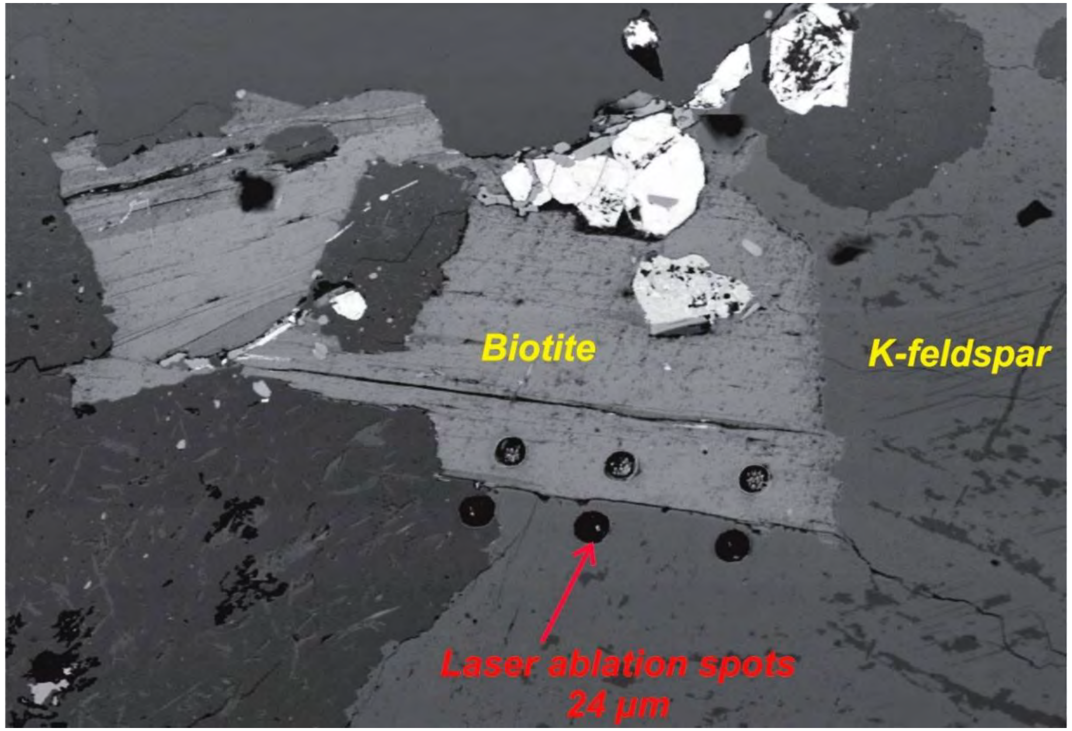
# Greisen-Related Sn-W-Mo-Mineralized Mount Douglas Granite, New Brunswick, Canada:

## An Analysis of Fertility Indicators




Nadia Mohammadi

Carleton University

University of New Brunswick

**GAC VIP-MDD Webinar**

March 11, 2021

Thursday @ 1:30 PM

Nadia.mohammadi@unb.ca

➢ **PhD Thesis: Petrogenesis of Sn-W-Mo Mineralized Intragranitic Systems within the Mount Douglas Granite, Southwestern NB, Canada**


***This project was supported by:***

New Brunswick Energy & Resource Development

President's Doctoral Scholarship (UNB)

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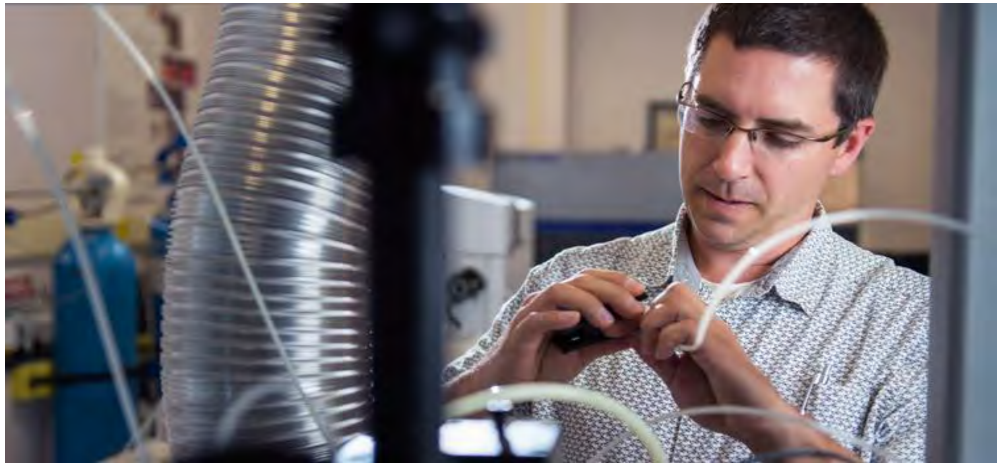
***Dr. Kay Thorne, Les Fyffe and Dr. Jim Walker***
New Brunswick Geological Surveys

***Dr. Xue-Ming Yang***
Manitoba Geological Survey

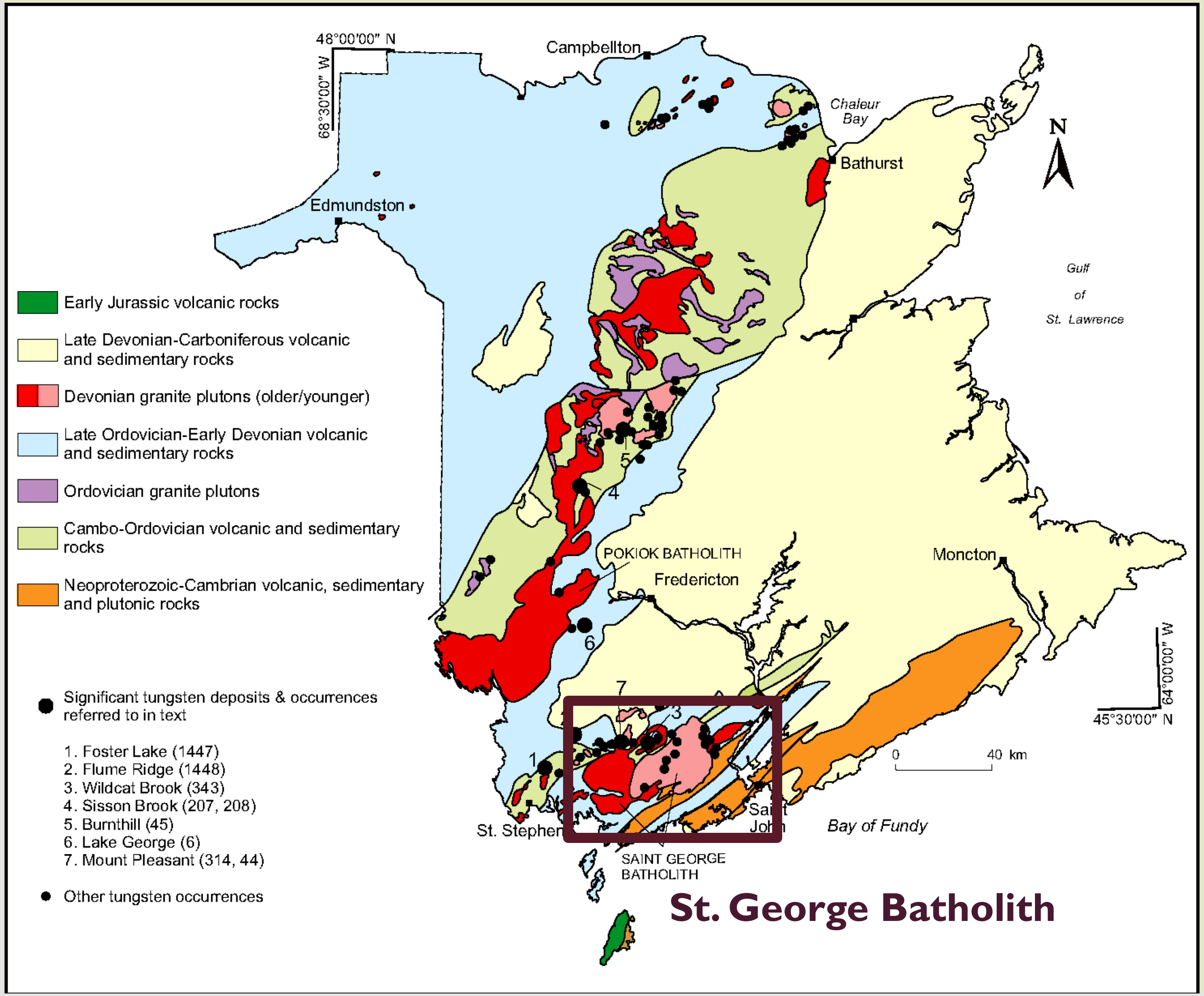

**Prof. David R. Lentz (UNB)**



**Prof. Chris McFarlane (UNB)**

# WHERE ARE WE?

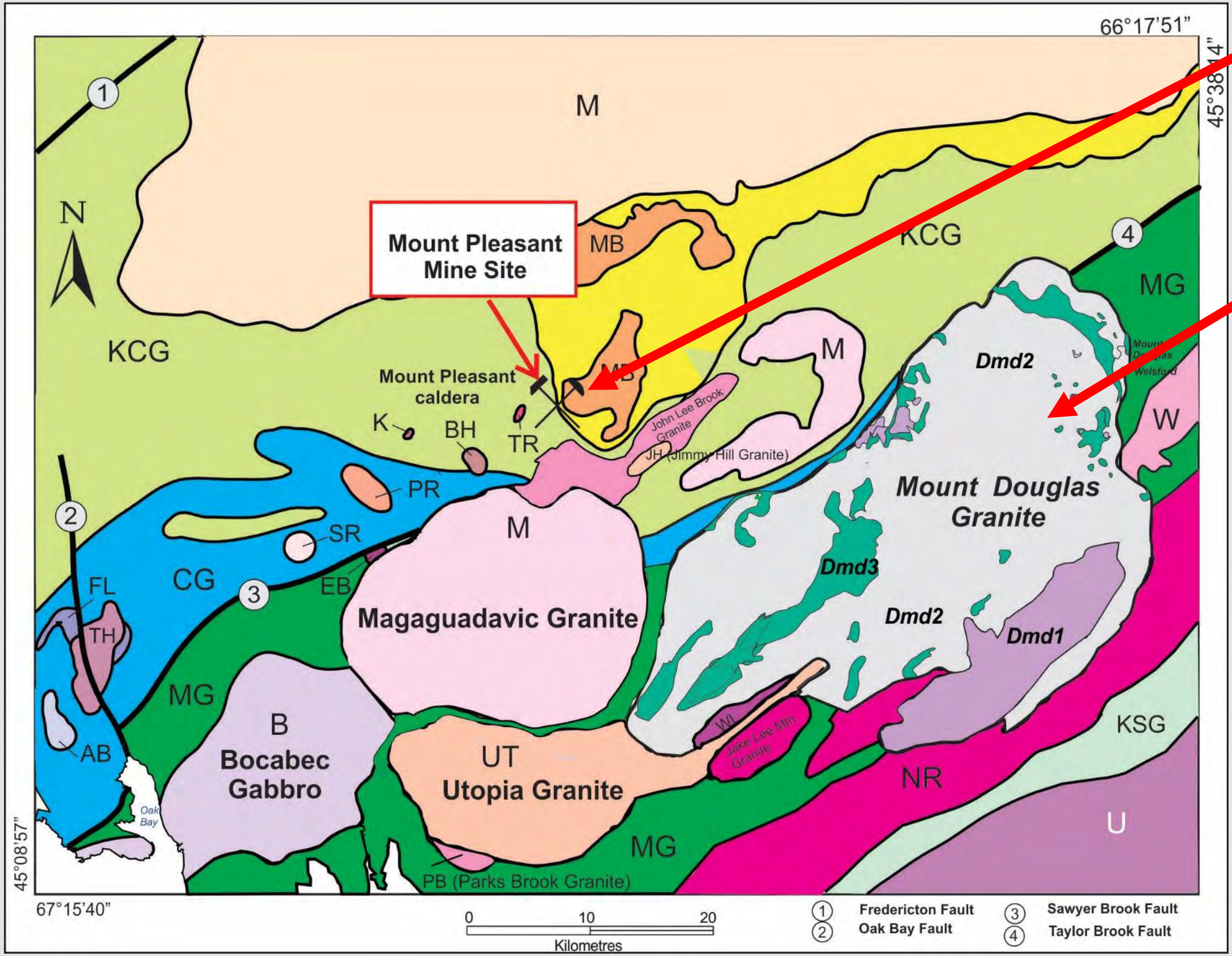
## Distribution of W & Mo deposits in New Brunswick





(Natural Resources Lands, Minerals and Petroleum, Mineral Commodity Profile No. 7)

# Saint George Batholith




*Modified after Thorne et al. (2013) & Mohammadi et al. (2017)*

**Granite systems Sn-W-Mo-Bi-In-Zn-bearing Mount Pleasant**

**Sn-W-Mo-bearing Mount Douglas Granite 368 ± 1 Ma**

**Mount Pleasant: Hosts the world’s largest known undeveloped resource of *indium* (Sinclair et al. 2006)**

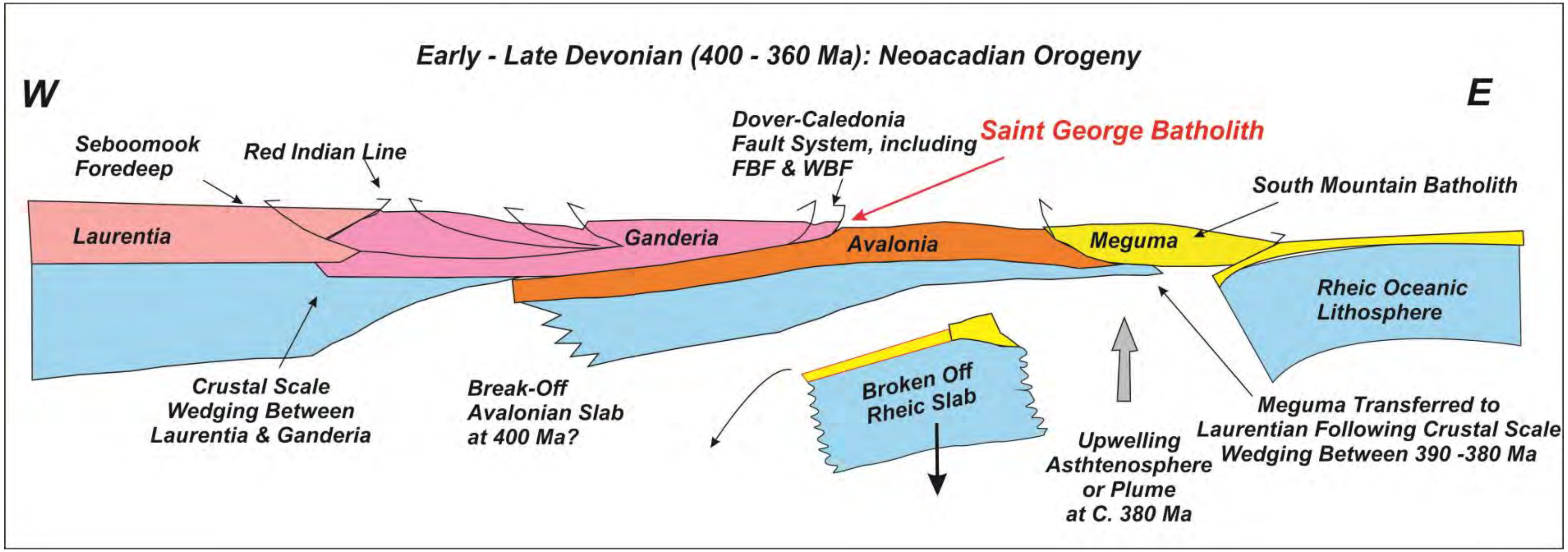
- McLeod (1990)
- Yang et al. (2003, 2008)
- Thorne et al. (2013)
- Mohammadi et al. (2019, 2020, 2021)

***Late Silurian -Late Devonian granitic series***

*Saint George Batholith*

| | |
|---|---|
| *Wellington Lake Granite: 415 ± 2 Ma* | Mount Douglas Granite: *368 ± 1 Ma* |
| *Jake Lee Mountain Granite: 418 ± 2 Ma* | Mount Pleasant: *370 ± 2 Ma* |
| Bocabec Gabbro: *422.1 ± 1.3 Ma* | Magaguadavic Granite: 396 ± 1 Ma |
| Utopia Granite: *425 ± 2 Ma* | John Lee Brook Granite: *413 ± 2 Ma* |

# Saint George Batholith Emplacement

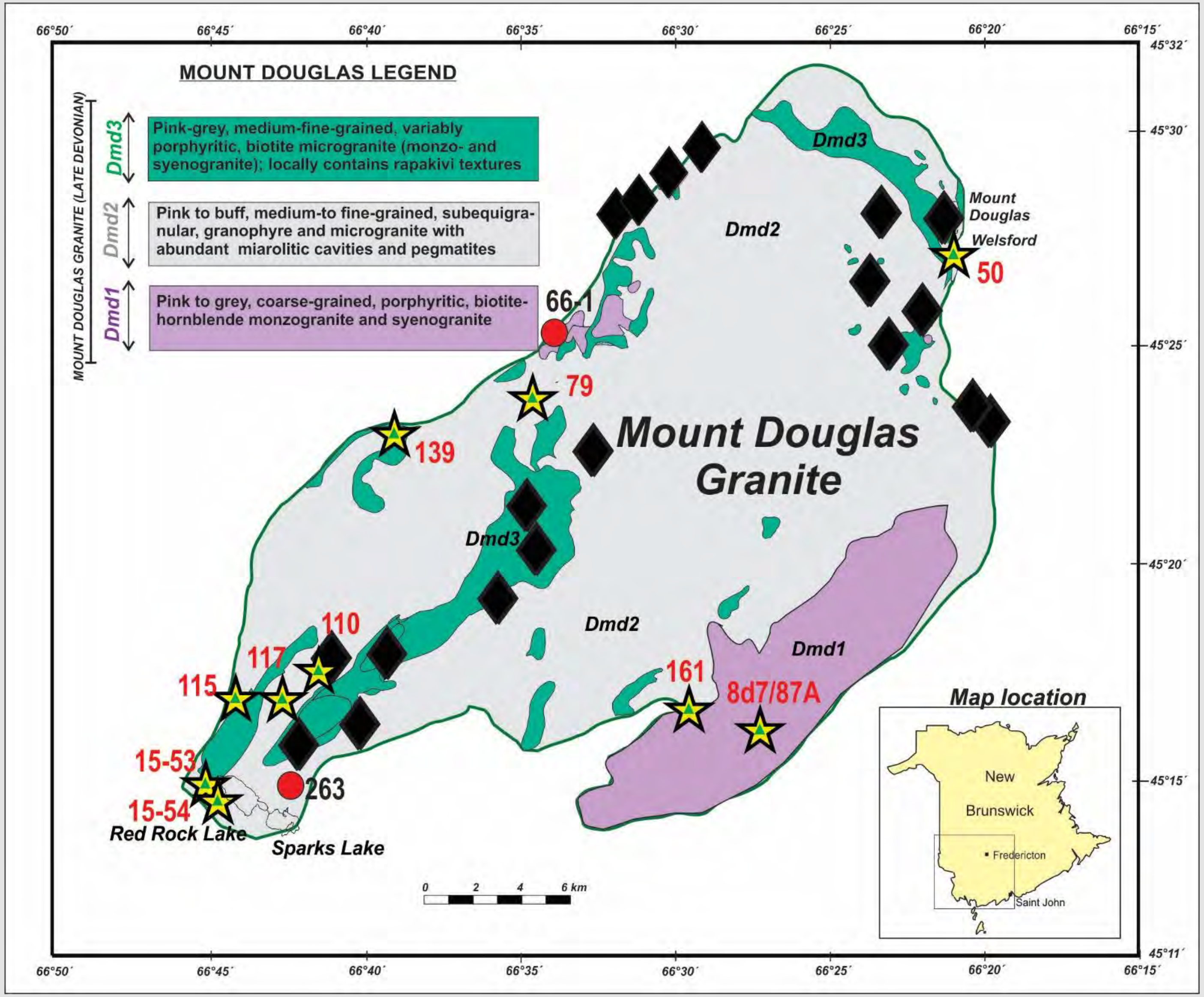



*Modified after Whalen, 1993; Whalen et al., 1996; van Staal et al., 2009*

***The Saint George batholith was emplaced during the Neoacadian Orogeny due to a process of continent-continent collision.***

***Accretion of Gander & Avalon zones that "stitches" the terrane-bounding Faults.***

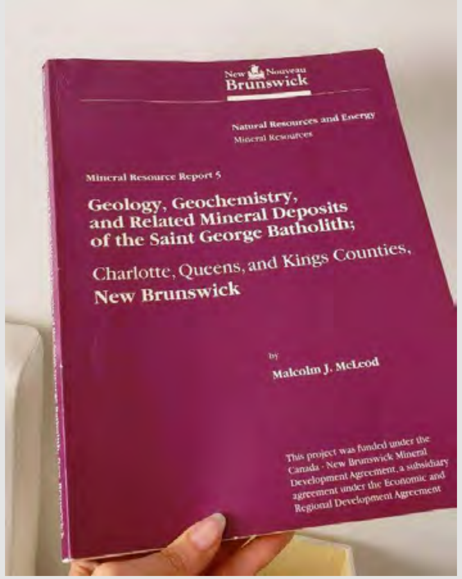
# Mount Douglas Granite and Mineralization




Modified map of mineral occurrences associated with the Mount Douglas Granite, based on the Metallogenic Map of New Brunswick (NR-7; 2002) and McLeod (1990).

**Sn-W-Mo-Zn-Bi-U bearing greisen veins (intragranite)**

Malcolm McLeod
New Brunswick Natural Resources




McLeod (1990)

# Questions

1 ➢ Biotite in Fractional Crystallization

2 ➢ Biotite in Mineral Exploration

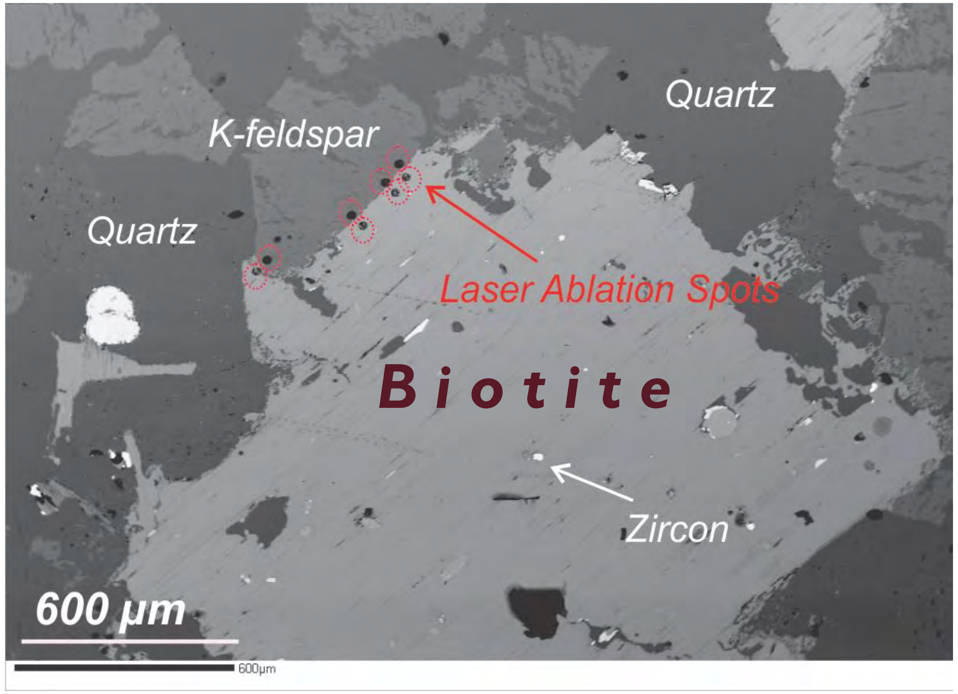
**Mount Douglas Granite:**

*A Unique Geological Setting*

It includes both ***barren*** and ***mineralized*** phases

**SEM-BSE Imaging & EPMA**

**Major elements & halogen (F and Cl)**




**Laser Ablation ICP-MS**

***Trace elements, metals and Rare Earth Elements***

# Field Work

## With Assistance of:

Dr. Dave Lentz (UNB)

Alexander Smith

## Grad Students @ UNB:

Dennis Sánchez Mora

Zeinab Azadbakht

Carlin Lentz

Eric Garcelon

## NB Geological Surveys:

Dr. Kay Thorne

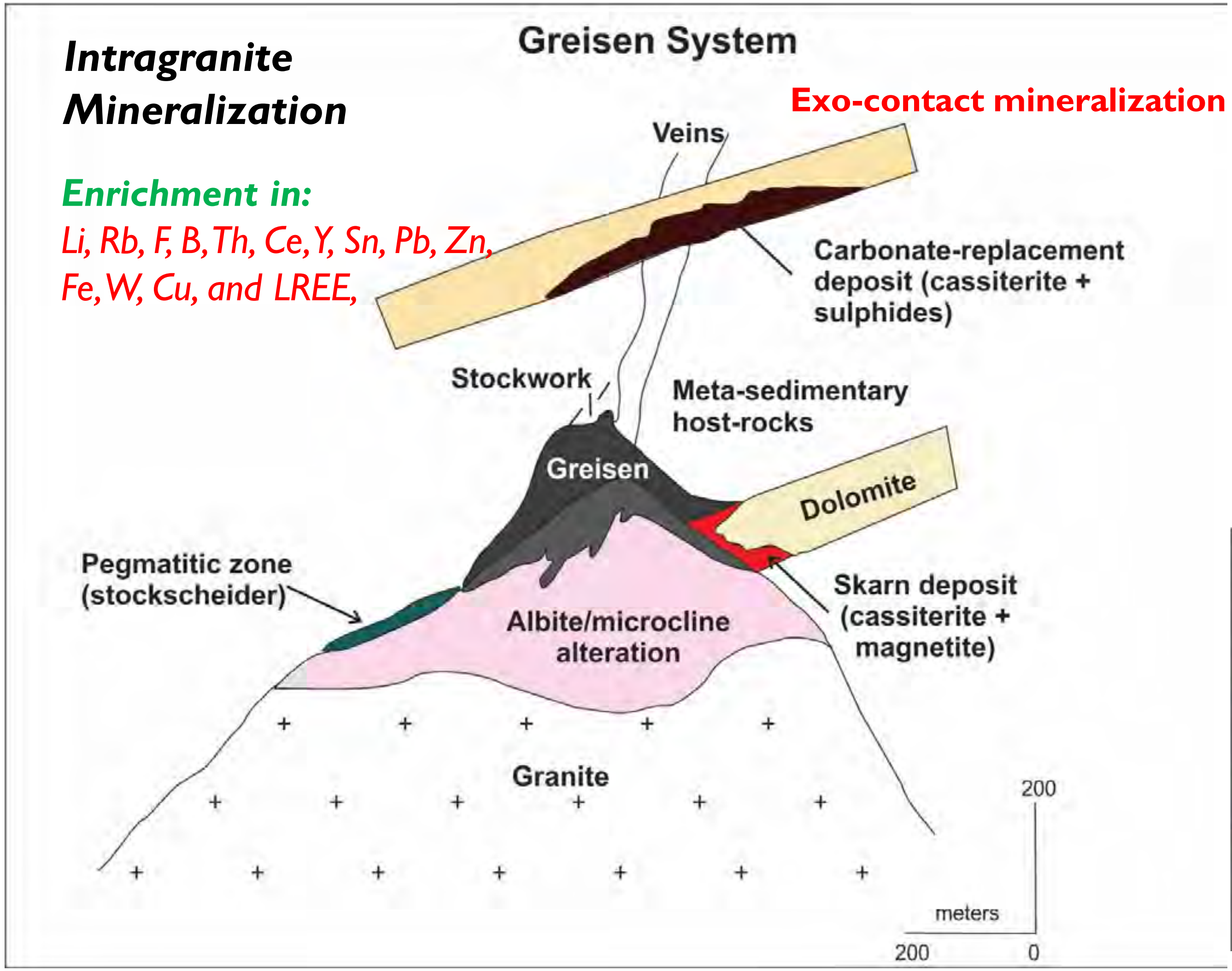
Les Fyffe

- 150 samples from granitic units
- 30 samples from greisen veins

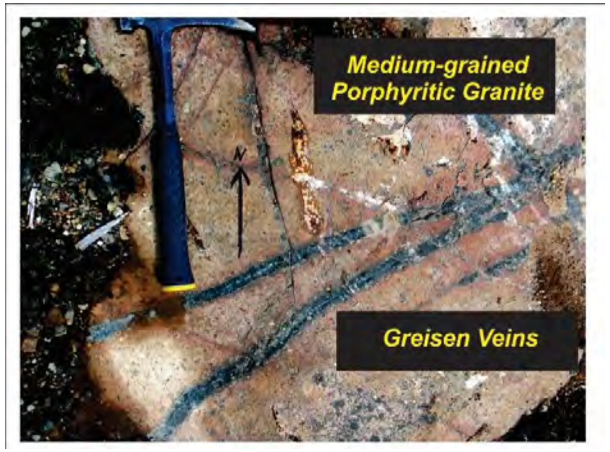
# Greisen Zones

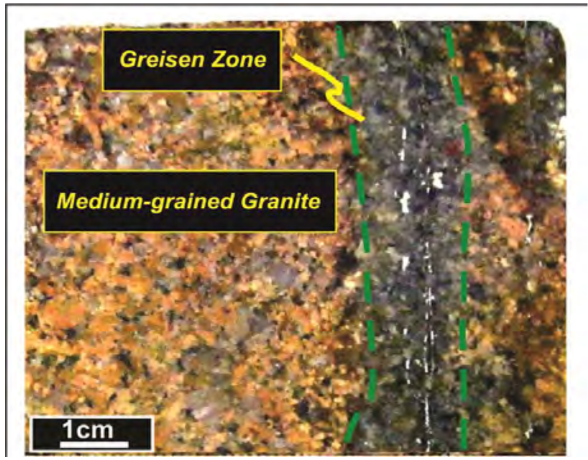
***Intragranite Mineralization***

***Enrichment in:***
*Li, Rb, F, B, Th, Ce, Y, Sn, Pb, Zn, Fe, W, Cu, and LREE,*

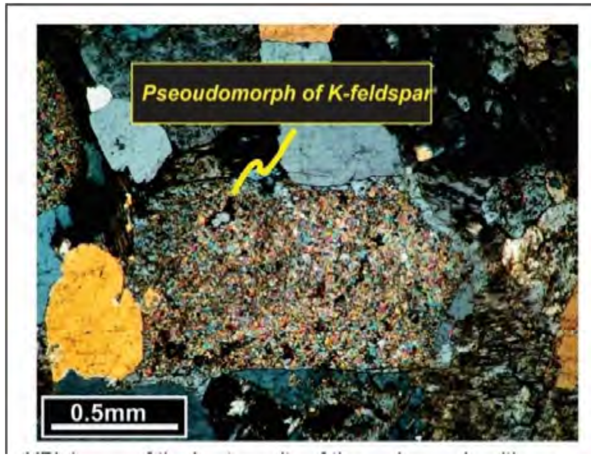



Modified after Sillitoe (1996), Sillitoe and Thompson (1988), Lang et al. (2000), and Lang and Baker (2001).



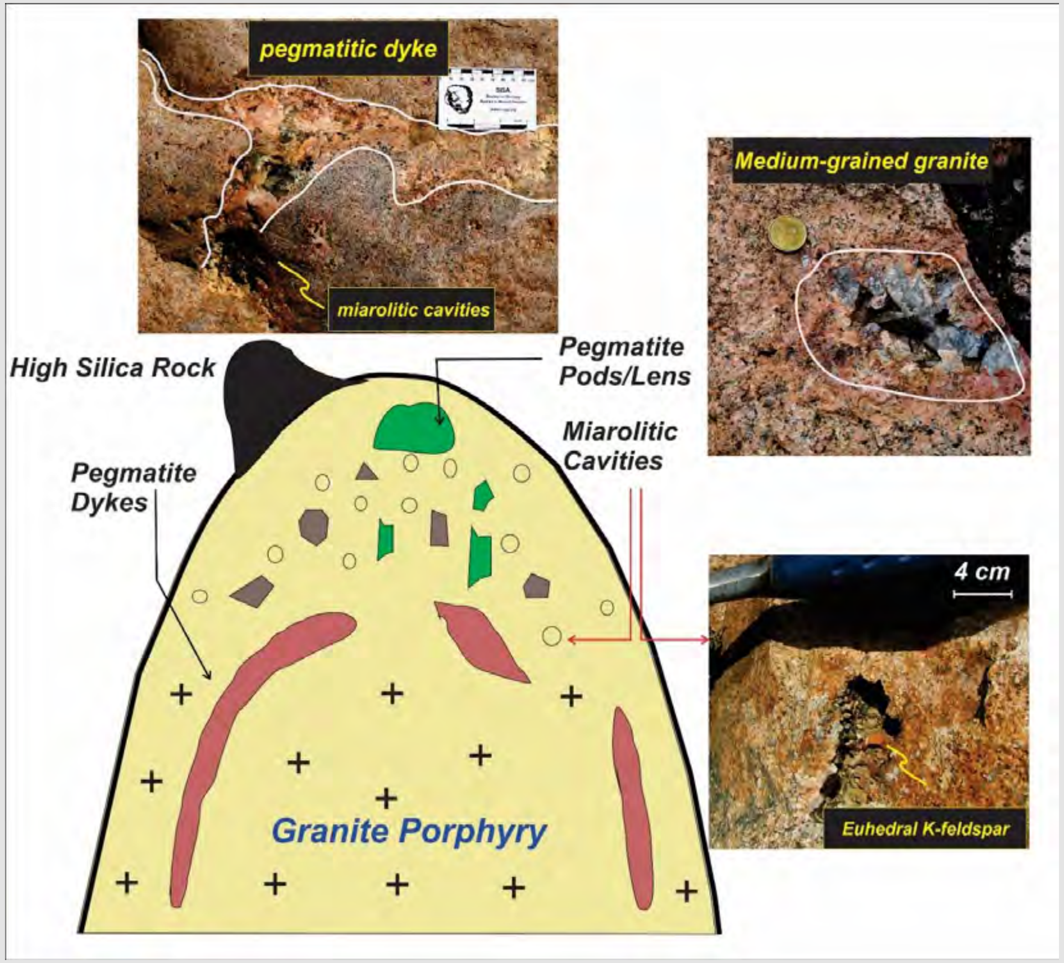





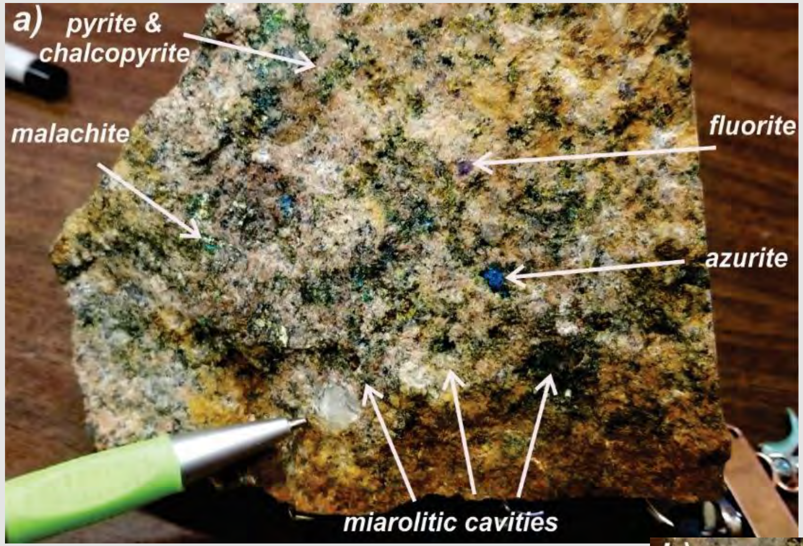



**Greisen:** A high silica granite with feldspars and biotite that are replaced by mica, quartz, fluorite ± tourmaline ± topaz.

## Mineralization associated with miarolitic cavities



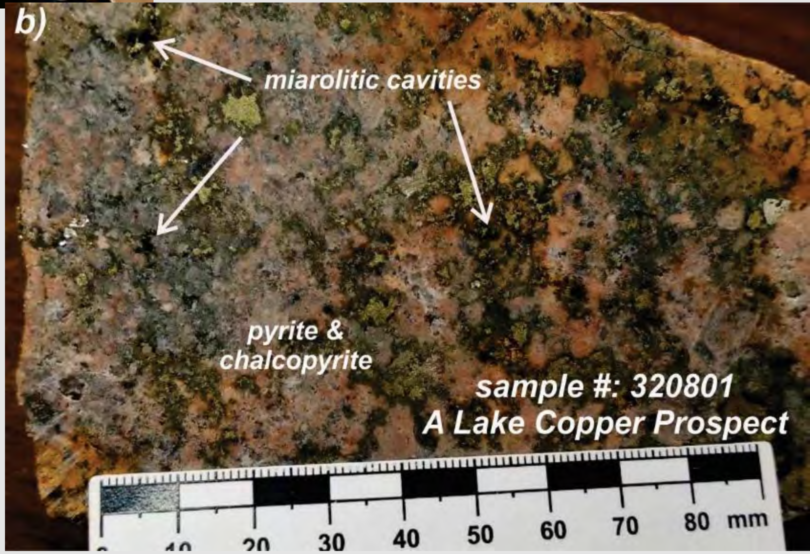

*Modified after Kirwin, 2005 & Pirajno, 2009*




**Question: *Magmatic-related mineralization or Post-Magmatic-related mineralization?***

**"A" Lake Copper Prospect**

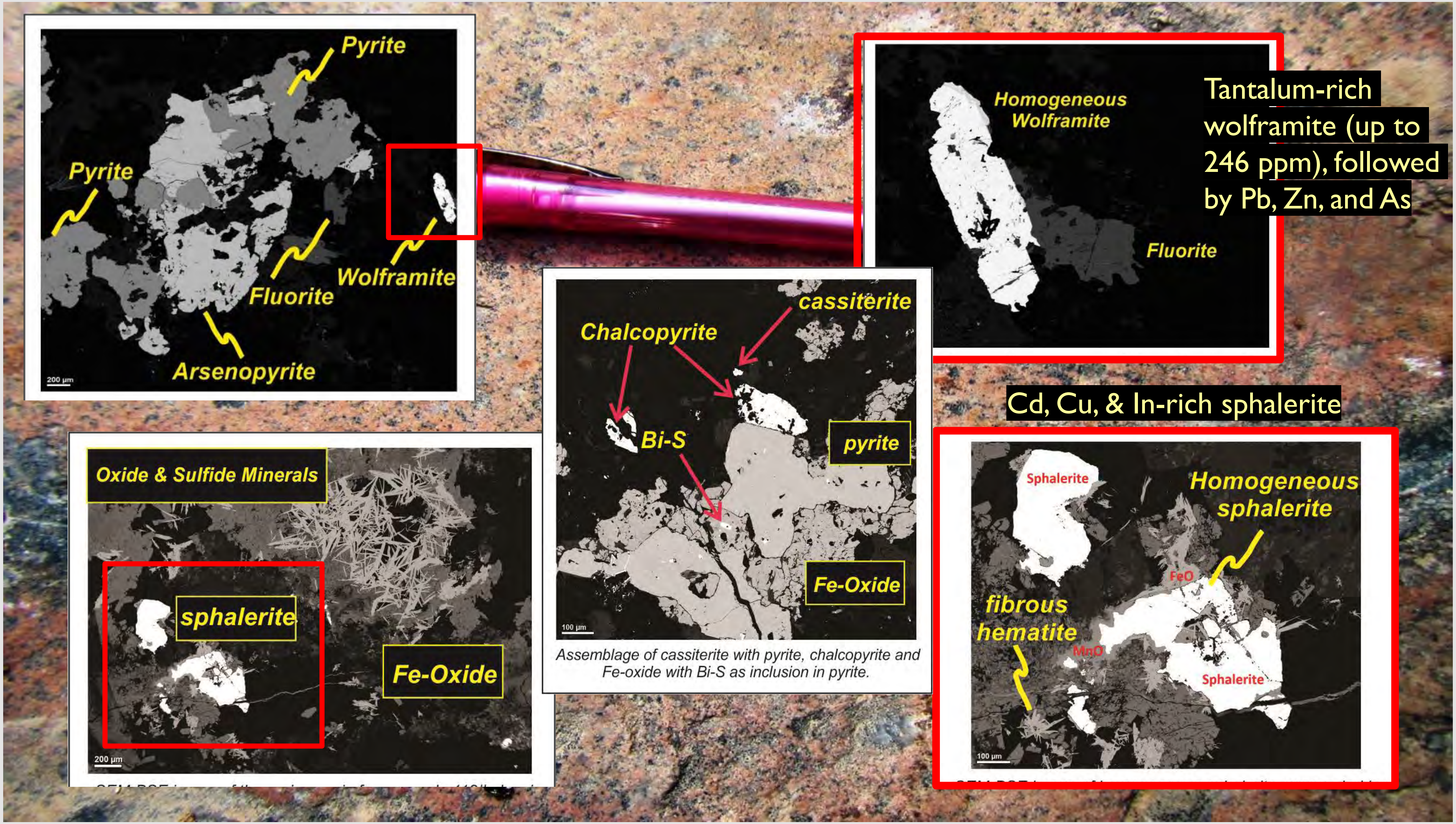
**John Wightman (Prospector)**




***second boiling (degassing)***

**8.24 wt.% Copper**

# Greisen veins: SEM-BSE Images




Assemblage of cassiterite with pyrite, chalcopyrite and Fe-oxide with Bi-S as inclusion in pyrite.

# Whole-Rock Geochemical Feature

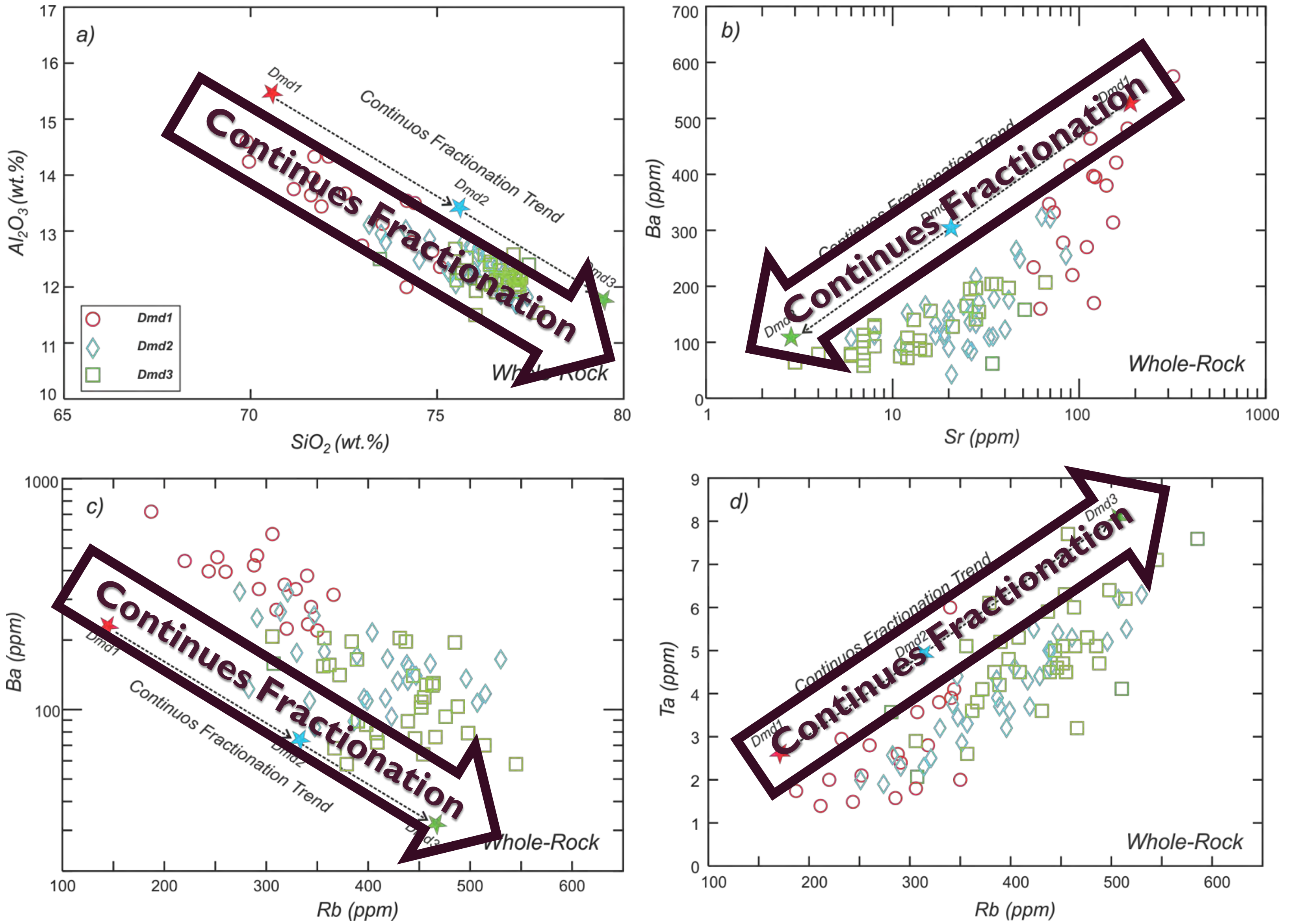
**Mount Douglas Granite:**

**A highly evolved post-orogenic granite that exhibits a hybrid S-type and A-type signature**

- $SiO_2$ (68-78 wt.%)
- $K_2O$ (3.5-7.8)
- Low CaO (≤ 1.77 wt.%)
- Low MgO (≤ 1.03 wt.%)

**Dmd3**

- Highest $SiO_2$: 76.4 wt.%
- high LILE (Li, Rb, Cs)
- HFS (Ta, Th, U)
- Y (≤ 138 ppm), and REE




**Different phases within the MDG have been formed through extreme fractional crystallization from Dmd1 toward Dmd3 that led to formation of mineral deposits**

# Whole Rock Geochemical Features (Trace Elements)

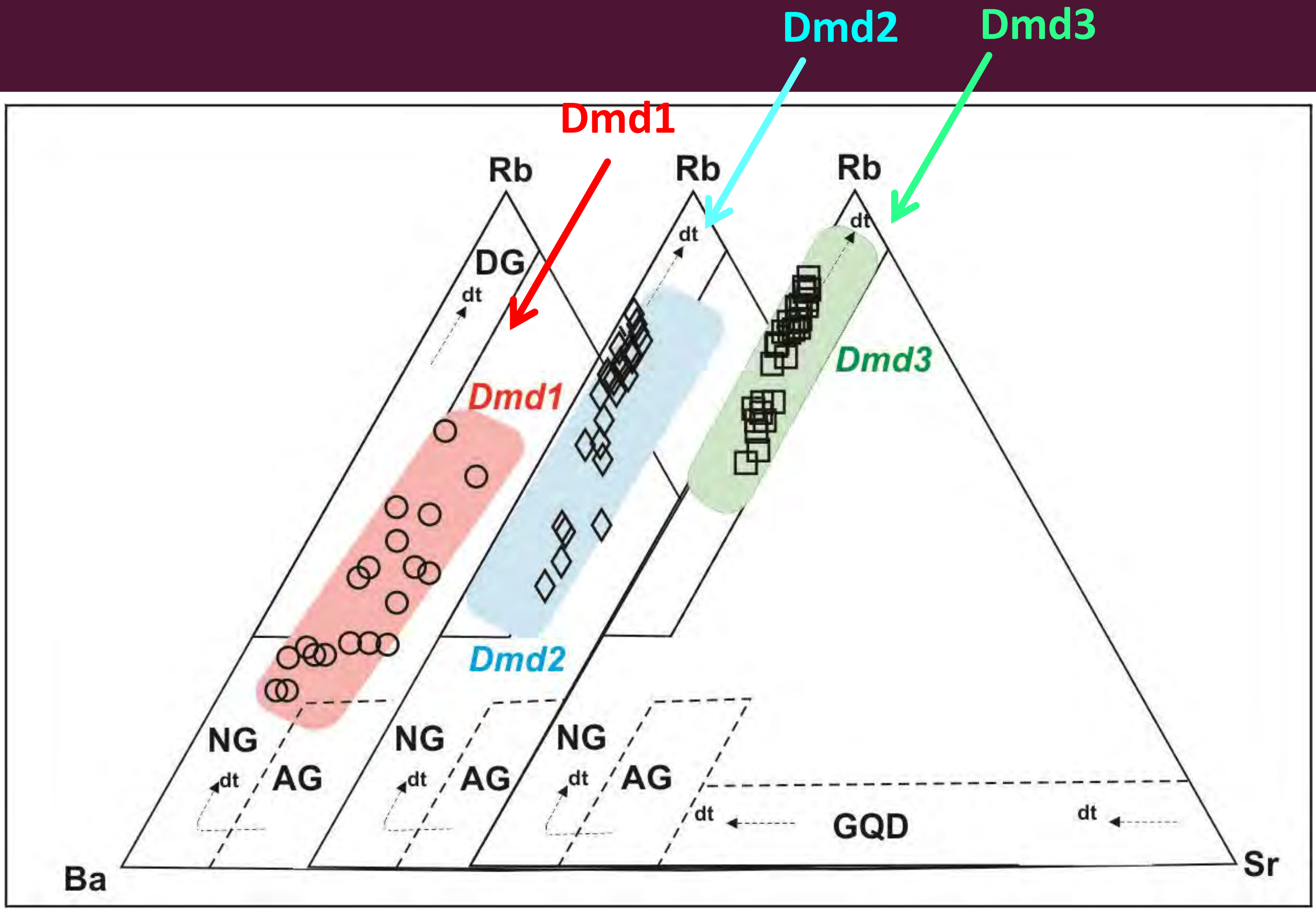
## Ba-Rb-Sr Diagram

***GQD: granodiorites, quartz diorites & diorites***

***AG: anomalous granites***

***NG: Normal Granites***

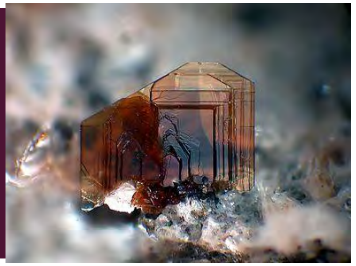
***DG: Strongly Differentiated Granites***

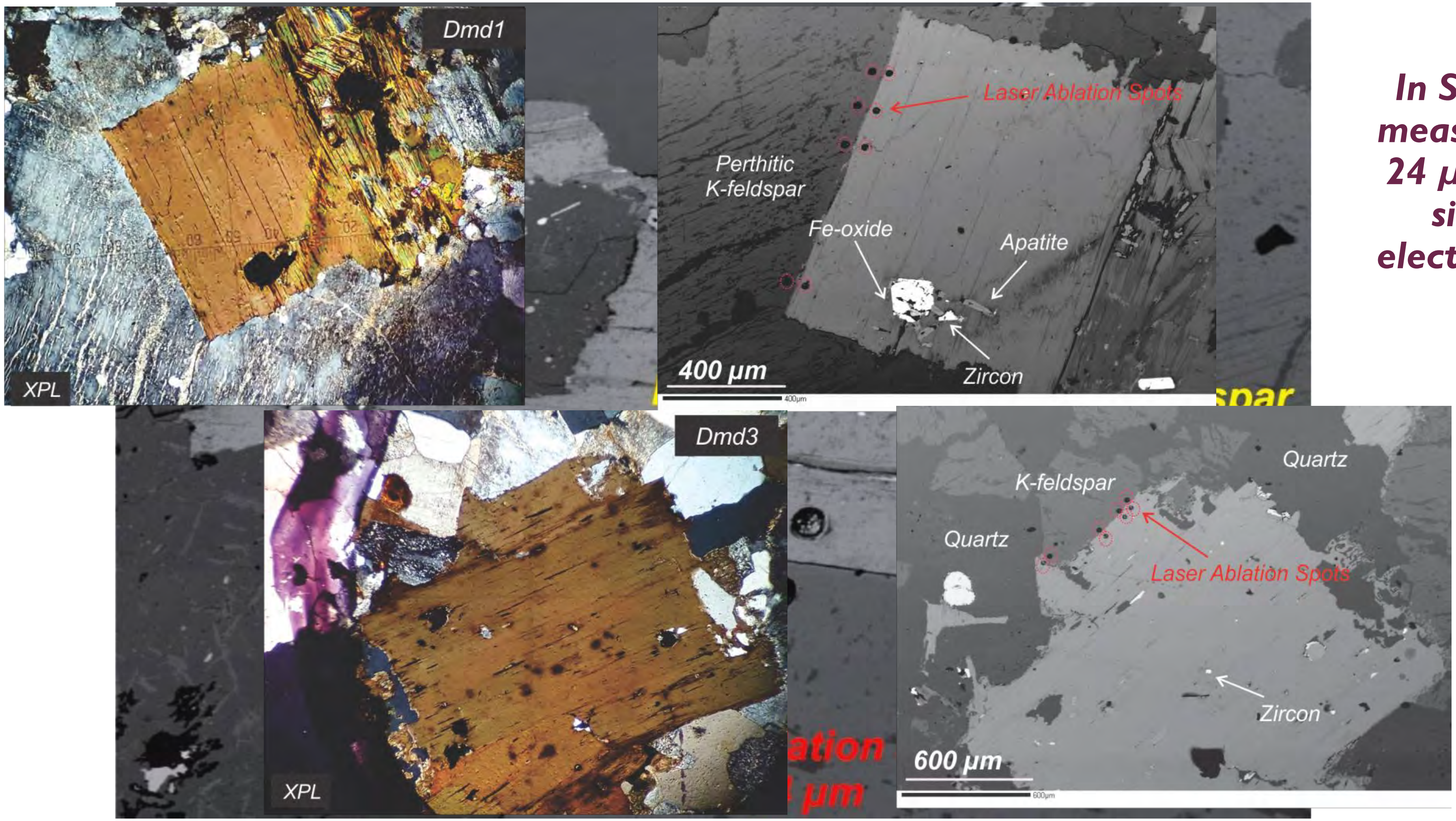



*El Bouseilly and Sokkary (1975)*

# **Biotite:** A Phyllosilicate (Ferromagnesian-type) Mica

$K(Mg, Fe)_3AlSi_3O_{10}(F, Cl, OH)_2$






***In Situ LA ICP-MS measurements using 24 µm crater beam size guided by electron microprobe***

# Biotite Composition

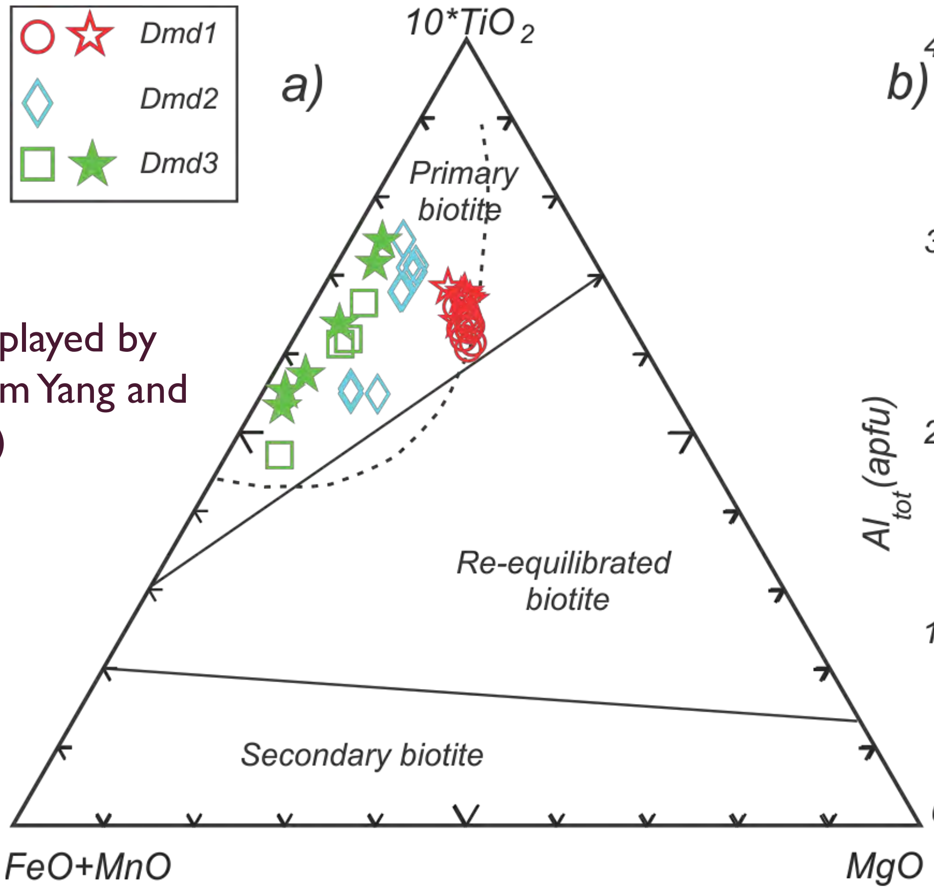
$K_{1.6}\ Na_{0.03}\ Ca_{0.01}\ (Mg_{2.3}\ Fe^{2+}_{1.9}\ Mn_{0.08}\ Fe^{3+}_{0.8}\ Ti_{0.47}\ Al_{0.07})\ [Si_{5.6}\ Al_{2.4}\ O_{22}]\ (OH_{3.20}\ F_{0.77}\ Cl_{0.03})$

***EMPA data:***

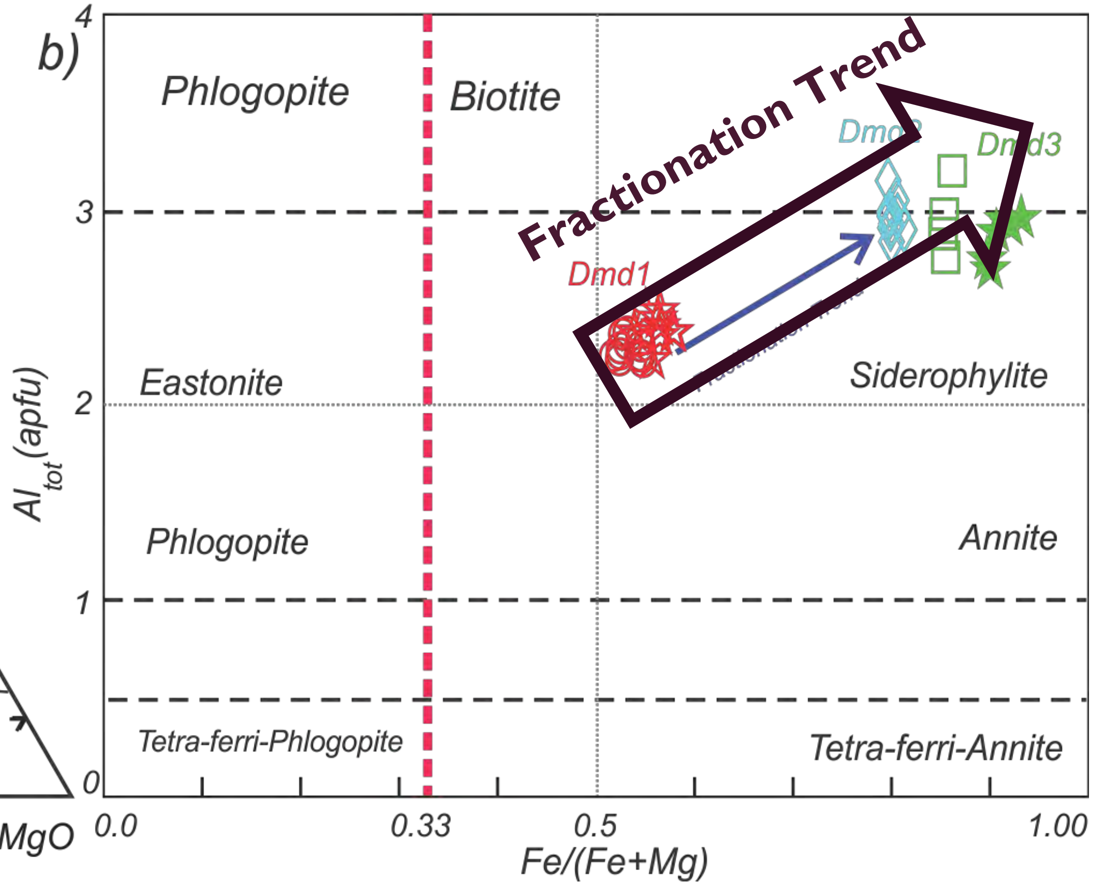
***Primary Biotite***

***Siderophylite-type Biotite***

The data displayed by stars are from Yang and Lentz (2005)




Nachit et al. (2005).




*International Mineralogical Association (IMA) diagram*

Deer et al., 1992; Rieder et al., 1998; Rieder, 2001

1

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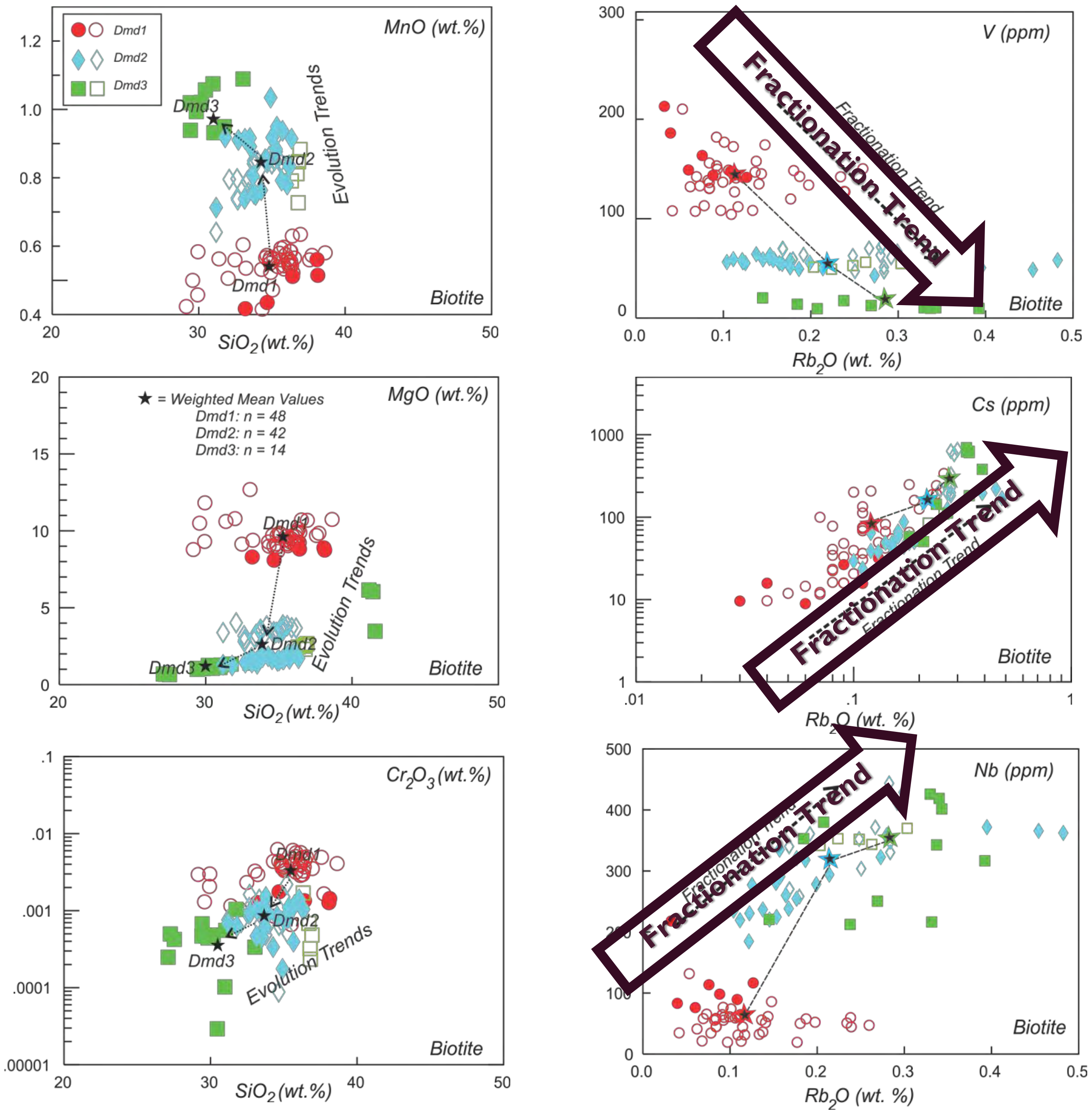
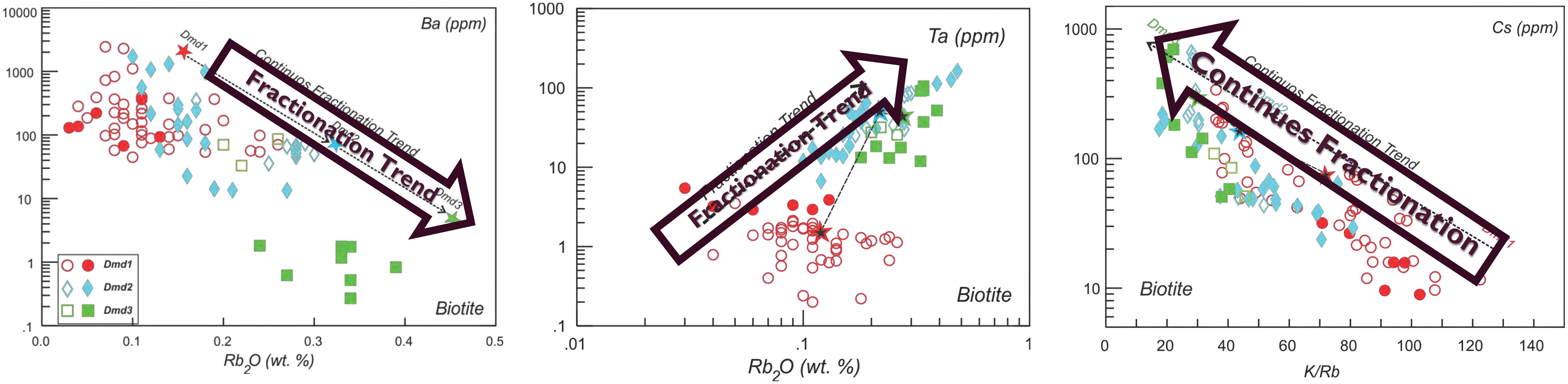
# Biotite: Fractional Crystallization

## Major Elements

## Trace Elements



# Biotite: Fractional Crystallization Indicies




## Cs *versus* K/Rb

**One of the best indicators of magmatic evolution**

2

# Biotite: An Indicator for Mineralization (?)

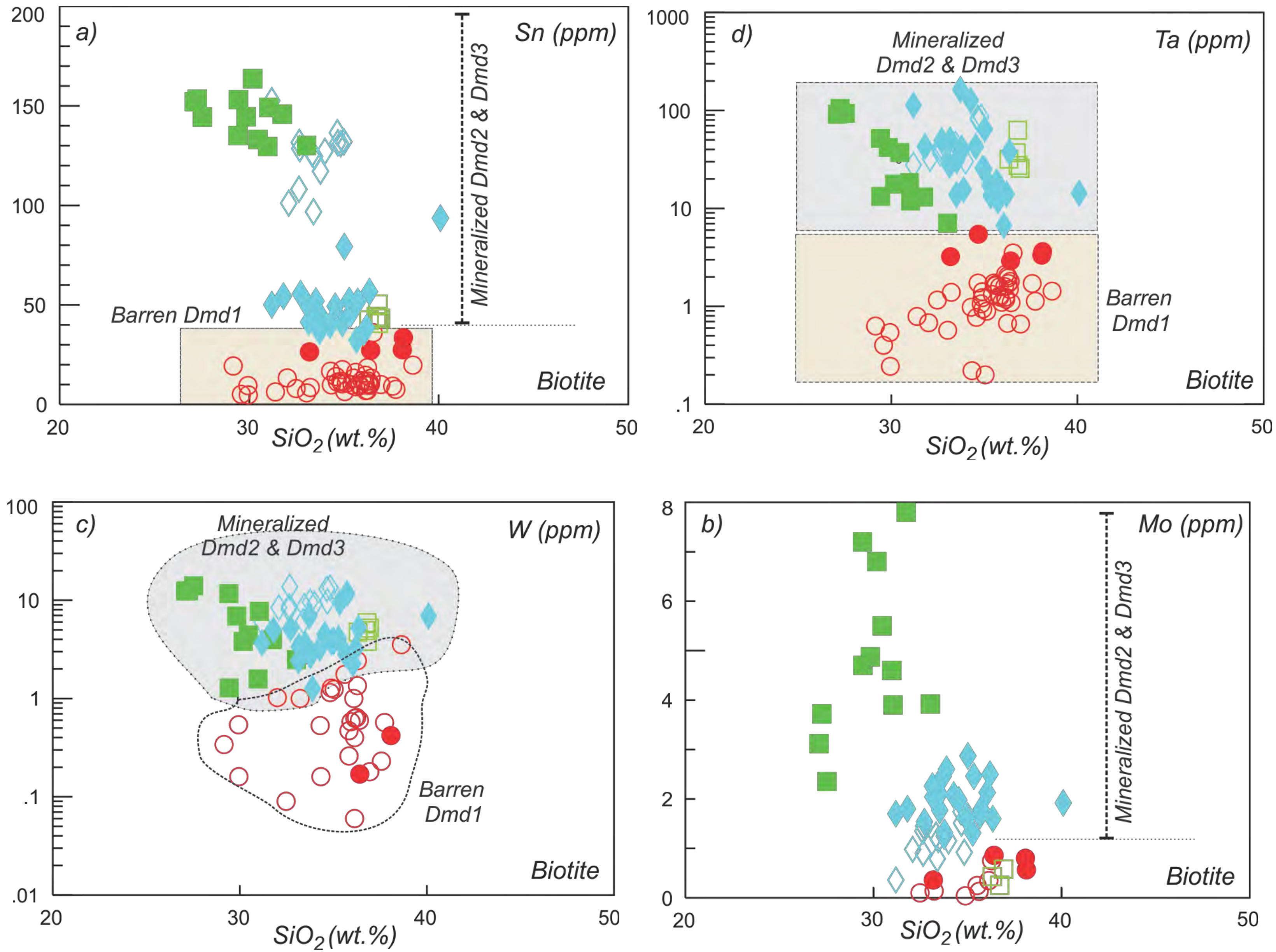
Biotite indicates the association of the most fractionated units (Dmd2 & Dmd3) with mineralization.

***Sn (≤ 164 ppm)***

***Ta (≤ 163 ppm)***

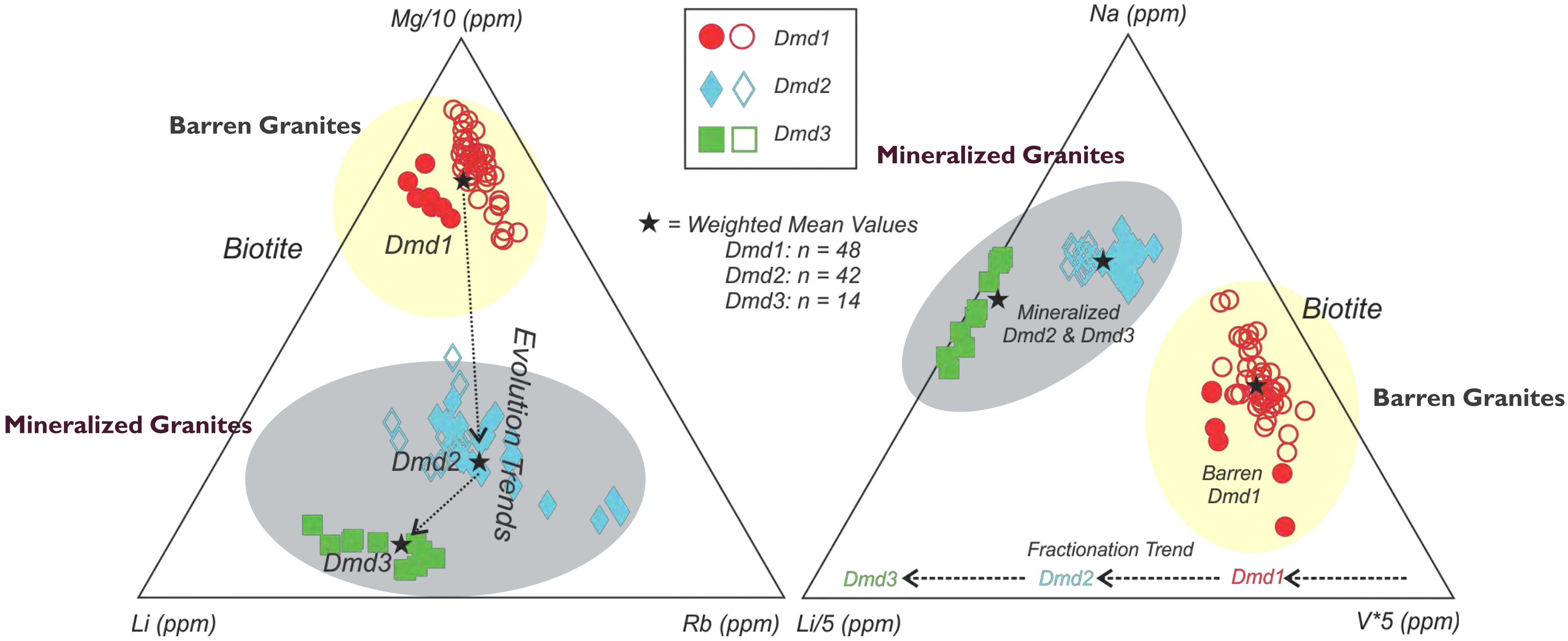
***W (≤ 14 ppm)***

***Mo (≤ 8 ppm)***




***The breakdown of the biotite lattice and conversion to muscovite or sericite during greisenization may be one of the most important factor producing the mineralized greisen zones in Dmd2 and Dmd3.***

# Biotite: An Indicator for Mineralization




Modified after Azadbakht & Lentz (2020)

# Partition coefficients (minerals/melt)

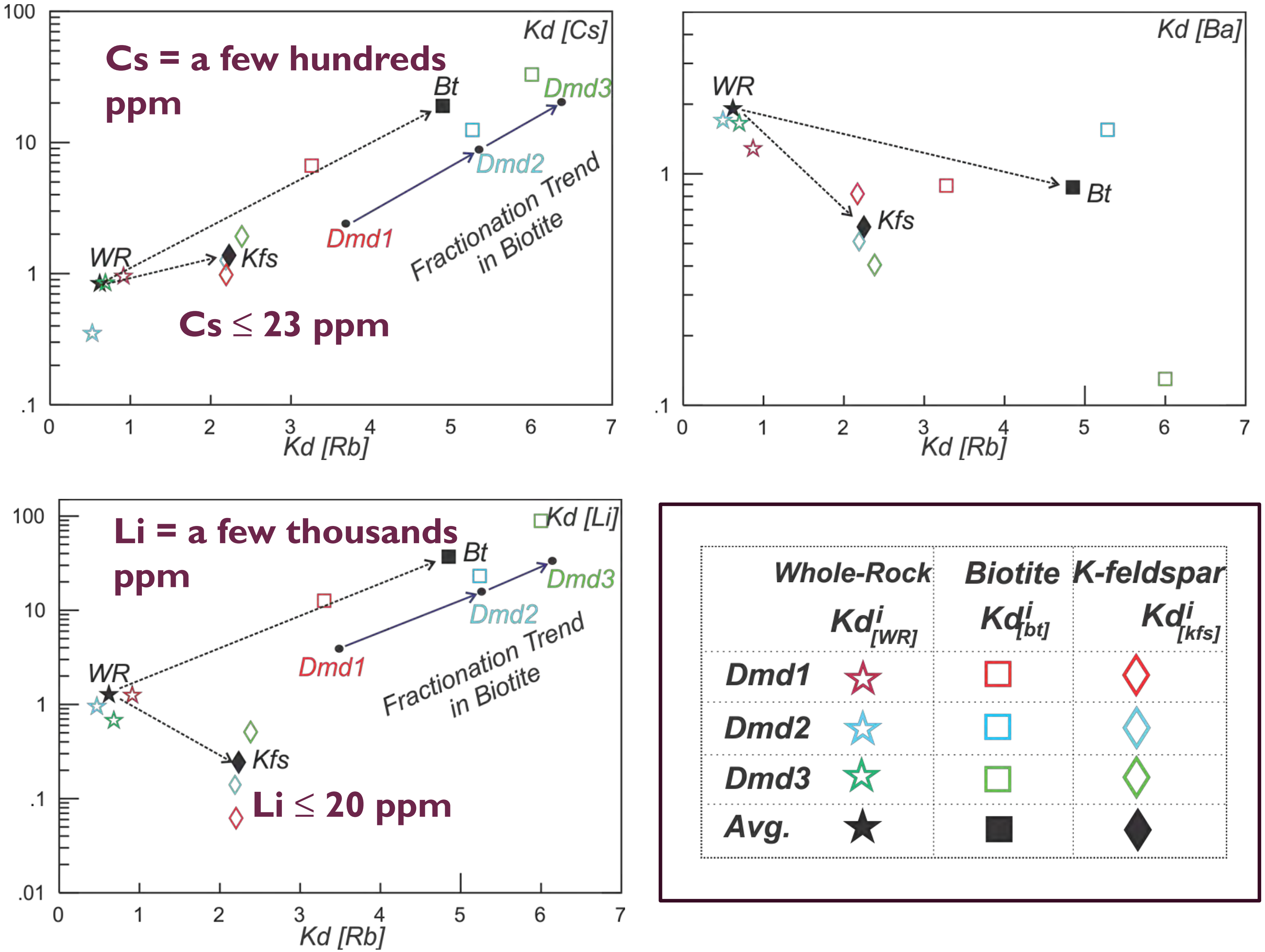
## Trace elements: Cs, Li, Ba, Rb

$$Kd = \frac{\text{concentration of trace element (i) in minerals}}{\text{concentration of trace element (i) in melt}}$$

**Kd**: minerals/melt partition coefficients

**[ i ]**: the concentration of a selected trace element

*Biotite and K-feldspar:* ***in equilibrium***



# Partition coefficients (minerals/melt)

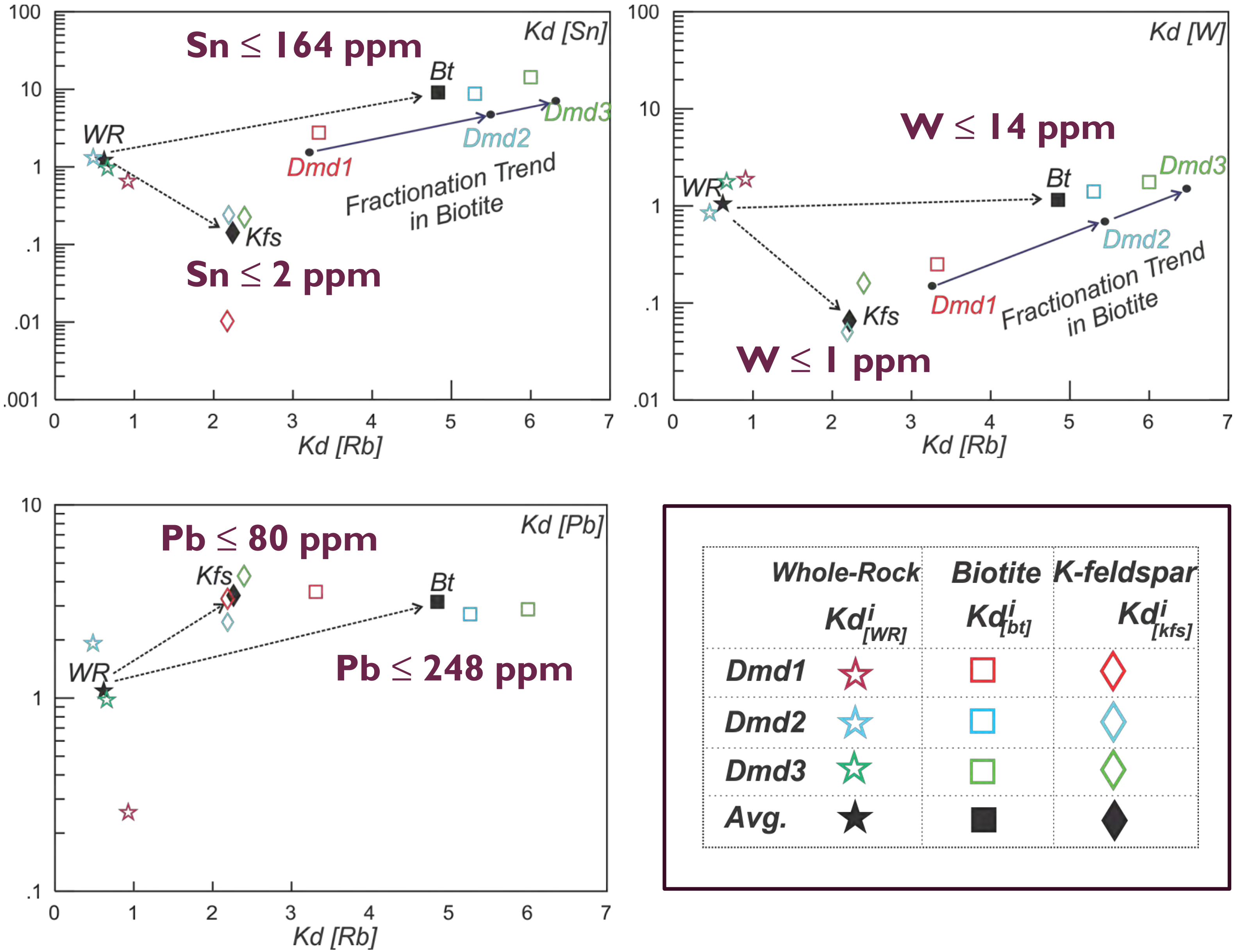
## Metals (Pb, Sn, W)

$$Kd = \frac{\text{concentration of trace element } [i] \text{ in minerals}}{\text{concentration of trace element } [i] \text{ in melt}}$$

**Kd**: minerals/melt partition coefficients

**[ i ]**: the concentration of a selected trace element

***"Fractional crystallization trend"***



# LITHOS

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Research Article

## Biotite composition as a tool for exploration: An example from Sn-W-Mo-bearing Mount Douglas Granite, New Brunswick, Canada

Check for updates

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# Summary

✓ ***Biotite composition: A tool for mineral exploration***

- Our new laser ablation ICP-MS & EPMA results from biotite appear considerably promising to ***discriminate barren granitic bodies from mineralized phases*** although further use of this approach requires caution as providing favourable conditions to form ore bodies must be considered.

- The technique used here appears to be fruitful for reconstituting the evolution of parental magmas, in which biotite record the evolution of granitic melts. We are able to establish that the sequential assembly of the Mount Douglas Granite can be attributed to a ***fractional crystallization process*** manifested by distinct systematic variation in biotite composition from least evolved unit, Dmd1, to more highly fractionated units, Dmd2 and Dmd3.

- A very unique geological setting of the Sn-W-Mo-U mineralized Mount Douglas Granite in New Brunswick, Canada, provides an exceptional reservoir to test applicability of biotite composition as a mineral exploration tool. Our dataset also highlights the importance of the ***Mount Douglas Granite system to serve as a robust example for universal comparison*** for further mineral exploration and recommends considering other ubiquitous minerals (e.g., zircon) in such systems as a ***"Fertility Indicator".***