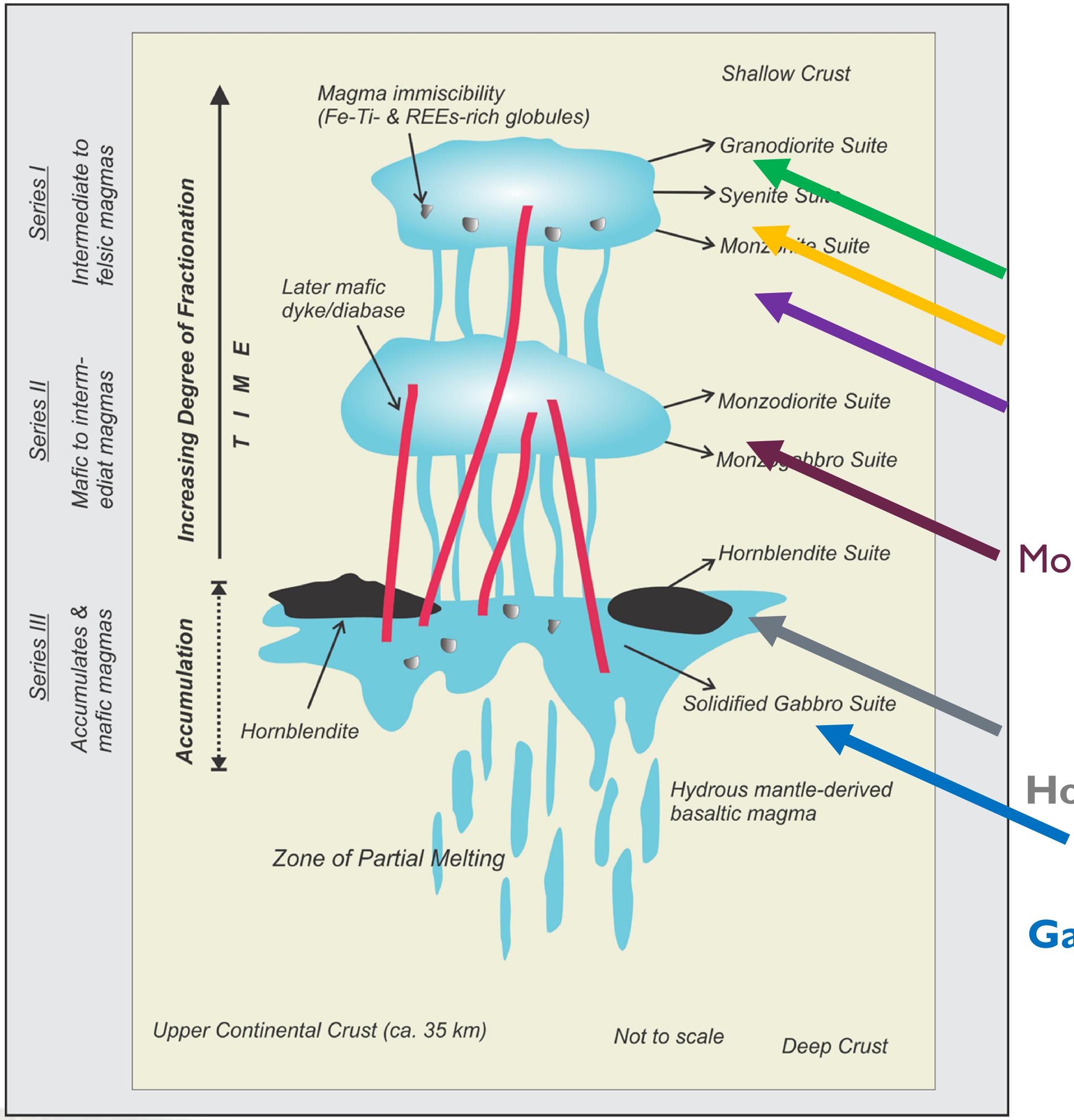
‘Accumulation’ to generate hornblendite suite (enriched in Ni, Cr, Sc)



“Fractional Crystallization”



“Accumulation”



Magmatic Evolution

Injection of later mafic diabase/dykes

Granodiorite: Lower crustal melts possibly associated with the mafic end members

Syenite: Fractionation of microcline crystals

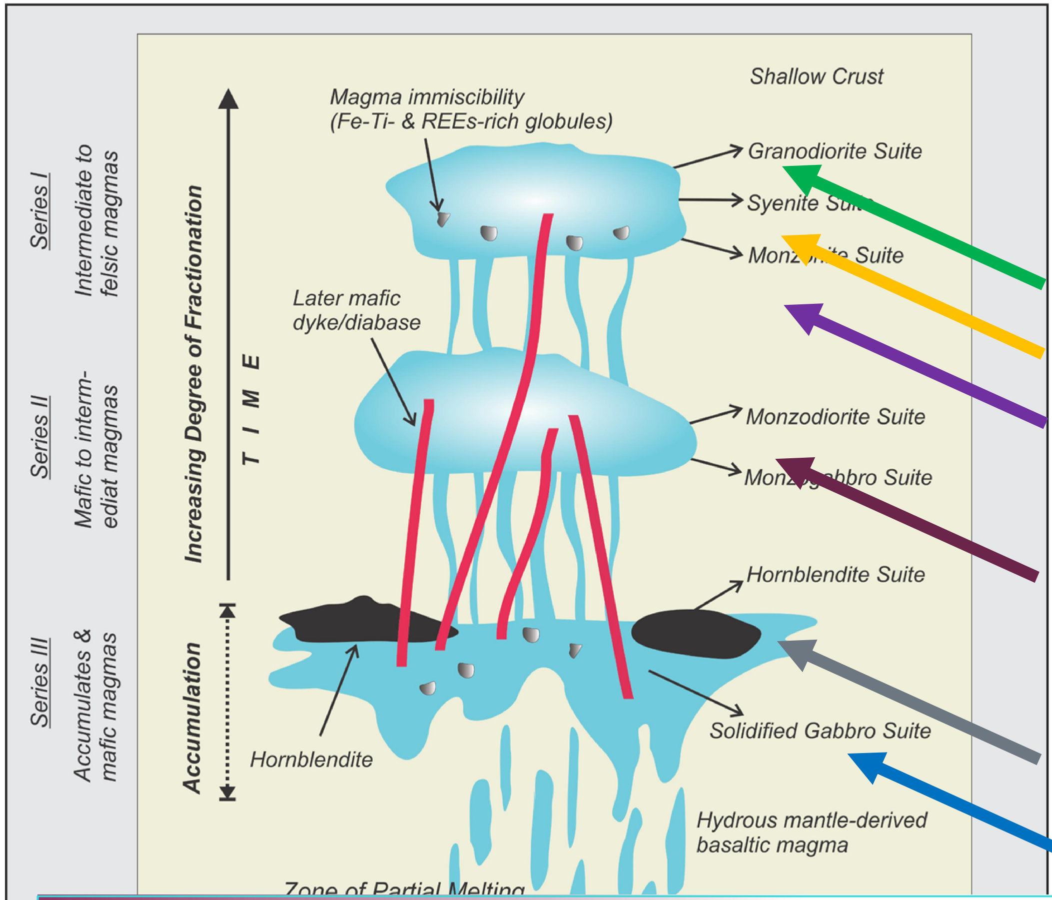
Monzonite: K-feldspar fractionation

Monzodiorite/gabbro: Fractionation of plagioclase, pyroxene & amphibole
Monzodiorite (plagioclase + hornblende ± pyroxene)
Monzogabbro (plagioclase + pyroxene ± hornblende)

Hornblendite: Settling of the early crystallized hornblende (+px)

Gabbro: Early-stage plagioclase-pyroxene-amphibole fractionation

Summary & Concluding Remarks



Magmatic Evolution

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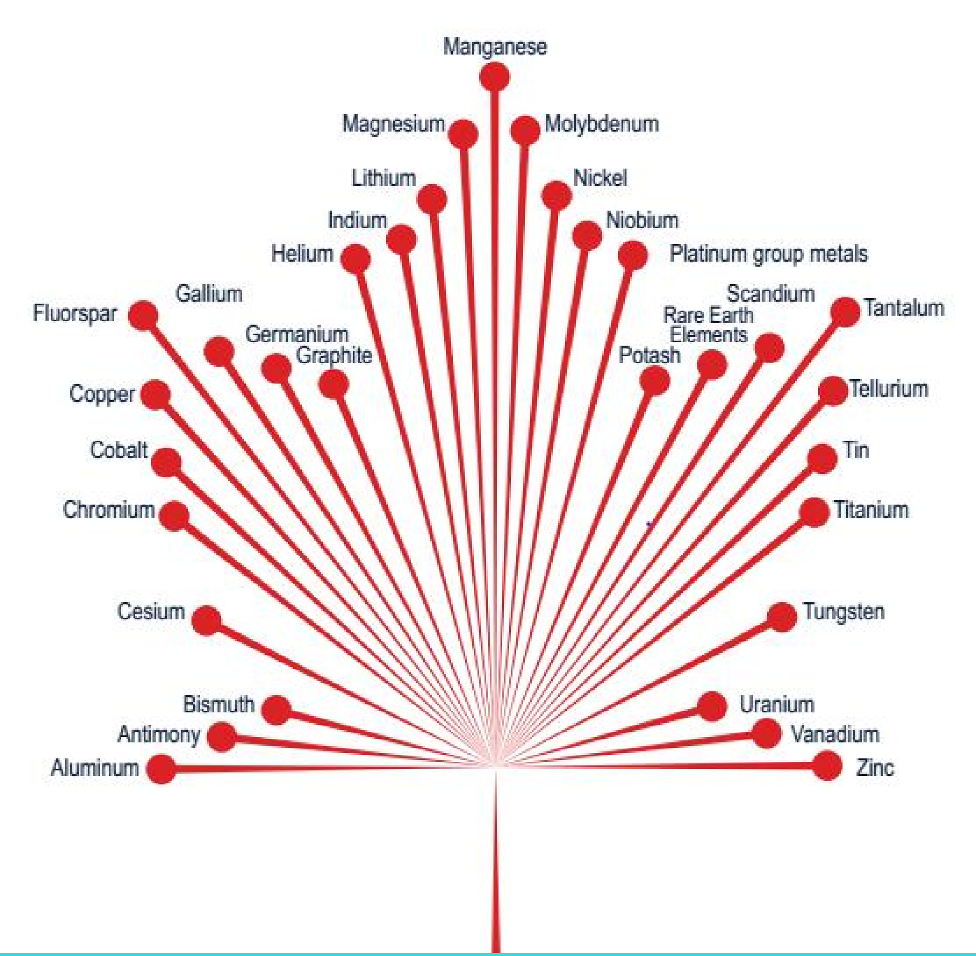
Monzogabbro (plagioclase + pyroxene ± hornblende)

Hornblendite: Settling of the early crystallized hornblende (+px)

Our model proposes that these suites share a similar basaltic parent magma generated from melting of a hydrous metasomatized mantle source that triggered an initial REE and incompatible element enrichment for the subsequent enrichment in the Strange Lake deposit.



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Thank you for your attention

And thanks to the organizers of this session:

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Jindřich Kynický

Ciro Cucciniello

Ashutosh Pandey

Rohit Pandey

TGI Ore Systems

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