Magmatic evolution in Devonian granitic rocks and relation to granophile mineralization in New Brunswick: Application of biotite trace element mapping with EPMA and LA-ICP-MS

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Abstract: Two suites of felsic intrusions were emplaced during the later parts of the Appalachian orogenic cycle in New Brunswick. However, just those associated with crustal thickening processes of Acadian orogeny, post Acadian uplift, and Neoacadian orogeny are mineralized with granophile elements to form Sn, W, Mo, Cu, Bi, Sb, and Au deposits, as well as Ta, Li, base-metals, and U mineralization. Biotite major element classification indicated that these intrusions are mostly A- and S-type granitoids and their hybrid varieties; some I-type granitoids are also present in the area.

Magmatic biotite from forty-two of these Devonian intrusions was studied by electron microprobe (EPMA) and LA -ICP-MS at the University of New Brunswick. Whereas major elements are typically constant from core to rim, biotite grains can show remarkable trace element zoning. LA-ICP-MS trace element maps were also produced when permitted by the size of the biotite, frequency of the mineral inclusions, degree of alteration, and the laser spot size required to achieve sub-ppm detection limits. In this study, unaltered biotite grains with minor mineral inclusions, and diameters larger than 300 μm, display trace-element zoning patterns. Furthermore, smaller biotite tends to be more susceptible to intracrystalline diffusion. As a result, their elemental zoning should be further studied and cross -checked with other characteristics.

Results of this study showed LILE zoning, including Cs, Ba, and Rb, for most of the biotite grains. As these elements are highly incompatible, any zoning can be a result of the magma evolution history recorded within the biotite crystalline structure. Any other trace element pattern following them will also be of an igneous source. For example, biotite grains from the Pleasant Ridge granite show an increase from core to rim for Cs and Sn and a decrease for W and Sc. Copper is also high along the cleavages where biotite is weakly altered to chlorite. These observations coupled with an increase in F/Cl content from 770 to 1300 indicate that fractional crystallisation of this granite led to Sn mineralization. Tin is positively correlated with Fe/(Fe+Mg), but negatively correlated with Fe_T/Ti; this relationship may indicate that the Sn content of biotite increases with low fo_2 and low temperatures as indicated by the iron/magnesium ratio.

According to the results, the use of biotite as an indicator of trace element changes within granitic systems was achieved; with the help of other types of data, the composition of biotite may be a useful tool to indicate a difference between barren and mineralized granophile-element rich systems.

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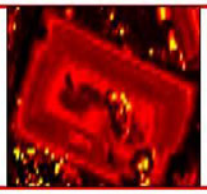
Magmatic Evolution in Devonian Granitic Rocks and Relation to Granophile Mineralization in New Brunswick: Application of Biotite Trace Element Mapping with EPMA and LA-ICP-MS

Zeinab Azadbakht , David Lentz, Christopher McFarlane

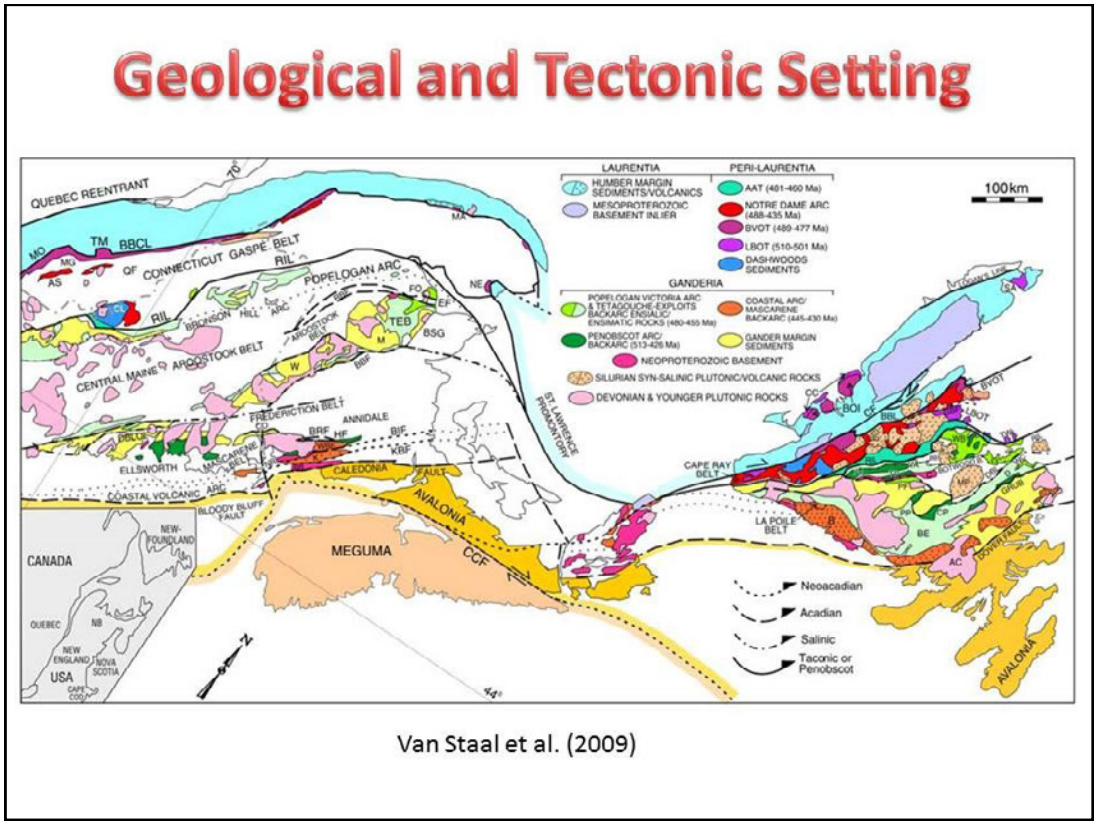
UNB



TGI 4 Ore Systems

Project Goals

- Document detailed chemistry of coexisting phyllosilicate mineral phases to reveal distinctive element signatures that may be specific to fertile granitoids.
- Provide a geochemical fingerprint for more-specific mineralization styles and prospectivity in the Acadian Plutonic Complex.


Geological and Tectonic Setting
LAURENTIA
PERI-LAURENTIA
HUMBER MARGIN SEDIMENTS/VOLCANICS
MESOPROTEROZOIC BASEMENT INLIER
AAT (461-460 Ma)
NOTRE DAME ARC (488-435 Ma)
BVOT (489-477 Ma)
LBOT (510-501 Ma)
DASHWOODS SEDIMENTS
100km
GANDERIA
POPELOGAN VICTORIA ARC & TETAGOUCHE-EXPLOITS BACKARC ENSIALIC/ ENSIMATIC ROCKS (480-455 Ma)
COASTAL ARC/ MASCARENE BACKARC (445-430 Ma)
PENOBSCOT ARC/ BACKARC (513-426 Ma)
GANDER MARGIN SEDIMENTS
NEOPROTEROZOIC BASEMENT
SILURIAN SYN-SALINIC PLUTONIC/VOLCANIC ROCKS
DEVONIAN & YOUNGER PLUTONIC ROCKS
QUEBEC REENTRANT
CONNECTICUT GASPÉ BELT
POPELOGAN ARC
CENTRAL MAINE
AROOSTOOK BELT
FREDERICTON BELT
ANNIDALE
CALEDONIA FAULT
AVALONIA
MEGUMA
CCF
BLOODY BLUFF FAULT
COASTAL VOLCANIC ARC
ELLSWORTH
CAPE RAY BELT
LA POILE BELT
CANADA
NEW-FOUNDLAND
QUEBEC
NB
NEW ENGLAND
NOVA SCOTIA
USA
Neoacadian
Acadian
Salinic
Taconic or Penobscot
Van Staal et al. (2009)

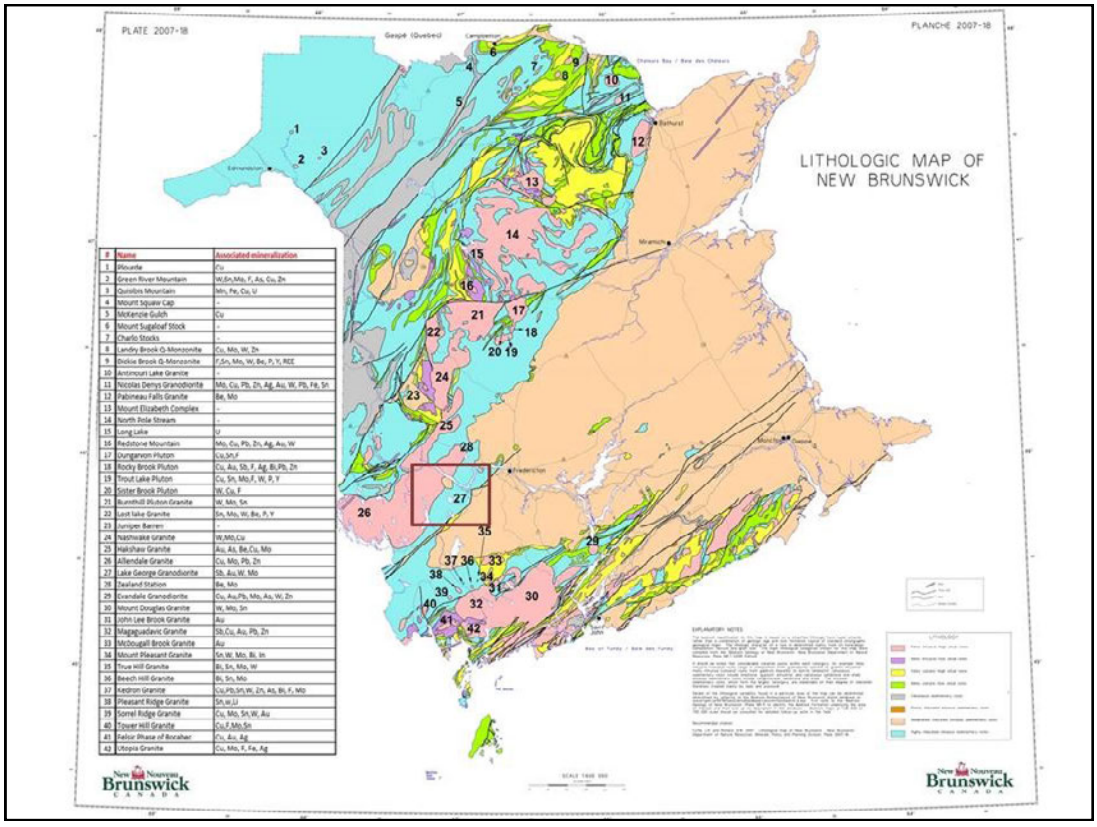
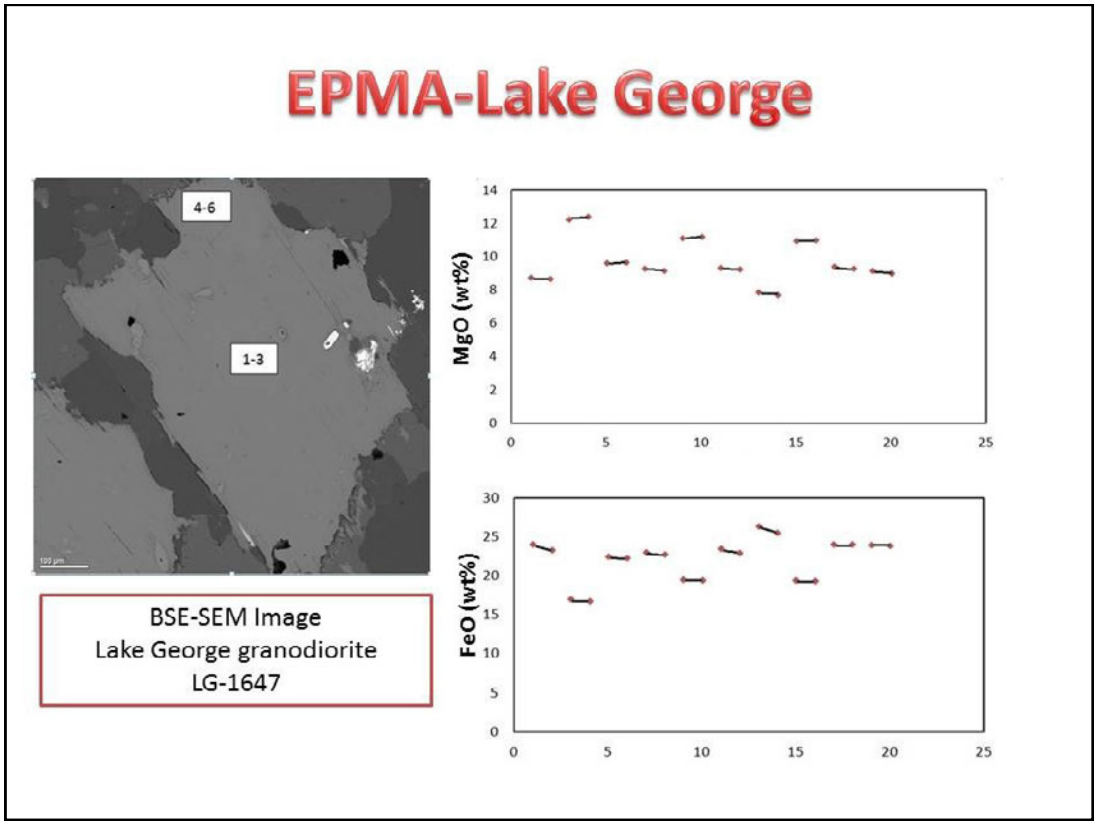
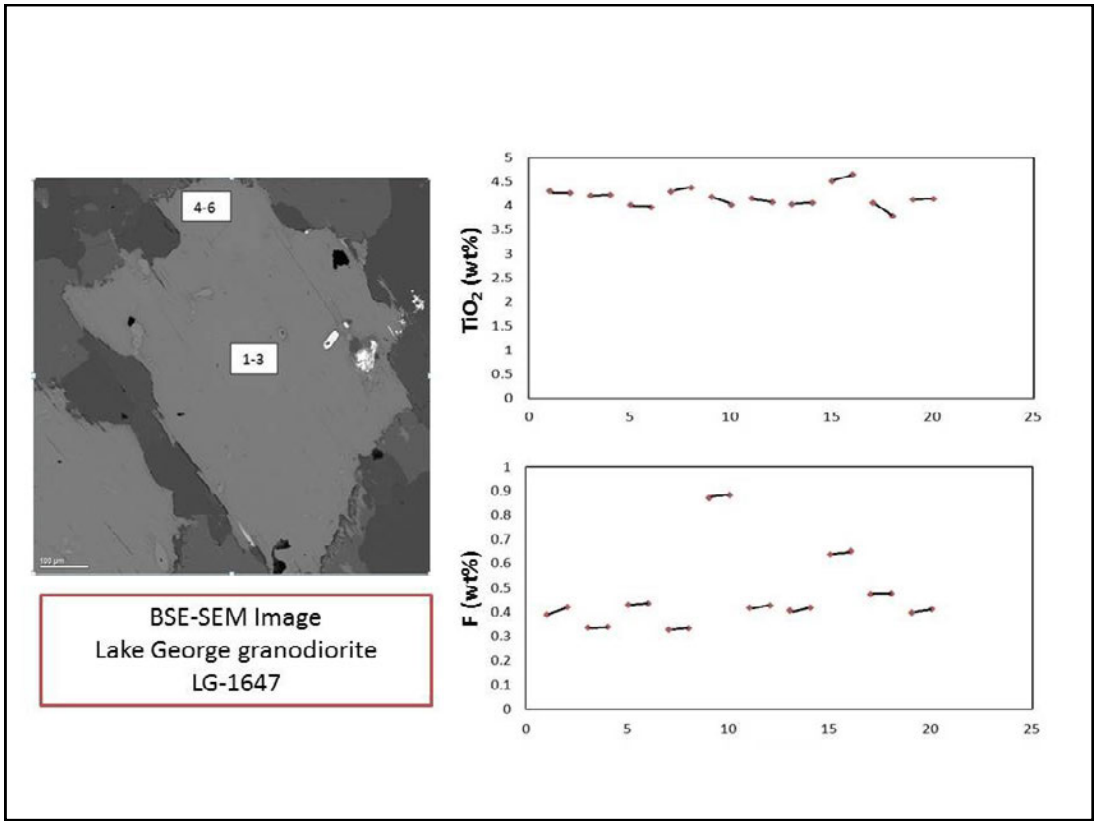
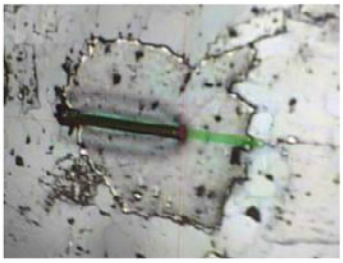


PLATE 2007-18
PLANCHE 2007-18
LITHOLOGIC MAP OF NEW BRUNSWICK
Brunswick

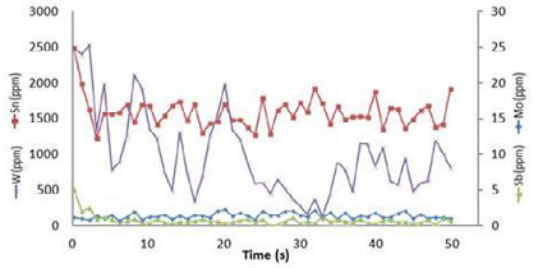

EPMA-Lake George
4-6
1-3
BSE-SEM Image
Lake George granodiorite
LG-1647
MgO (wt%)
FeO (wt%)

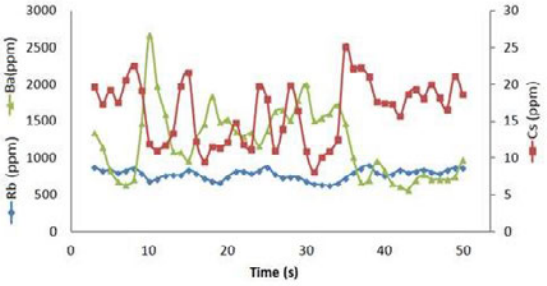

4-6
1-3
BSE-SEM Image
Lake George granodiorite
LG-1647
TiO2 (wt%)
F (wt%)

LA-ICPMS- Lake George

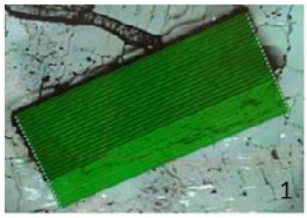


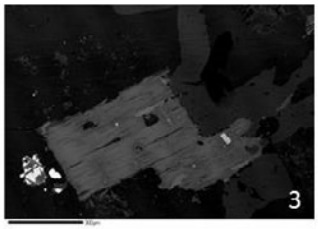
Photomicrograph of a biotite from Lake George granodiorite
LG-1748
(Field of view is 600µ)

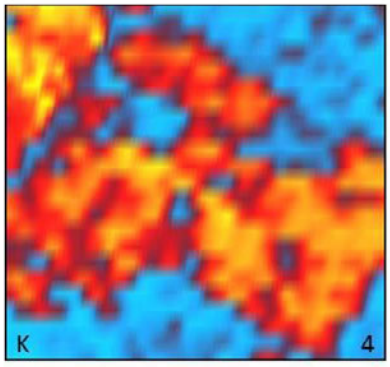


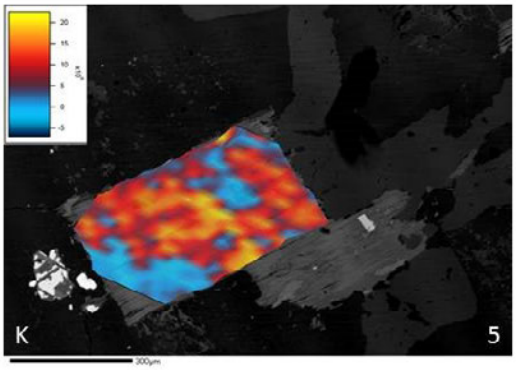


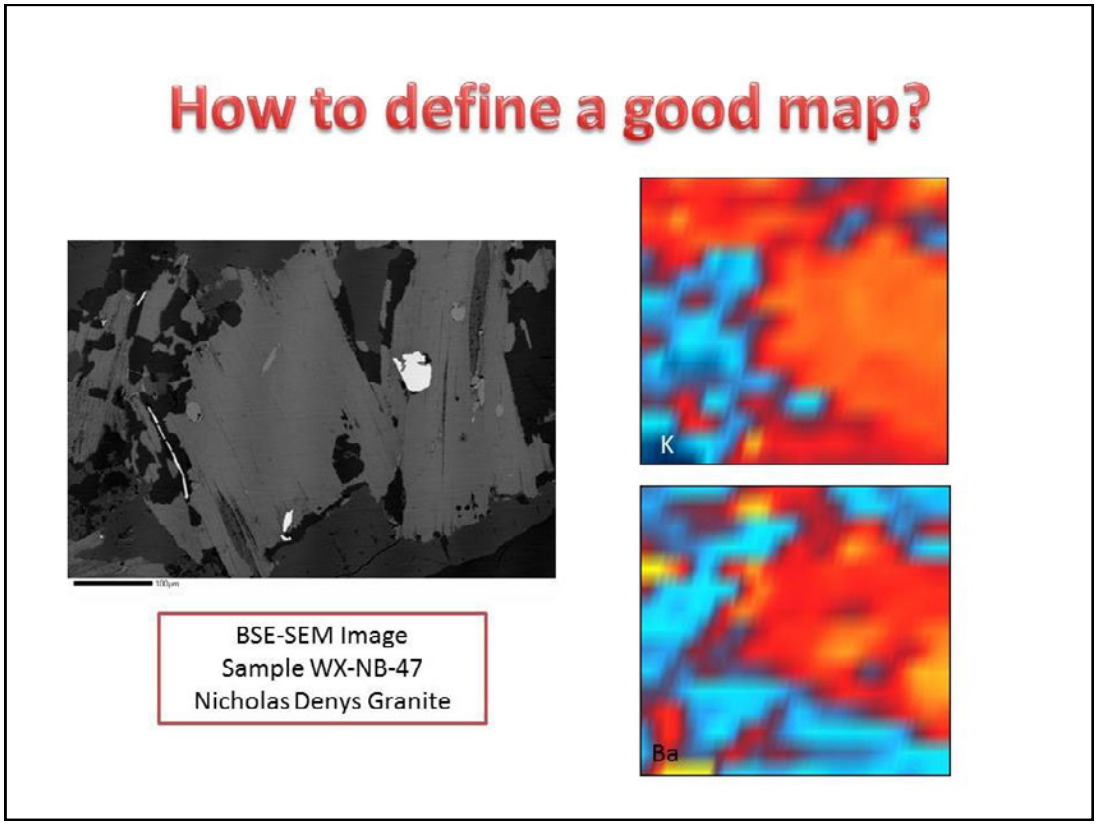
How to make a laser map

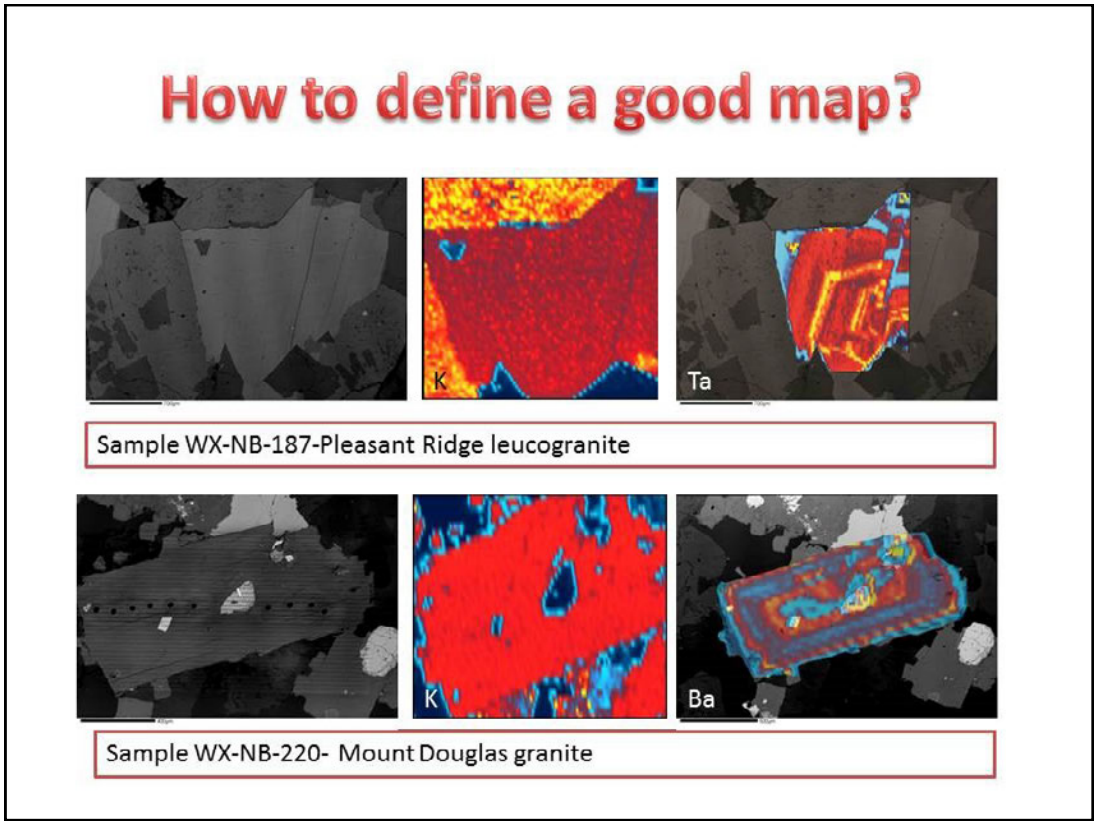


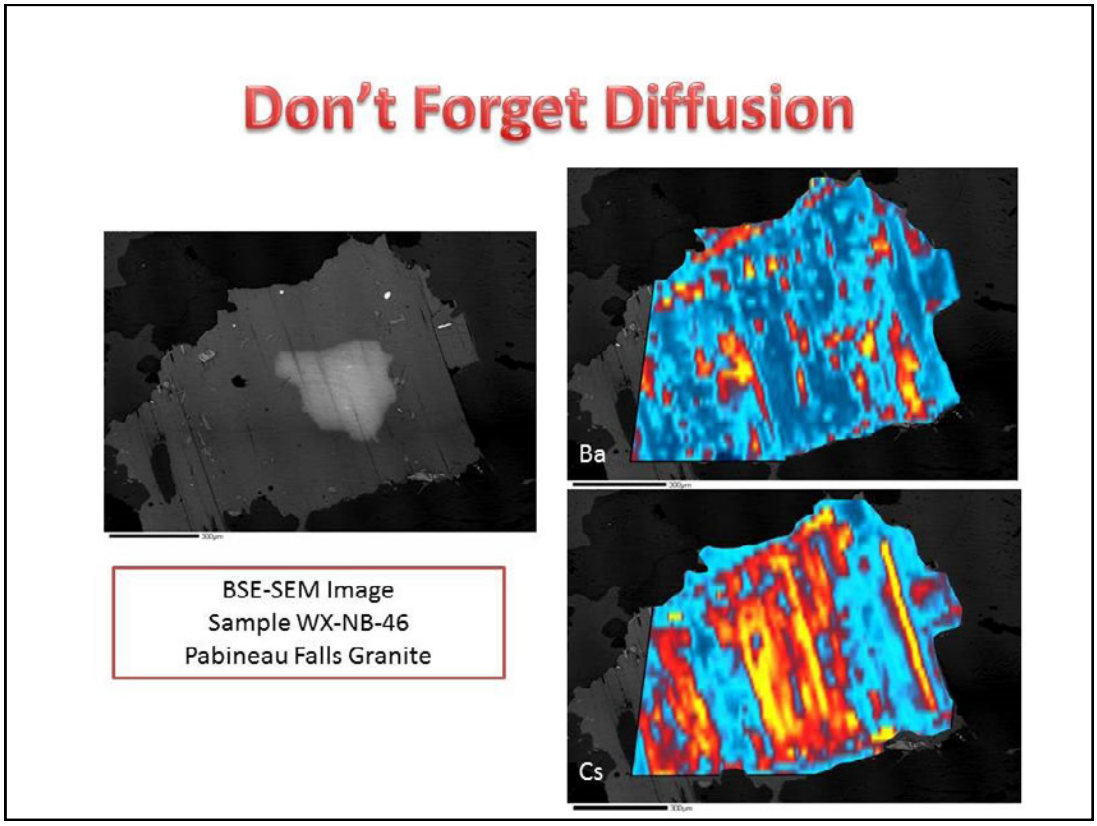


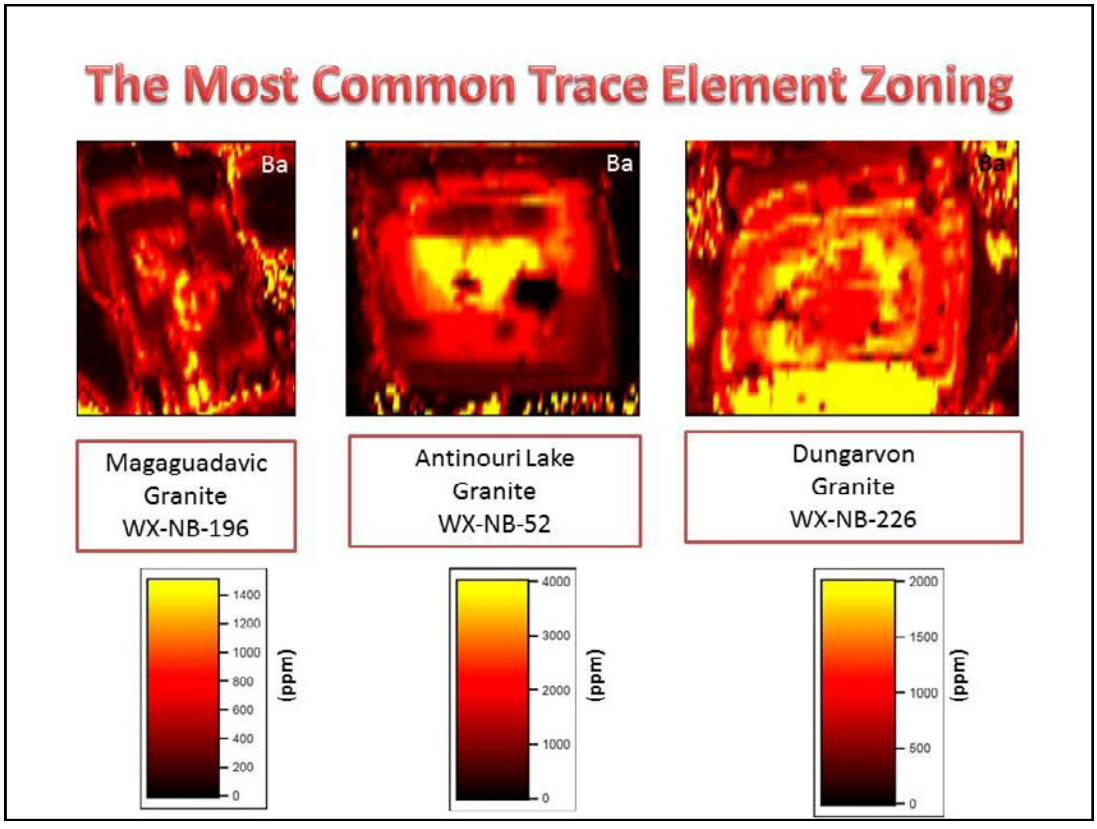





How to define a good map?
K
Ba
BSE-SEM Image
Sample WX-NB-47
Nicholas Denys Granite

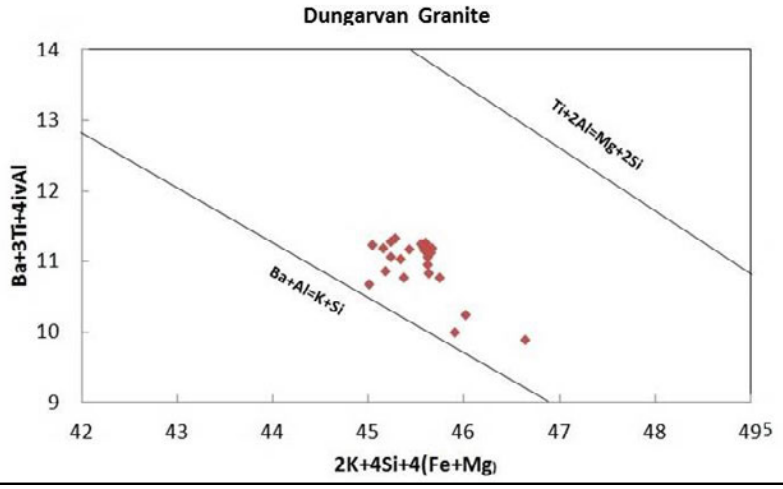

How to define a good map?
K
Ta
Sample WX-NB-187-Pleasant Ridge leucogranite
K
Ba
Sample WX-NB-220- Mount Douglas granite

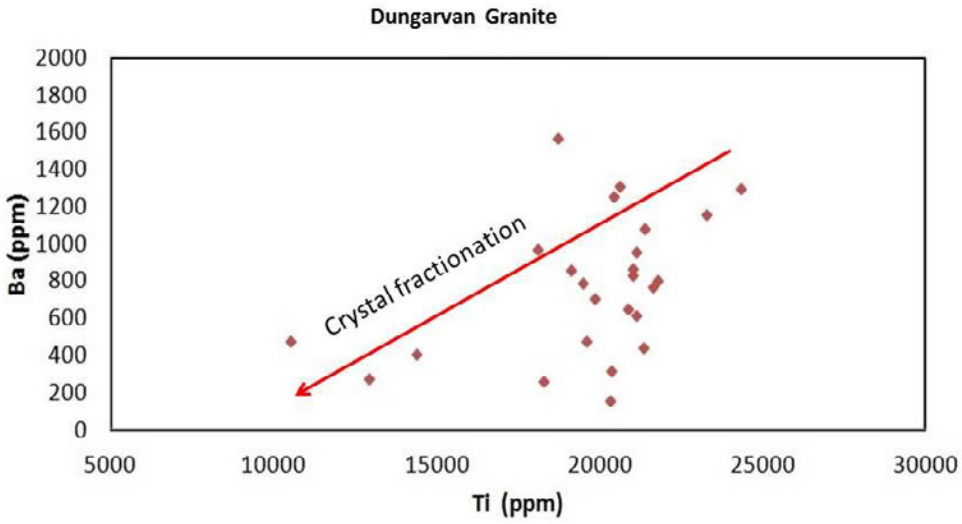

Don't Forget Diffusion
Ba
Cs
BSE-SEM Image
Sample WX-NB-46
Pabineau Falls Granite

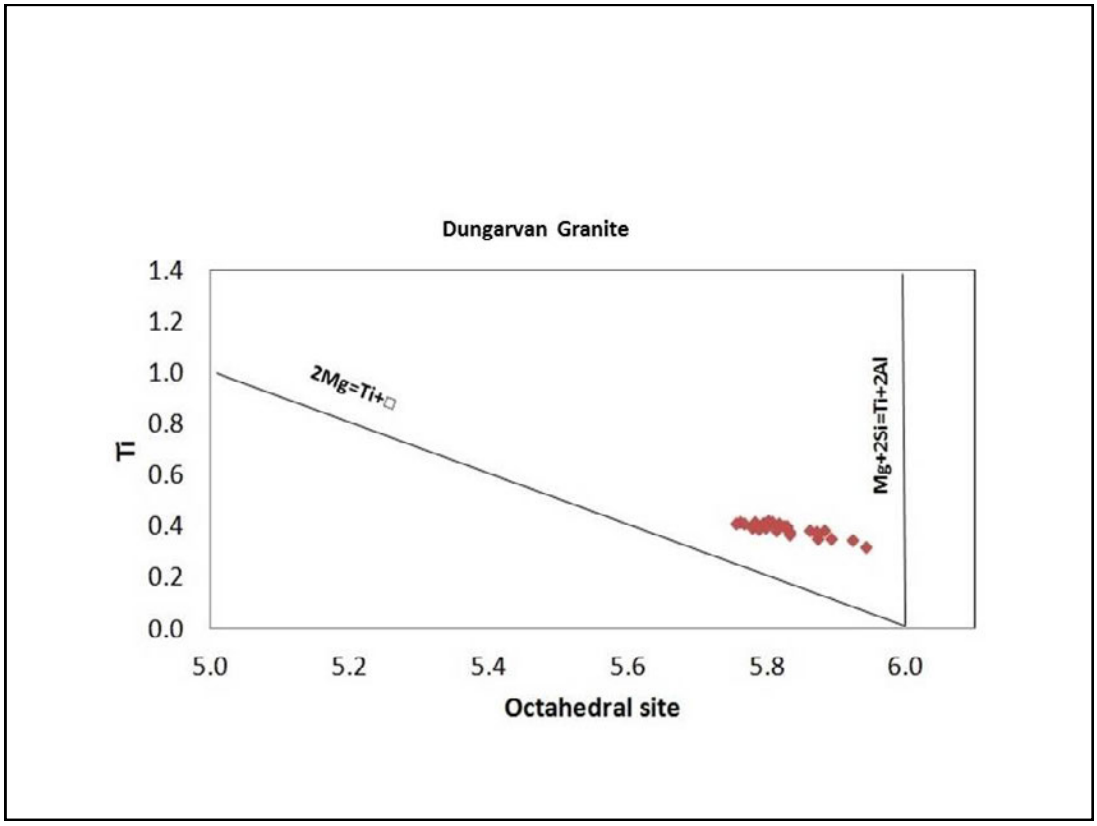

The Most Common Trace Element Zoning
Ba
Ba
Ba
Magaguadavic Granite WX-NB-196
Antinouri Lake Granite WX-NB-52
Dungarvon Granite WX-NB-226
1400
1200
1000
800
600
400
200
0
(ppm)
4000
3000
2000
1000
0
(ppm)
2000
1500
1000
500
0
(ppm)

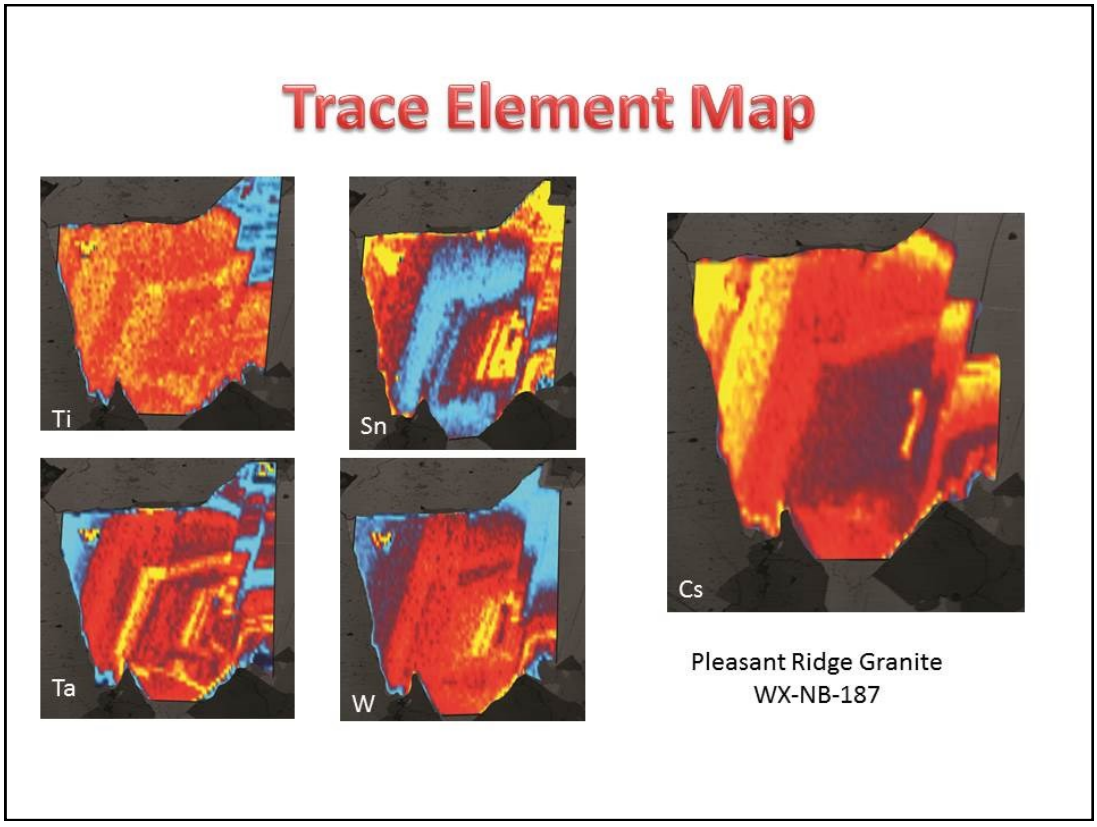
Element Substitution

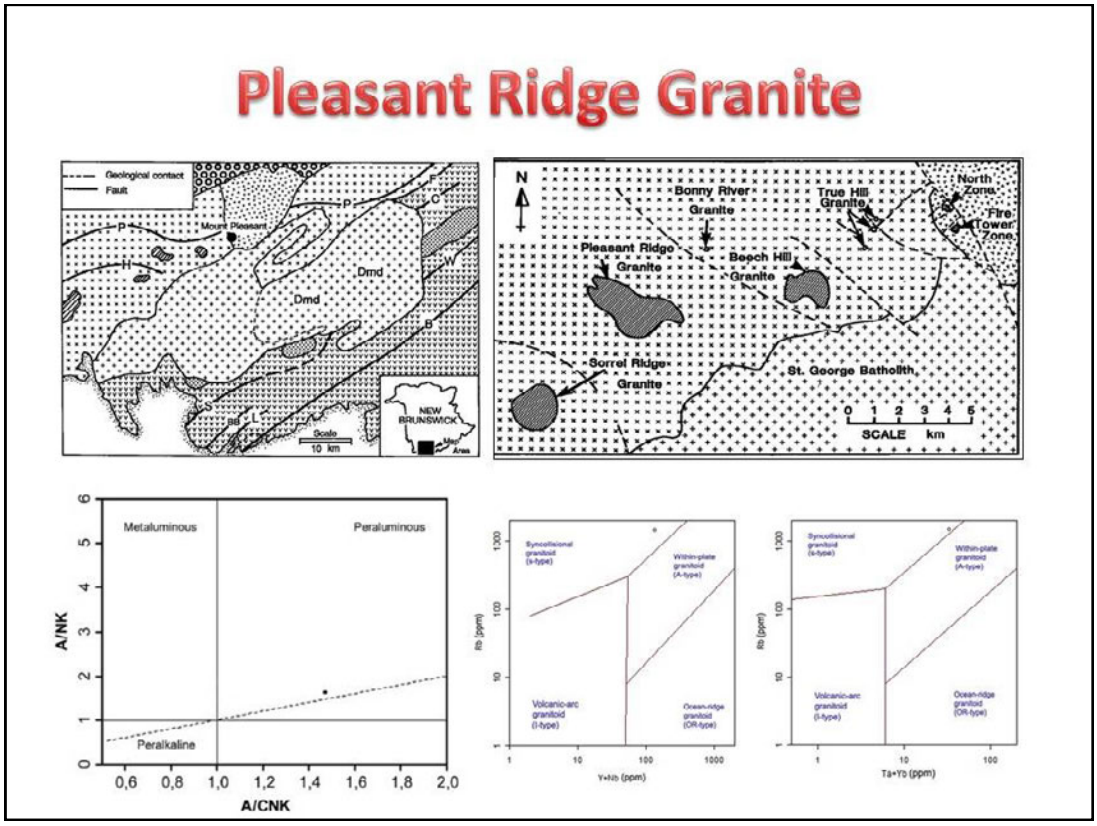
	T site	O site	A site
After calculation	8.00	5.65	1.75
Full site	8.00	6.00	2

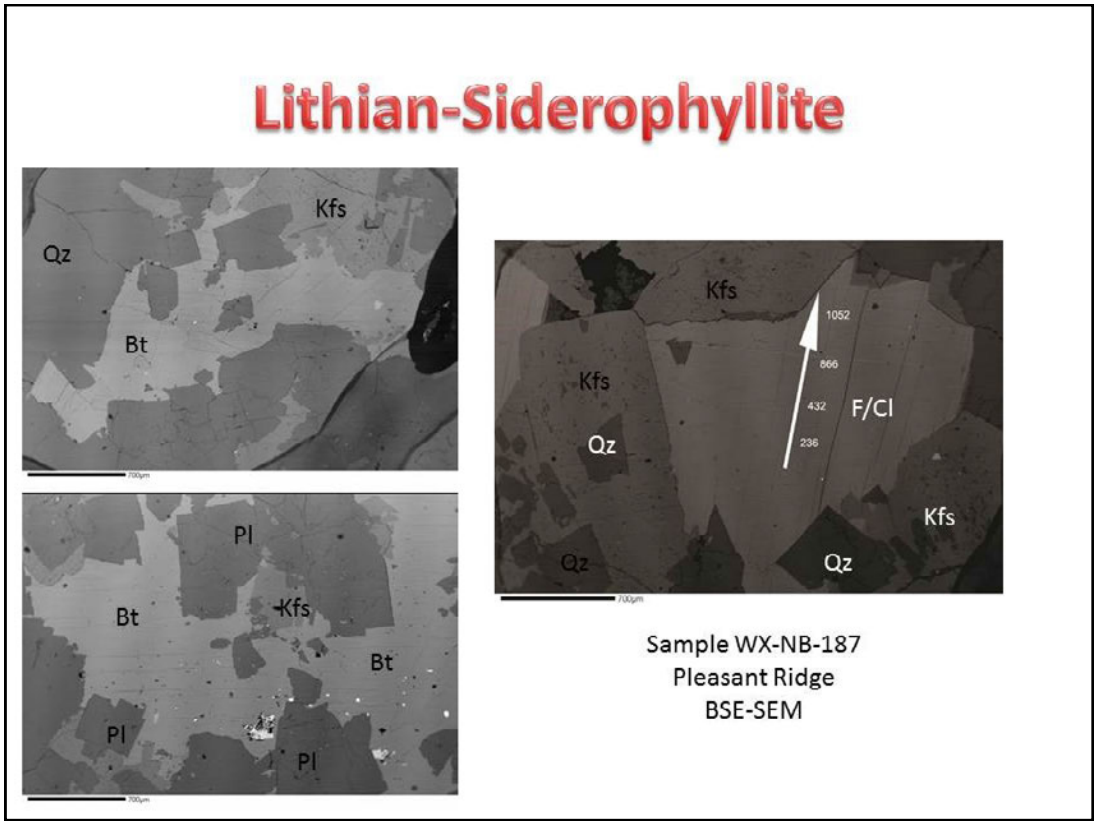


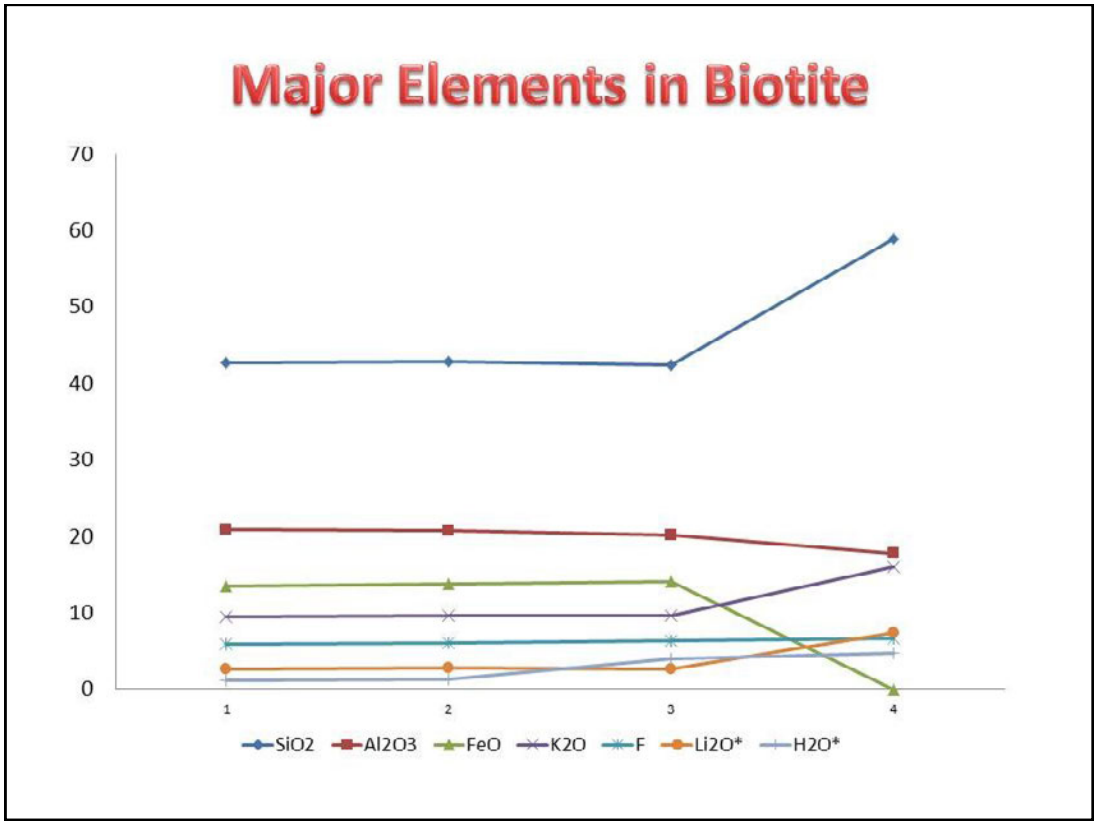


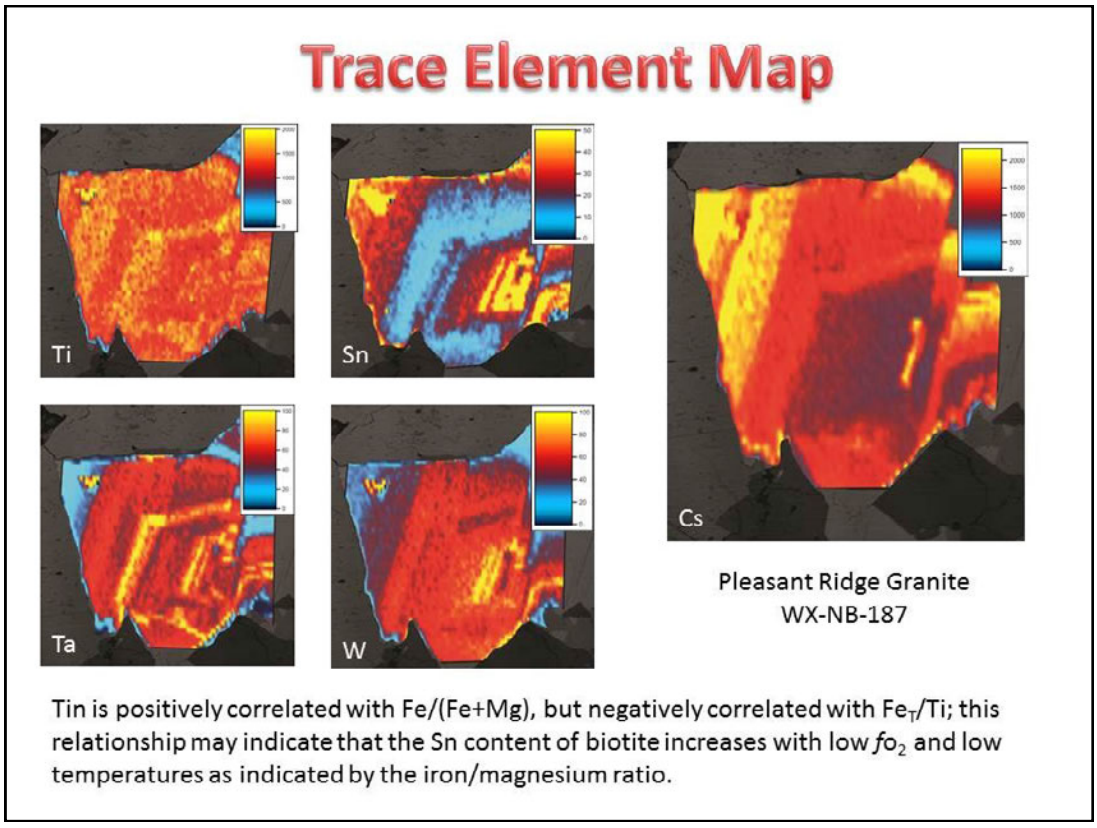

Dungarvan Granite
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Ti
2Mg=Ti+□
Mg+2Si=Ti+2Al
5.0
5.2
5.4
5.6
5.8
6.0
Octahedral site


Trace Element Map
Ti
Sn
Cs
Ta
W
Pleasant Ridge Granite
WX-NB-187


Pleasant Ridge Granite
Geological contact
Fault
Mount Pleasant
Dmd
Scale
10 km
NEW BRUNSWICK
N
Bonny River Granite
True Hill Granite
North Zone
Fire Tower Zone
Pleasant Ridge Granite
Beech Hill Granite
Sorrel Ridge Granite
St. George Batholith
0 1 2 3 4 5
SCALE km
Metaluminous
Peraluminous
Peralkaline
A/NK
A/CNK
0,6 0,8 1,0 1,2 1,4 1,6 1,8 2,0
Syncollisional granitoid (s-type)
Within-plate granitoid (A-type)
Volcanic-arc granitoid (I-type)
Ocean-ridge granitoid (OR-type)
Rb (ppm)
Y+Nb (ppm)
Ta+Yb (ppm)


Lithian-Siderophyllite
Qz
Kfs
Bt
Pl
Kfs
Bt
Bt
Pl
Pl
Kfs
Kfs
Qz
1052
866
432
236
F/Cl
Kfs
Qz
Qz
Sample WX-NB-187
Pleasant Ridge
BSE-SEM


Major Elements in Biotite
70
60
50
40
30
20
10
0
1
2
3
4
SiO2
Al2O3
FeO
K2O
F
Li2O*
H2O*


Trace Element Map
Ti
Sn
Cs
Ta
W
Pleasant Ridge Granite
WX-NB-187
Tin is positively correlated with Fe/(Fe+Mg), but negatively correlated with Fe_T/Ti; this relationship may indicate that the Sn content of biotite increases with low fo_2 and low temperatures as indicated by the iron/magnesium ratio.

Future Studies

- Analyze adjacent K-feldspar with laser and study the equilibrium between them and biotite.
- Further study of the apatite , and analyze this mineral with laser
- Comparing the collected data with the biotite result and future explore the granophile mineralization in New Brunswick.

Is biotite a good mineral to study magmatic evolution history?

- Yes

How close is this project to the goal?

- Pretty close

Conclusion

- Laser-ablation ICPMS map is a perfect way to study changes in mica group minerals.
- Size of the grain, frequency of mineral inclusion, degree of alteration, and the laser spot size required are the limitations of this method.
- Mica group minerals and specifically Lithium biotite are good indictor of magma evolution history.

Acknowledgment

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- Dave Lentz
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