PGE potential of Ultramafic-Mafic Intrusions in Ontario: Vectors to PGE mineralization and where next…..

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Project Sponsors

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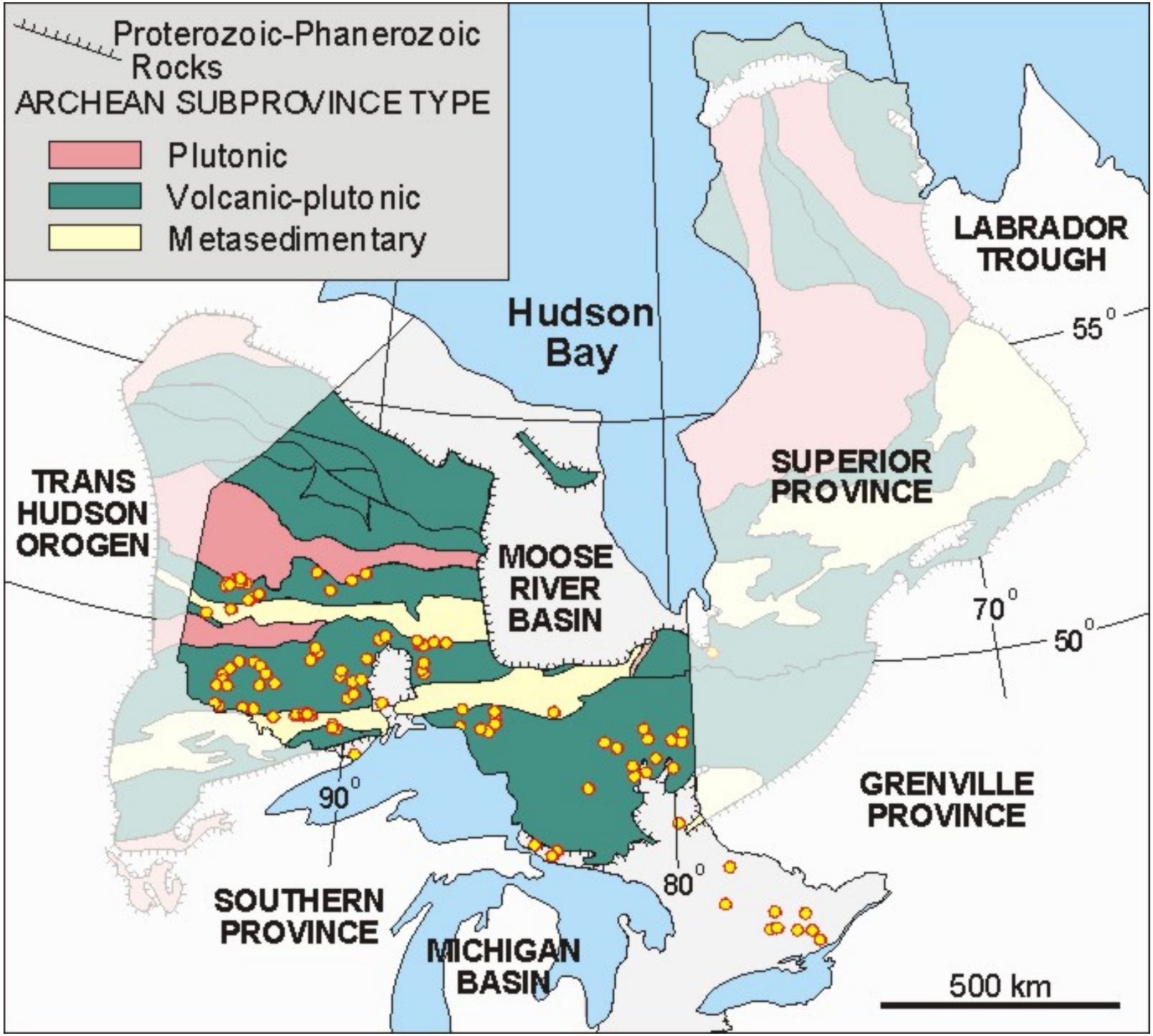
  - **Christine Vaillancourt & Carole-Anne MacDonald**
- **NSERC**
- **CAMIRO**

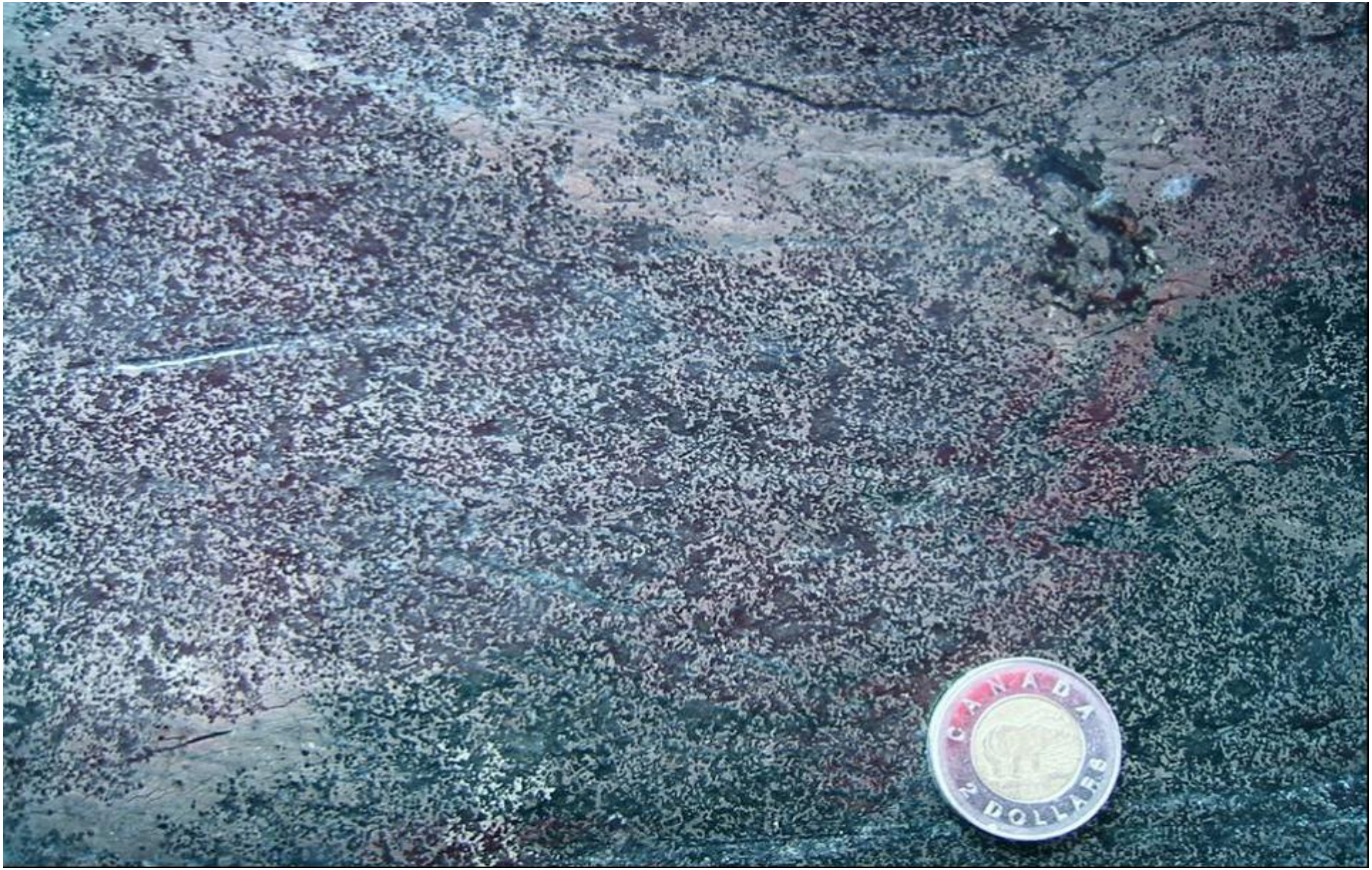
Introduction

- Aims were to identify key criteria for PGE prospectivity
- Petrogenesis and metallogenesis of 109 mafic-ultramafic intrusions in Ontario (Canada) was determined
  - n = 4830
- Range includes:
  - Archean to Palaeoproterozoic intrusions
  - Komatiitic, tholeiitic, calc-alkalic, alkalic and sanukitoid magmatic affinities
  - PGE mineralized economic to PGE-subeconomic to non-mineralised
- Importantly, WE ANALYSED BARREN INTRUSIONS TO UNDERSTAND THE COMPLETE SYSTEM!!


Proterozoic-Phanerozoic Rocks
ARCHEAN SUBPROVINCE TYPE
Plutonic
Volcanic-plutonic
Metasedimentary
Hudson Bay
LABRADOR TROUGH
55°
SUPERIOR PROVINCE
TRANS HUDSON OROGEN
MOOSE RIVER BASIN
70°
50°
90°
GRENVILLE PROVINCE
80°
SOUTHERN PROVINCE
MICHIGAN BASIN
500 km

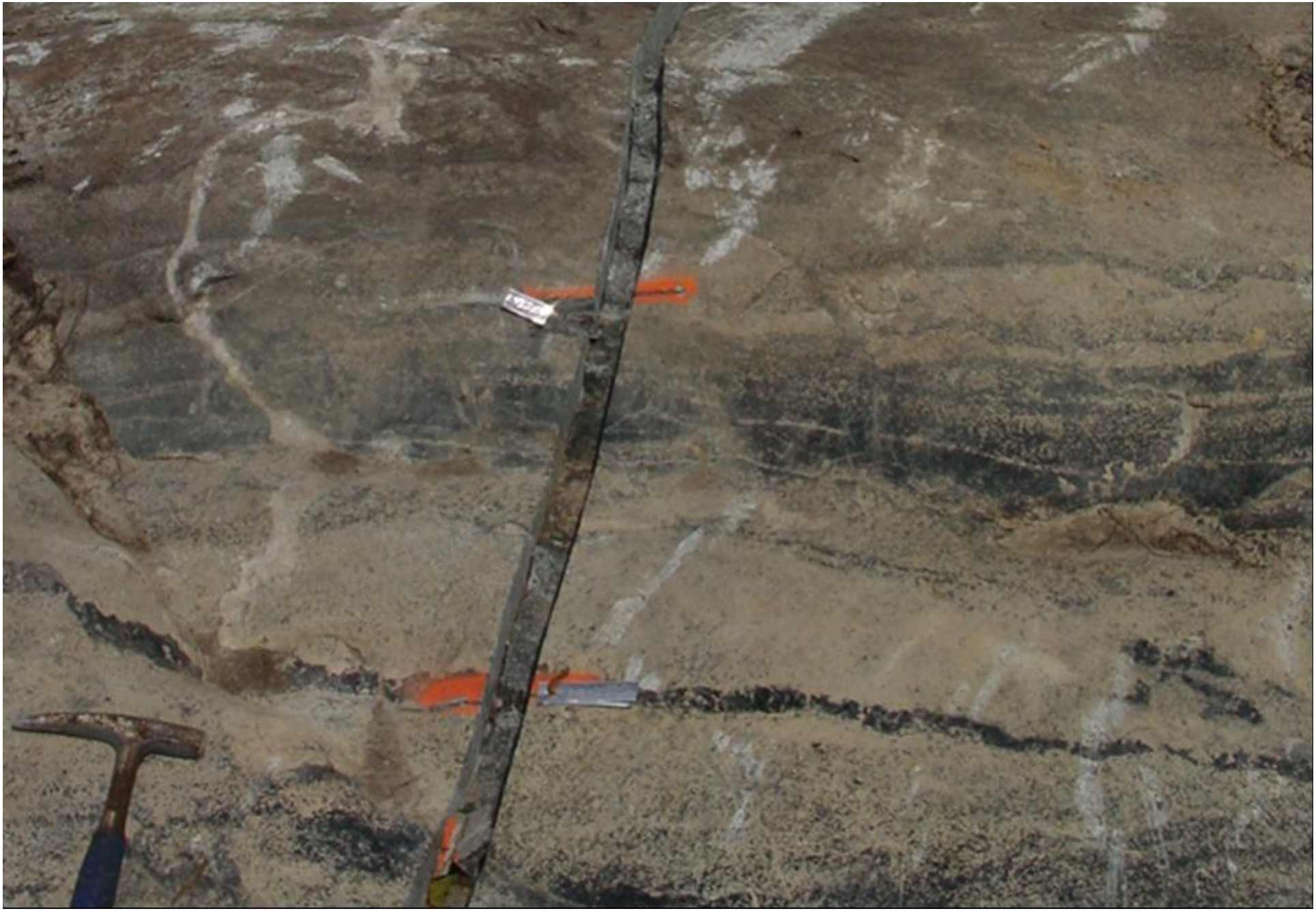
Mineralization Types

Type	Distribution	Examples
I	contact/marginal	Coldwell, Kawene, **Shakespeare**, Tib Lake, Seagull
II	stratabound internal disseminated	Roaring River
III	stratiform reef-style	Moshkinabi, Centre Hill, Ghost Range, Seagull, Coldwell
IV	hydrothermally-metamorphically deposited or mobilized	**Lac des Iles**
V	tectonically mobilized	Trout Bay



Type 1: Contact marginal: Net-textured ore, Alexo Mine, Dundonald Township

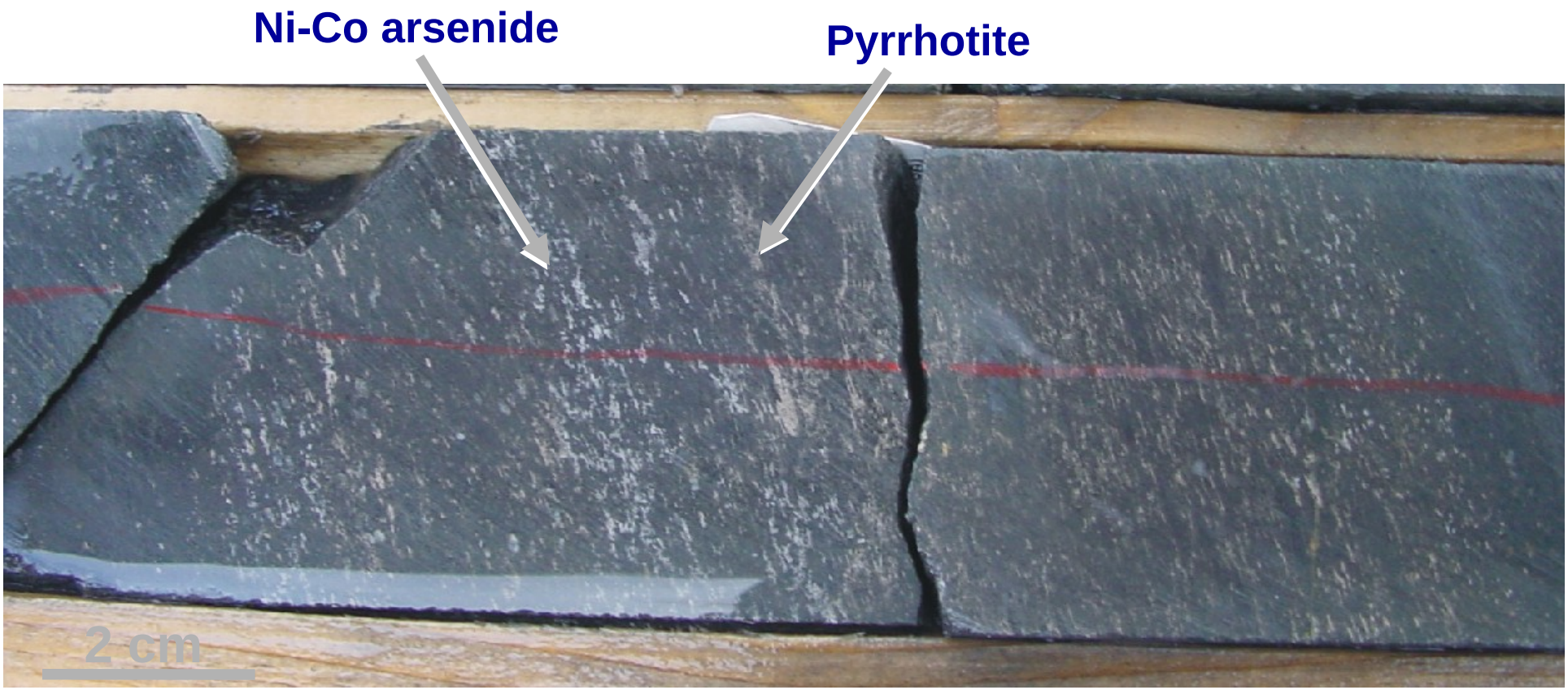
Type 2: Internal stratibound disseminated: Ccp-Po blebs in gabbro, Entwine Lake (Jason Arnold)



Type 3: Reef Type: Layered gabbro, Moshkinabi (Christine Vaillancourt)

Type 4: Hydrothermally remobilized Roby Zone – varitextured

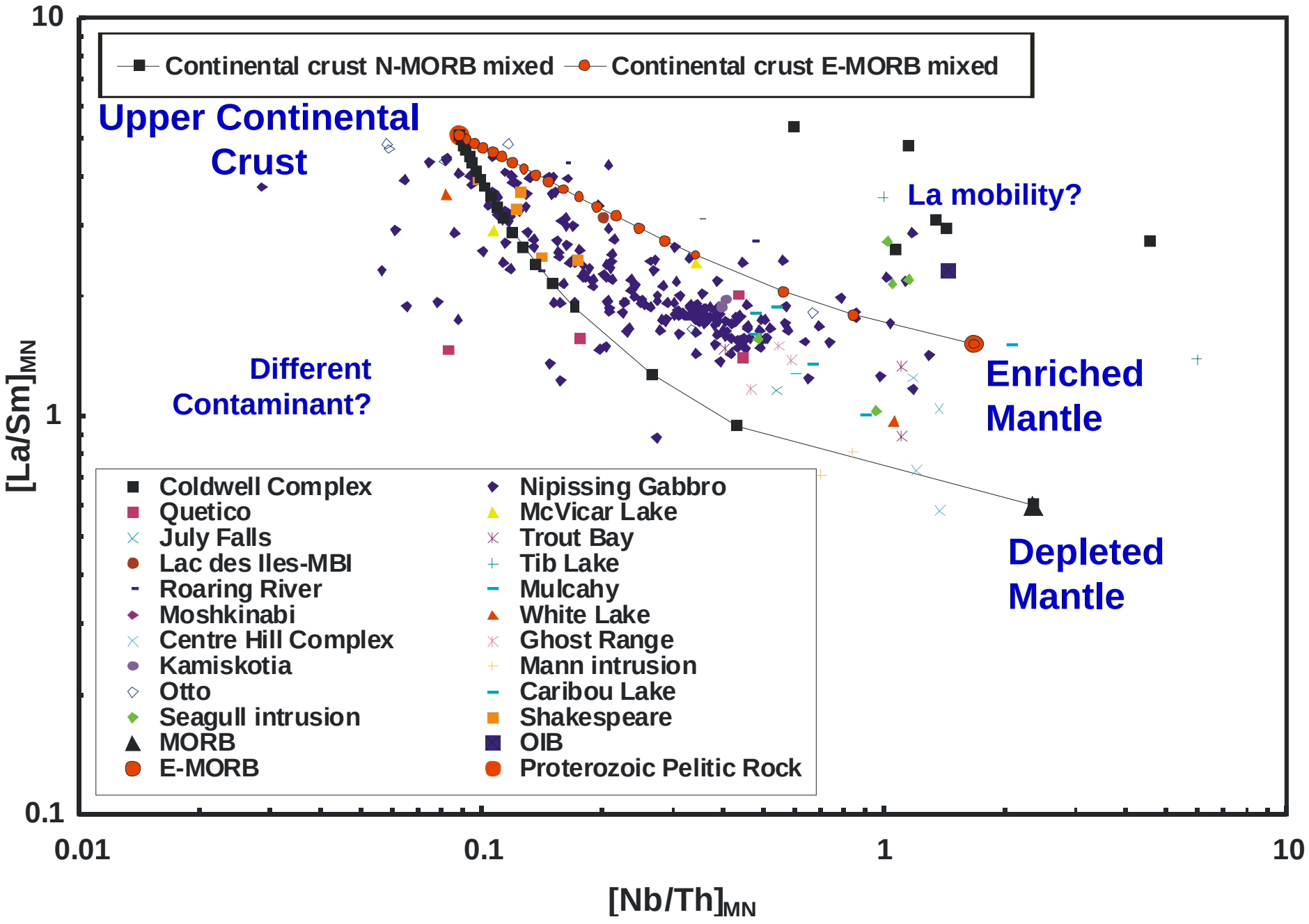
Type 5: Mineralized SUIF, Trout Bay area, Red Lake region (Christine Vaillancourt)



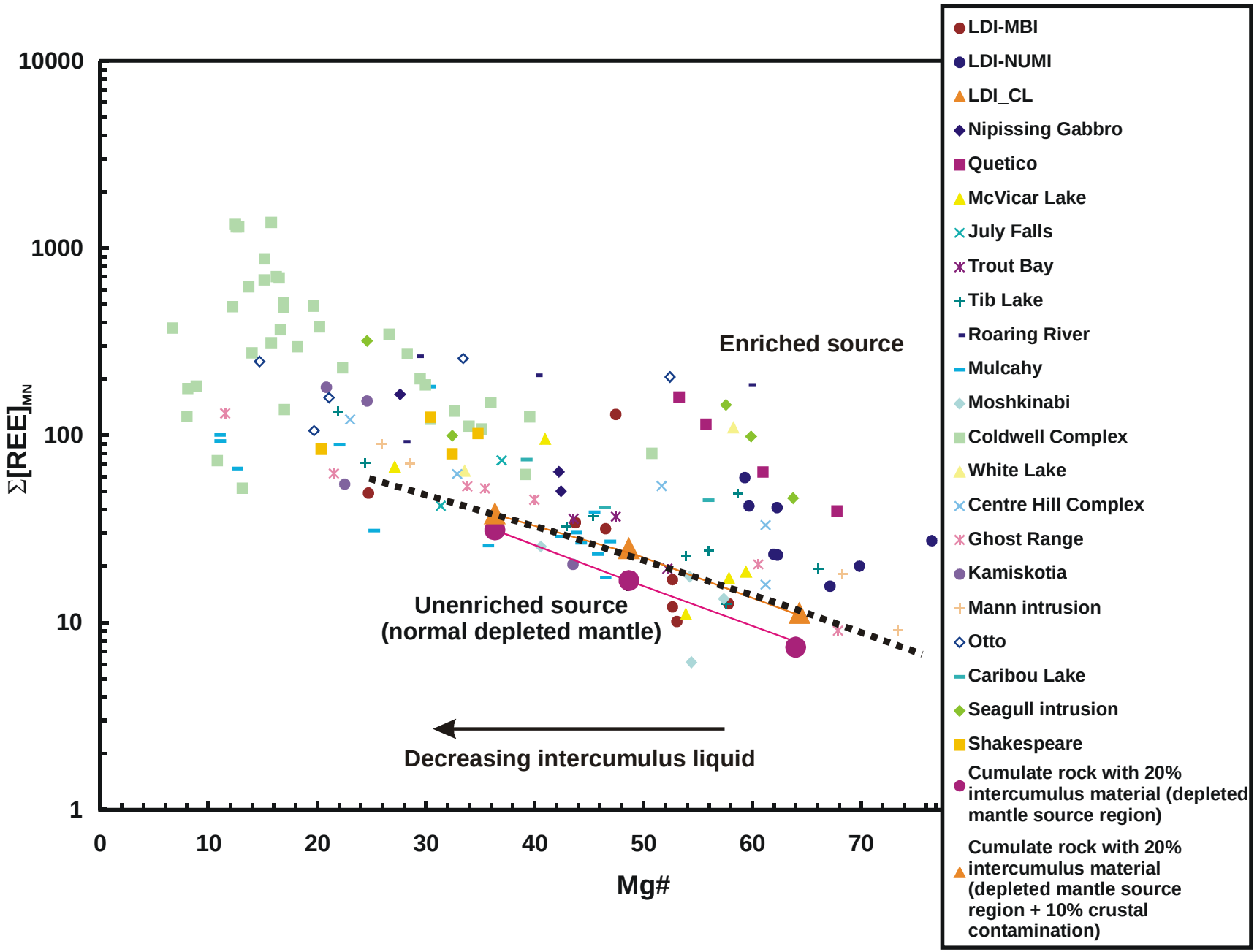
Type 5: Ni-Co-PPGE arsenide mineralization in recrystallized Amph-Chl-Tc rock, Peterson property, Red Lake region (Christine Vaillancourt)

Petrogenesis

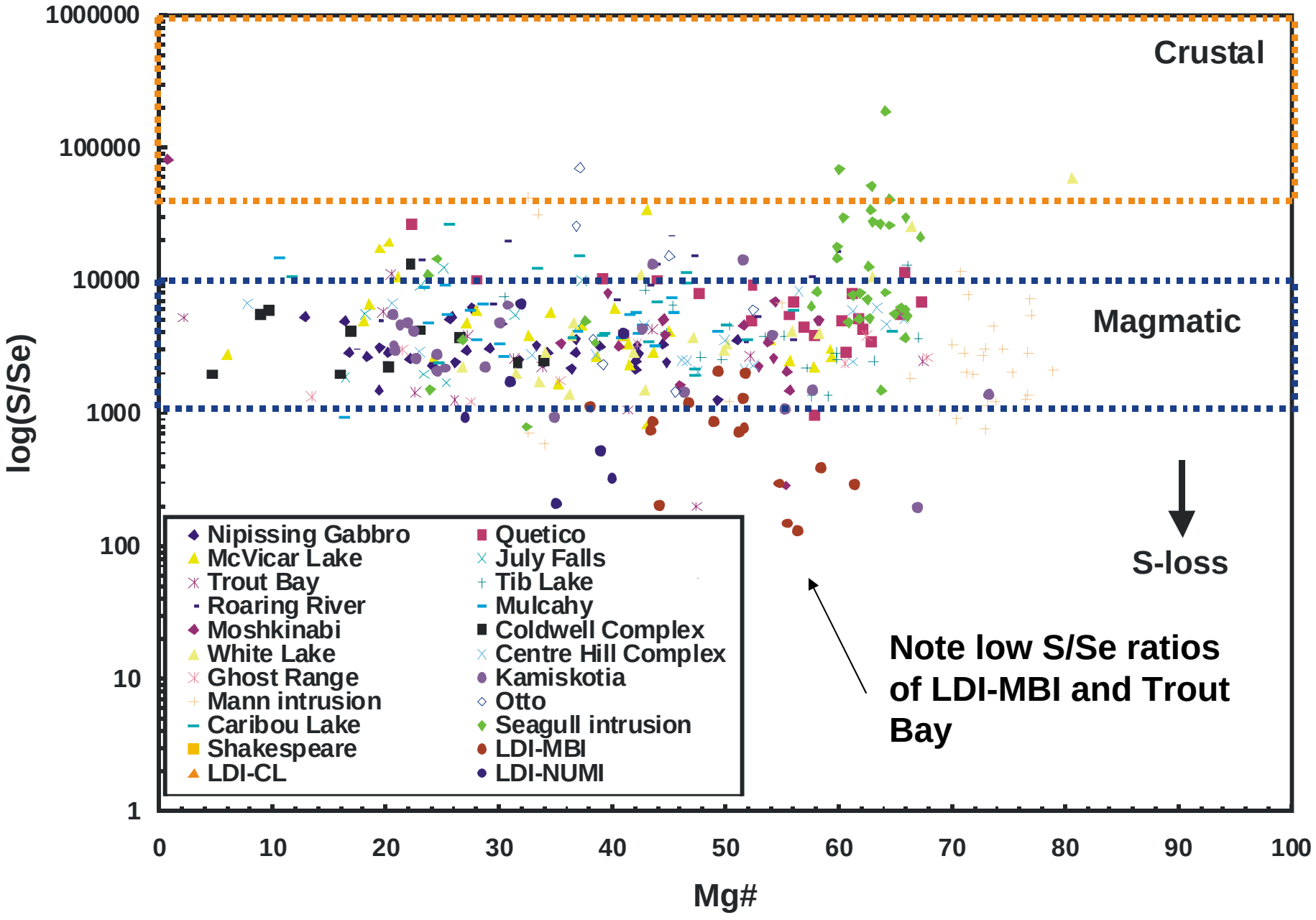
Crustal contamination versus Enriched source



Crustal contamination versus Enriched source



Crustal contamination



	Continental Crustal Contamination		
Mantle Source	***None to Minor***	***Local***	***Uniform***
Strongly Depleted (refractory)		**Moshkinabi** Mulcahy	McVicar Lake Kamiskotia Caribou Lake
Strongly Depleted (refractory), then **metasomatically enriched**	**Coldwell** **Coldwell** **Lac des Iles - MBI** **Lac des Iles - NUMI** **Kawene** **Roaring River** July Falls Otto	**Shakespeare**	
Normal depleted	Centre Hill	**Mann** **Trout Bay**	Ghost Range White Lake Mulcahy
Normal depleted, then **metasomatically enriched**	**Tib Lake**		
Enriched		**Seagull** **Seagull**	

Magma Type

- PGE mineralization is hosted by intrusions derived from a variety of magma types
  - Most magmas form PGE mineralization
- Tholeiitic intrusions most commonly host PGE mineralization
- Alkaline intrusions with large abundances of mafic-ultramafic rocks are a less common host of PGE mineralization

Source Composition

- The most significant PGE reserves and resources (e.g., Coldwell Complex, Lac des Iles, Seagull, Shakespeare) are from intrusions from enriched or metasomatized mantle sources (e.g., sub-arc mantle)
- PGE mineralization is also associated with intrusions from normal depleted mantle (e.g., Moshkinabi and Mann intrusions)
  - Such PGE mineralization is typically of lower tonnage and grade

Degree of Partial Melting

- **The degree of prior melt extraction is not important**
  - **mineralized intrusions are derived from sources that have experienced variable degrees of prior partial melting**

Magma Diversification Processes

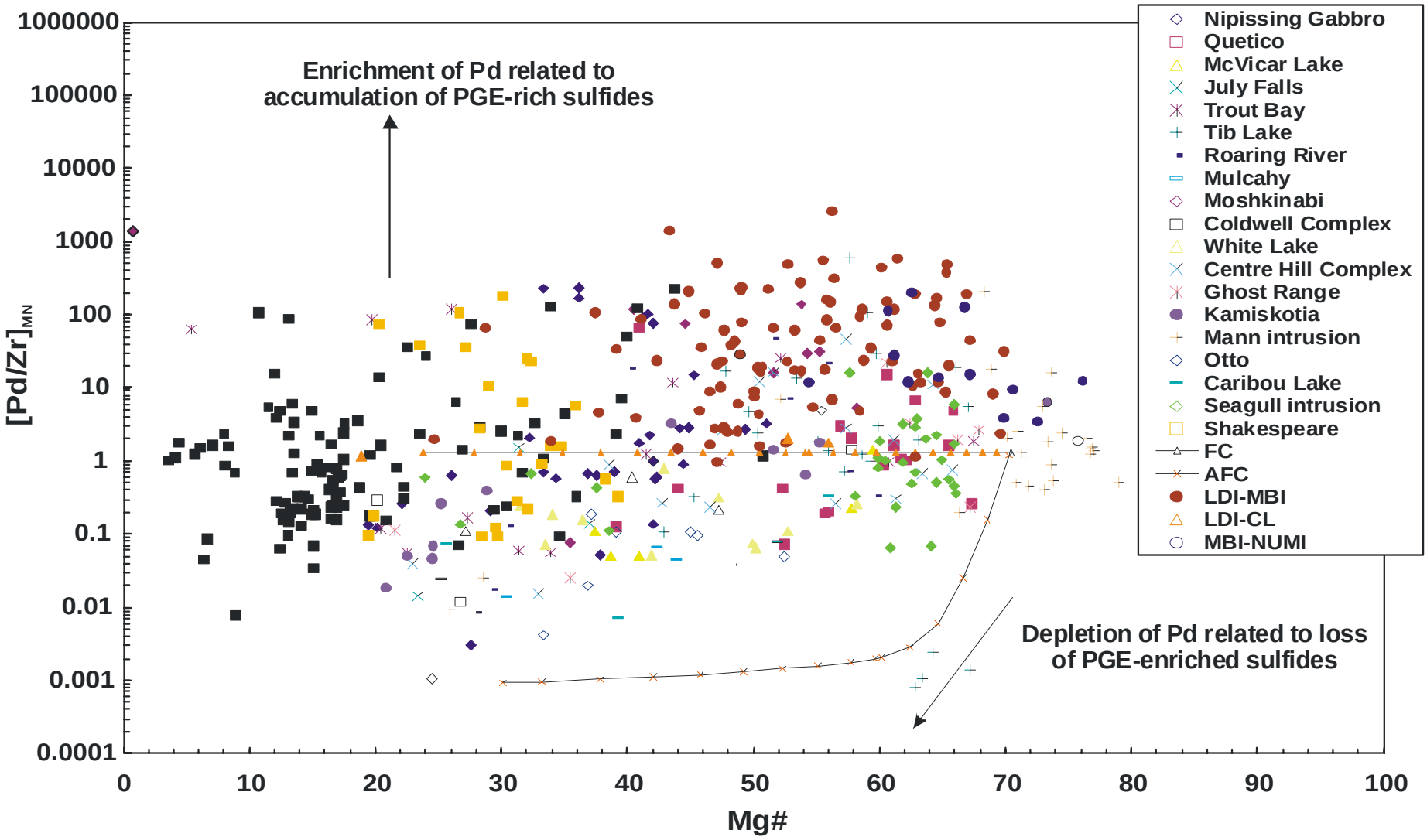
- **Mineralized intrusions are either uncontaminated or only locally contaminated by upper crust**
  - **Where contaminated, may have aided in triggered sulfide saturation**
  - **Where uncontaminated, sulfide saturation was likely induced by fractionation crystallization**
  - **In some cases (e.g., Lac des Iles), PGE may have also been concentrated into late-stage volatile-rich phases**

Magma Diversification Processes

- **Intrusions that are uniformly contaminated rarely host significant tenors/tonnages of PGE mineralization**
  - **can host significant amounts of Ni-Cu-PGE mineralization**
    - **e.g., the Shakespeare intrusion**

Metallogenesis

Identification of PGE rich magmas



Trend	Intrusion
Elevated Pt, Pd	**Lac des Iles-MBI, Trout Bay, Tib Lake**
Elevated Pt, Pd, but lowest Mg# rocks are depleted	**Coldwell/Coldwell, Roaring River, Mann/Mann, Lac des Iles-NUMI**
PGE follow FC trend, high PGE rocks have accumulated sulfide, and lowest Mg# rocks are depleted	**Moshkinabi,** Centre Hill, **Seagull/Seagull**, Nipissing Gabbro
PGE follow FC trend, and lowest Mg# rocks are depleted	**Kawene**, Ghost Range, Kamiskotia, Lac des Iles-CL
Depleted in PGE, Ni, and Cu above mineralized zone	**Shakespeare**, Nipissing Gabbro
Depleted in PGE, but not Ni or Cu	Mulcahy
Uniformly depleted	McVicar Lake, Otto Stock, White Lake, July Falls, Caribou Lake

Sulfide-Saturation History and Mineralization Type

- **Type I contact-type mineralization is associated with rocks containing elevated to normal abundances of PGEs**
  - **In most cases, the rocks overlying the mineralized zones are depleted in PGEs**
- **Type II internal disseminated mineralization is associated with rocks containing high abundances of PGEs**
  - **However, other, typically more fractionated, portions of the intrusions can be depleted in PGEs**

Sulfide-Saturation History and Mineralization Type

- **Type III reef type mineralization is associated with rocks containing normal PGE abundances, but enrichment in samples with accumulated PGE**
- **Type IV hydrothermally-deposited or hydrothermally-mobilized mineralization is associated with PGE-enriched magmas (in Ontario)**

Sulfide-Saturation History and Mineralization Type

- Some intrusions are depleted in PGE, but not Ni or Cu, suggesting that some PGE-enriched sulfides were lost during ascent and/or emplacement
  - Such intrusions still have potential to host Ni-Cu deposits
- Some intrusions are uniformly depleted in PGE and have little potential for PGE mineralization

Sulfide-Saturation History and Mineralization Type

- **Mineralized intrusions with the most significant PGE mineralization (highest grade and largest tonnage) have high background PGE abundances for their Mg# or MgO content**

Summary

- Mineralized intrusions with the most significant PGE mineralization (highest grade and largest tonnage) have the high background PGE abundances for their Mg# or MgO content
- Intrusions derived from enriched sources should be preferentially explored for PGE mineralization
  - Such rocks have high abundances of MILE (Ti, Zr, MREE-HREE) and very high abundances of all HILE (e.g., Cs, Rb, U, Th, Nb, Ta, LREE)
- Intrusions derived from normal depleted sources are still good targets for PGE mineralization, but are not as favourable

Summary

- In all cases where significant PGE mineralization is present, a specific process has “triggered” PGE segregation: crustal contamination, magma mixing, and/or fractionation crystallization
- Uniformly contaminated intrusions have low PGE potential, but such intrusions may host Ni-Cu mineralization
- The degree of prior melt extraction is not a significant factor for PGE prospectivity

So what's the important message out of this for exploration and future work research work…..

- **In Ontario:**
  - **The best intrusions have high background PGE abundances**
  - **The intrusions from the best areas have enriched metasomatised mantle**
    - **Prospective zones with enriched mantle can be mapped out**
- **Where next….**
  - **Fennoscandia – do the same relationships apply?**