Using biotite composition of the Devonian Mount Elizabeth Intrusive Complex, New Brunswick, as a proxy for magma fertility and differentiation in W-Mo-Au-Sb mineralized magmatic hydrothermal systems

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Abstract: The Early Devonian (418 ± 1 Ma, monazite U-Pb) Mount Elizabeth intrusive complex, New Brunswick, Canada, is a multiphase metaluminous to weakly peraluminous, high K calc-alkaline body that shows within plate affinity. The complex consists of apparently contemporaneous igneous suites including a mafic suite, an eastern peraluminous granite suite and a western alkali granite suite. The eastern part comprises compositionally and texturally homogenous biotite granite, whereas the western part is mostly heterogeneous and contains five different units. The most abundant phase of the western suite is medium- to coarse-grained alkaline equigranular granite. This complex poorly exposed so that most of the available data, including inferred contact relationships, is based on geophysical data. It should be added that no mineral occurrences have been reported so far from this complex.

Fresh biotite from this intrusion was analysed from core to rim by electron microprobe, and laser ablation ICP-MS at the University of New Brunswick to test whether biotite preserves a record of magma evolution in terms of major and trace-element and halogen compositional variations. Subhedral to elongate biotite phenocrysts are less than 700 µm long and reddish brown in colour indicative of a reduced I-type source. A calc-alkaline affinity is also suggested by biotite major element classification schemes. Biotite is locally altered to chlorite along cleavage planes, and typically contain iron oxides, monazite, ilmenite, apatite, xenotime, and zircon as mineral inclusions.

Results of electron microprobe and laser ablation ICP-MS studies indicate that biotite grains are homogenous in major elements; however, they show variation in trace elements from core to rim. The biotite grains investigated have the highest Sn, W, Sb, and Mo concentrations recorded thus far among Devonian-related granitoid intrusions of New Brunswick (130, 40, 1, 3 ppm, respectively). There is no systematic correlation between major elements including Fe_{Tot}, or Fe_{Tot}/Ti and any of these trace elements. To further study trace-element distribution, a biotite from each of the phases was mapped with laser-ablation ICP-MS revealing patchy Ba, Rb, and Cs zoning. These patterns are interpreted to be a result of localized hydrothermal alteration and intracrystalline volume diffusion in these biotite grains. The intracrystalline distribution of Sn, W, Mo and Sb is homogeneous. Furthermore, halogen contents analysed by EPMA indicate that hydroxyl is the dominant component of hydroxyl site followed by fluorine. It also showed that these biotites formed from strongly contaminated and reduced I-type granite.

As a result, high concentration of Sn in biotite is interpreted to be caused by crustal contamination, and low-temperature hydrothermal processes (sub-solidus) rather than being magmatic in origin.

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Zeinab Azadbakht, David Lentz
Christopher McFarlane

UNB

TGI 4 Ore Systems

Outline

Whalen (1993):

- Project goal
- Geological and tectonic setting
- Mount Elizabeth Intrusive Complex
- Whole Rock Geochemistry
- Tectonic Setting
- Isotopic Characteristics of the Gander Granites

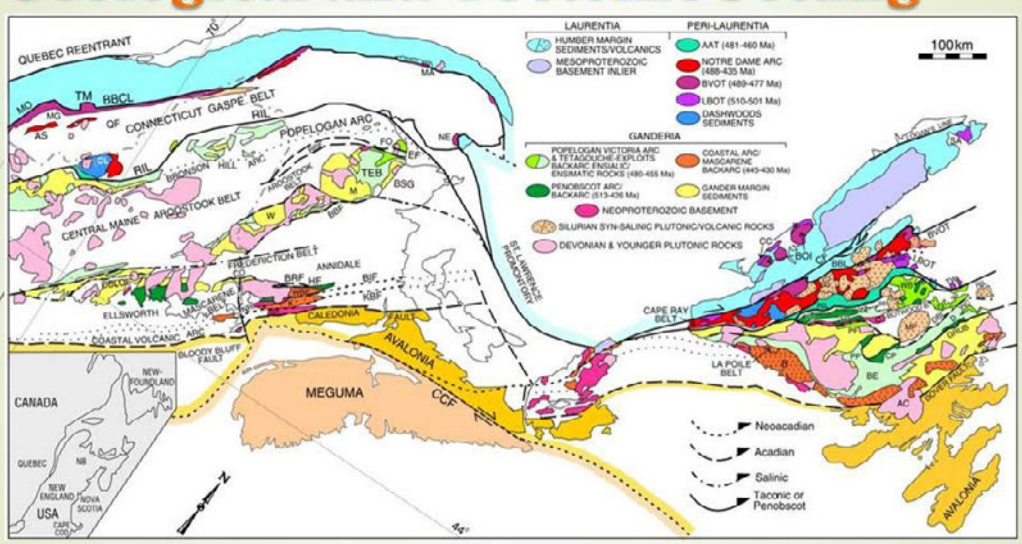
My research:

- Petrography
- Biotite Classification
- Biotite Halogen Study
- Magmatic Hydrothermal Fluid
- Trace Element
- Conclusion

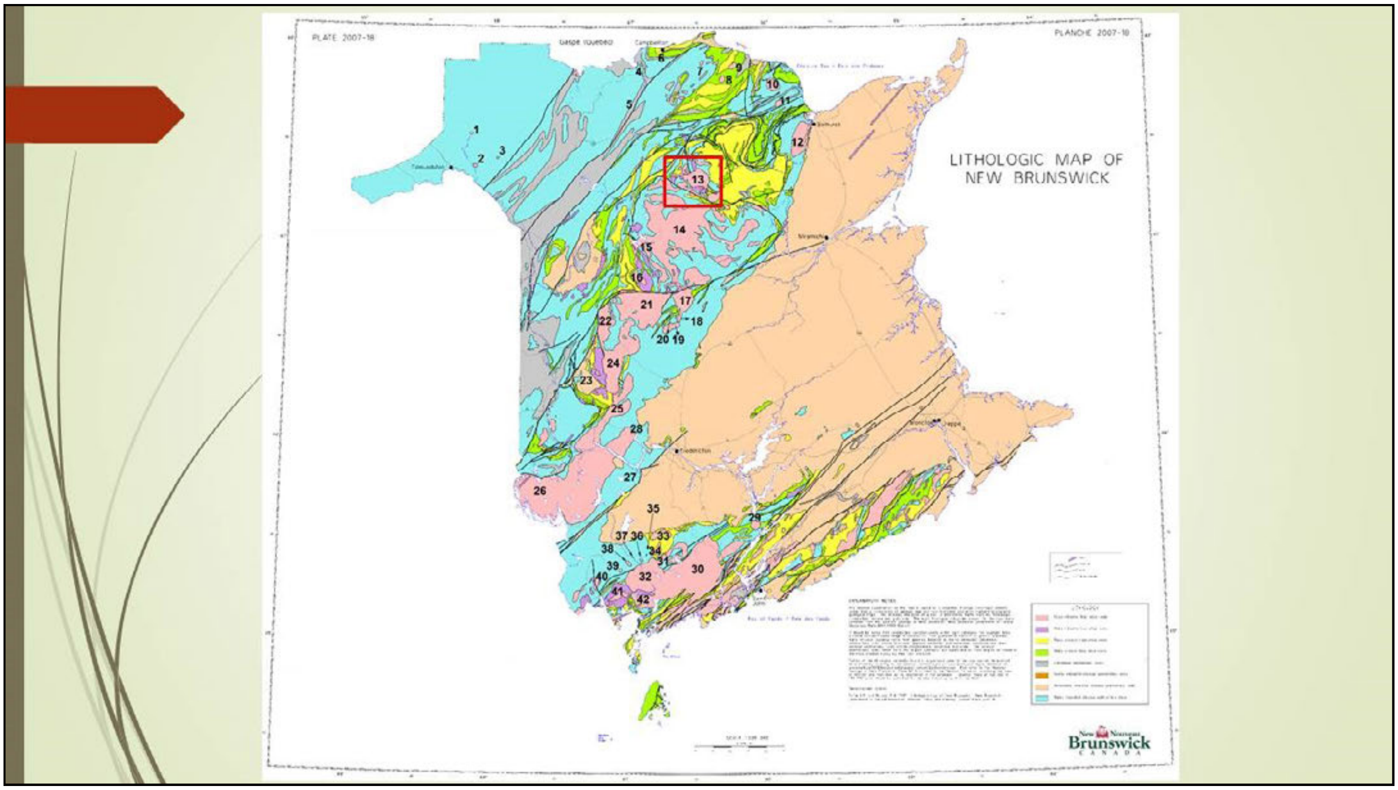
Project Goals

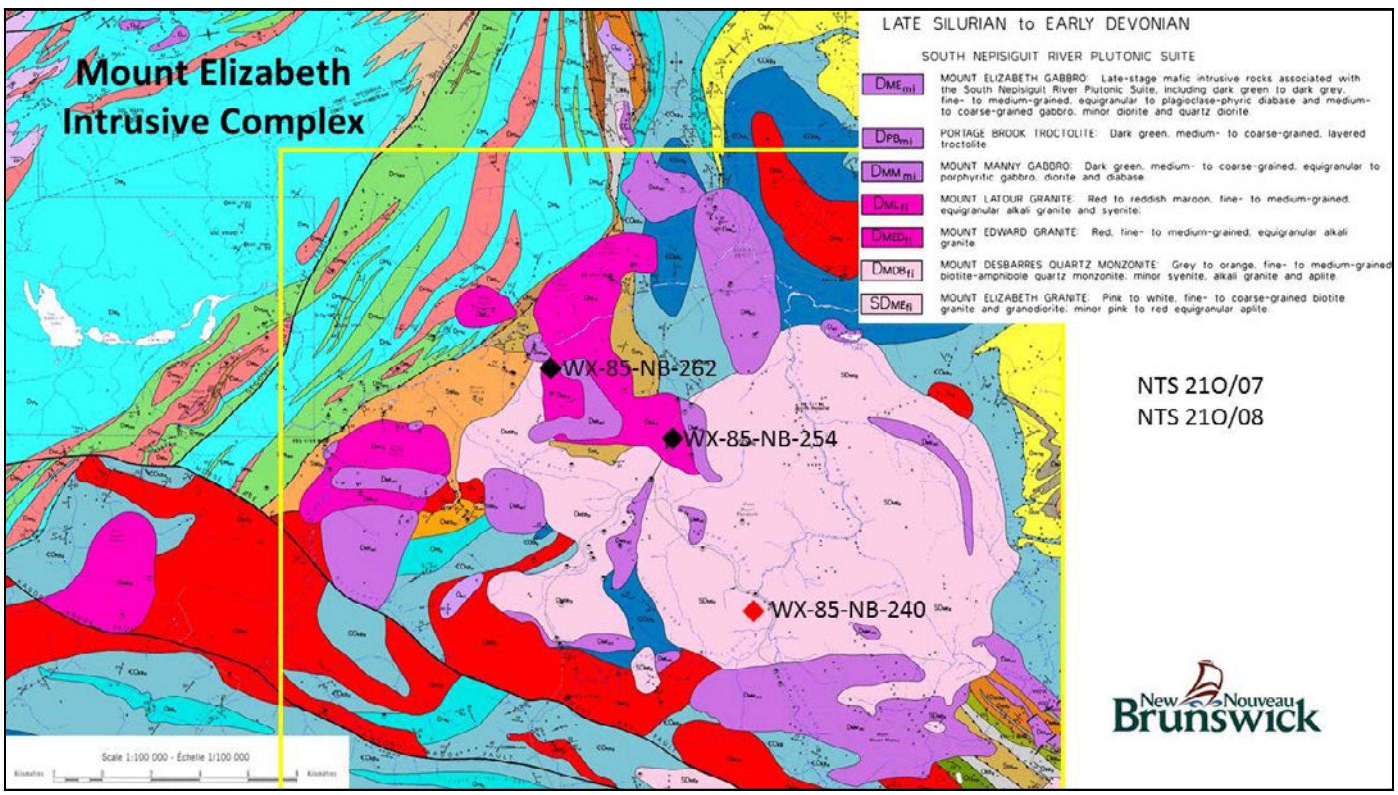
- Document detailed chemistry of coexisting phyllosilicate mineral phases to reveal distinctive element signatures that may be specific to fertile granitoids.
- Provide a geochemical fingerprint for more-specific mineralization styles and prospectivity in the Acadian Plutonic Complex.

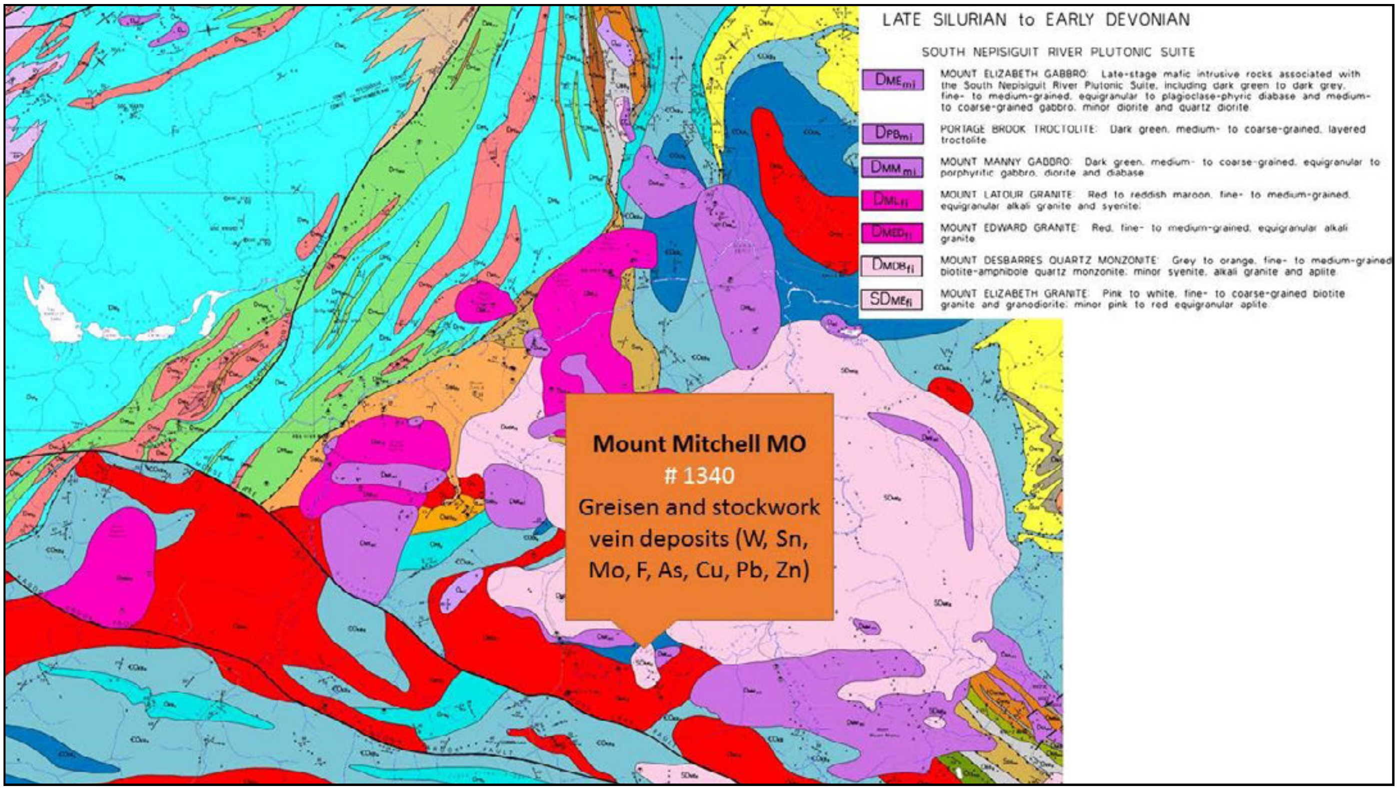
Geological and Tectonic Setting



van Staal et al. (2009)


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


Mount Elizabeth
Intrusive Complex
LATE SILURIAN to EARLY DEVONIAN
SOUTH NEPISIGUIT RIVER PLUTONIC SUITE
DME mi
MOUNT ELIZABETH GABBRO: Late-stage mafic intrusive rocks associated with the South Nepisiguit River Plutonic Suite, including dark green to dark grey, fine- to medium-grained, equigranular to plagioclase-phyric diabase and medium- to coarse-grained gabbro, minor diorite and quartz diorite
DPB mi
PORTAGE BROOK TROCTOLITE: Dark green, medium- to coarse-grained, layered troctolite
DMM mi
MOUNT MANNY GABBRO: Dark green, medium- to coarse-grained, equigranular to porphyritic gabbro, diorite and diabase
DML fi
MOUNT LATOUR GRANITE: Red to reddish maroon, fine- to medium-grained, equigranular alkali granite and syenite;
DMED fi
MOUNT EDWARD GRANITE: Red, fine- to medium-grained, equigranular alkali granite
DMDB fi
MOUNT DESBARRES QUARTZ MONZONITE: Grey to orange, fine- to medium-grained biotite-amphibole quartz monzonite, minor syenite, alkali granite and aplite
SDME fi
MOUNT ELIZABETH GRANITE: Pink to white, fine- to coarse-grained biotite granite and granodiorite; minor pink to red equigranular aplite
WX-85-NB-262
WX-85-NB-254
WX-85-NB-240
NTS 21O/07
NTS 21O/08
Scale 1:100 000 - Échelle 1/100 000


LATE SILURIAN to EARLY DEVONIAN
SOUTH NEPISIGUIT RIVER PLUTONIC SUITE
DMEmi
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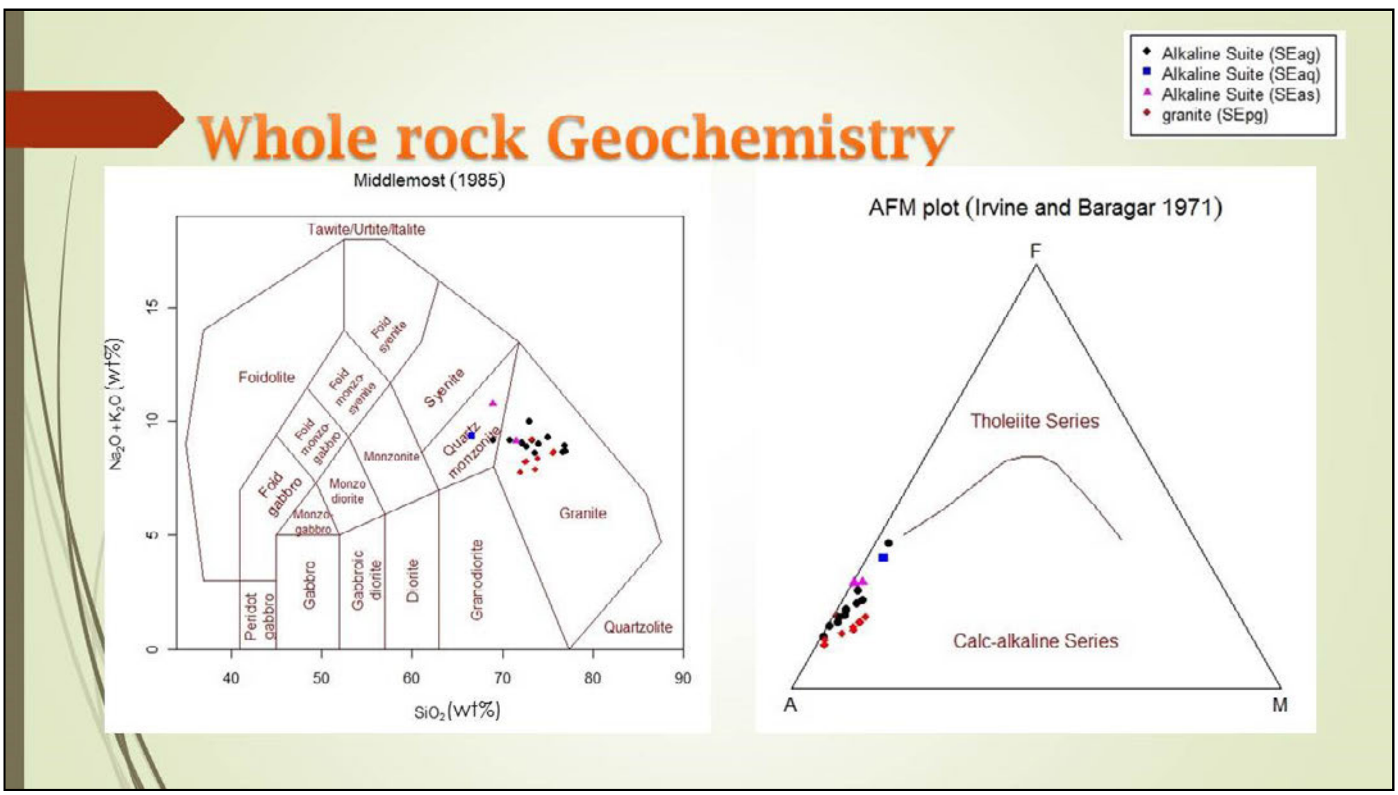
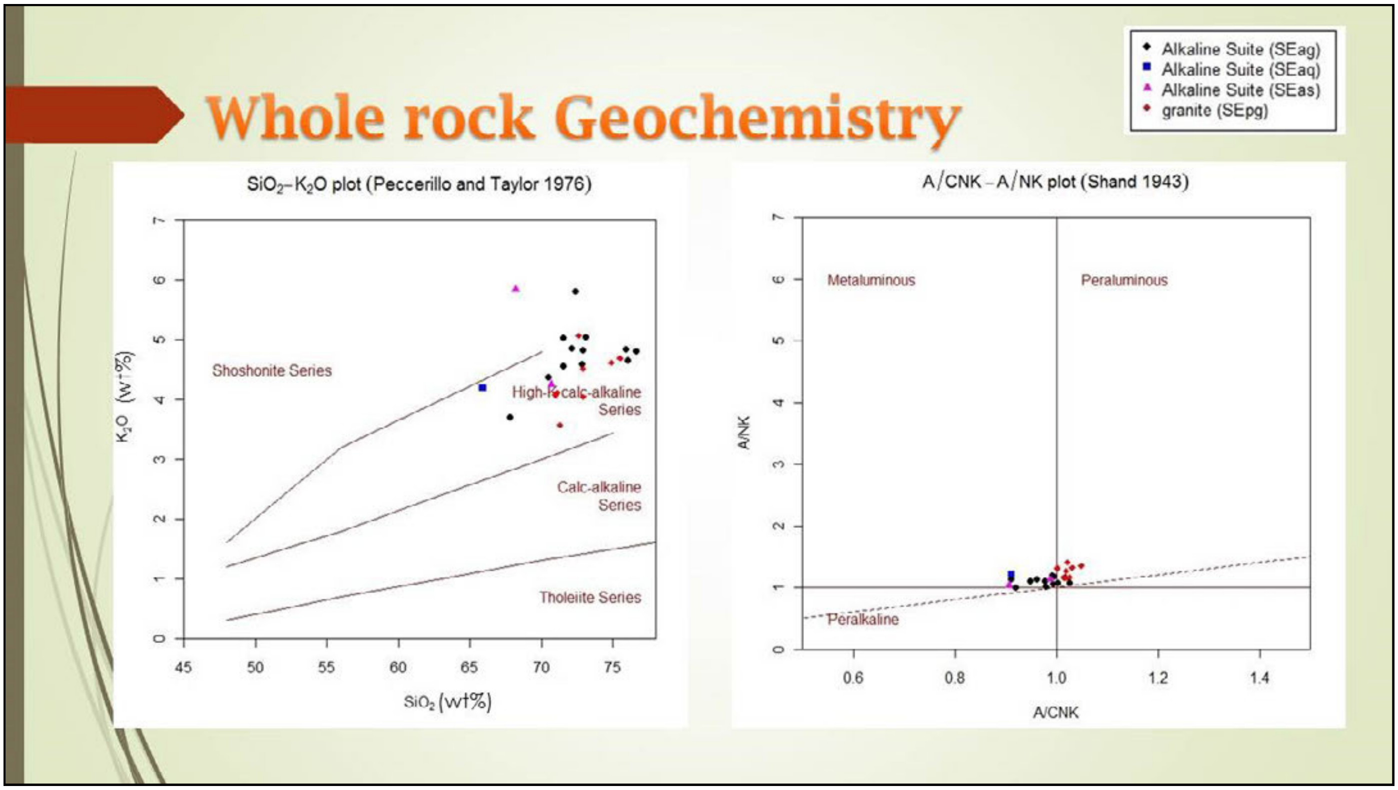
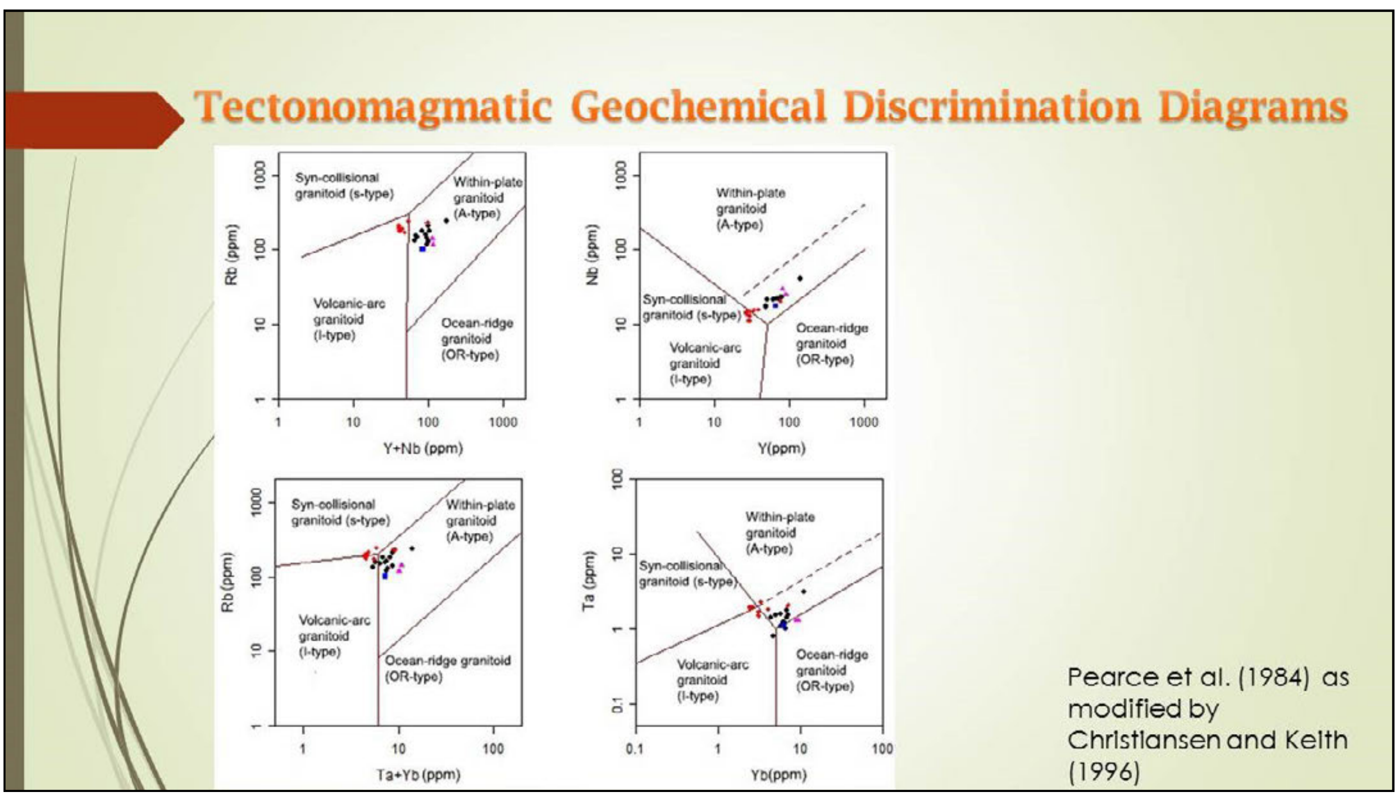
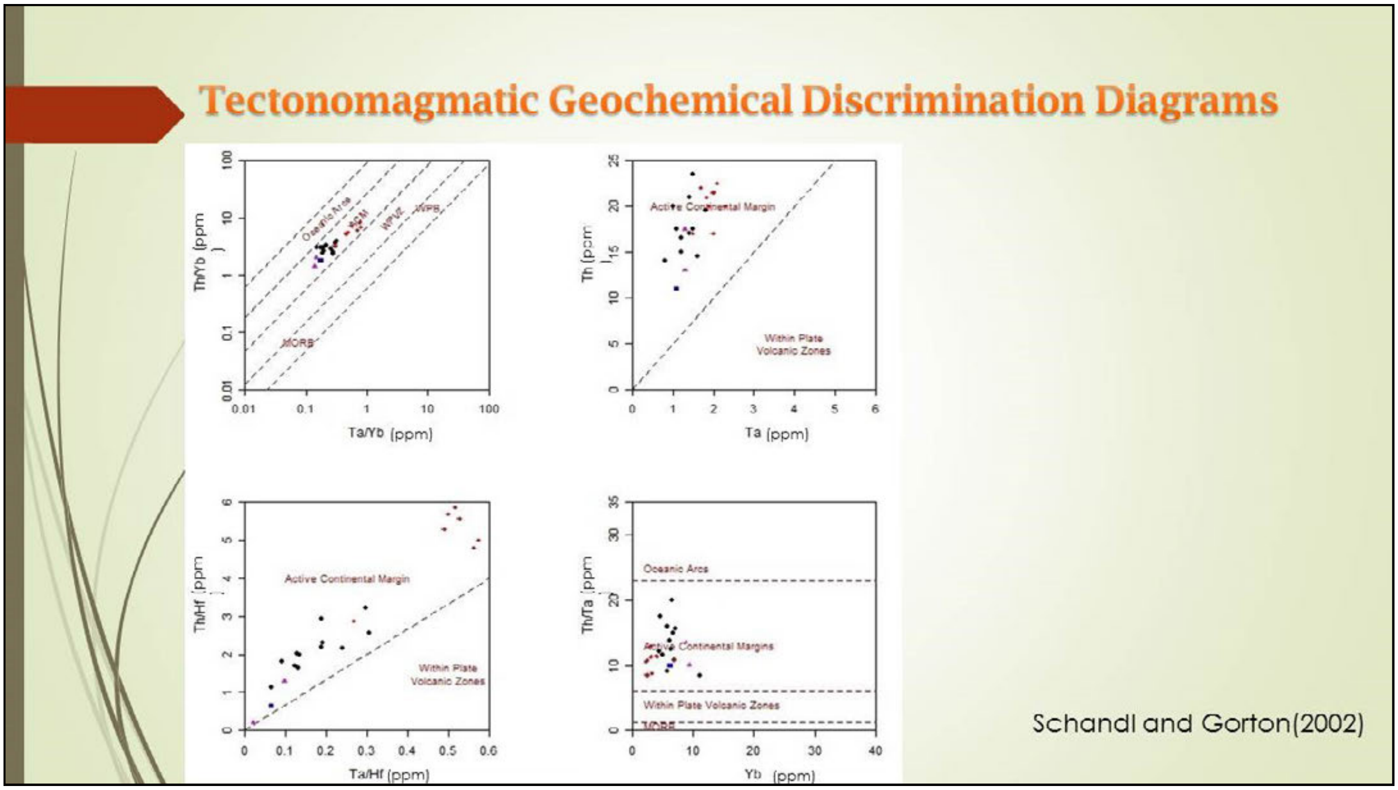
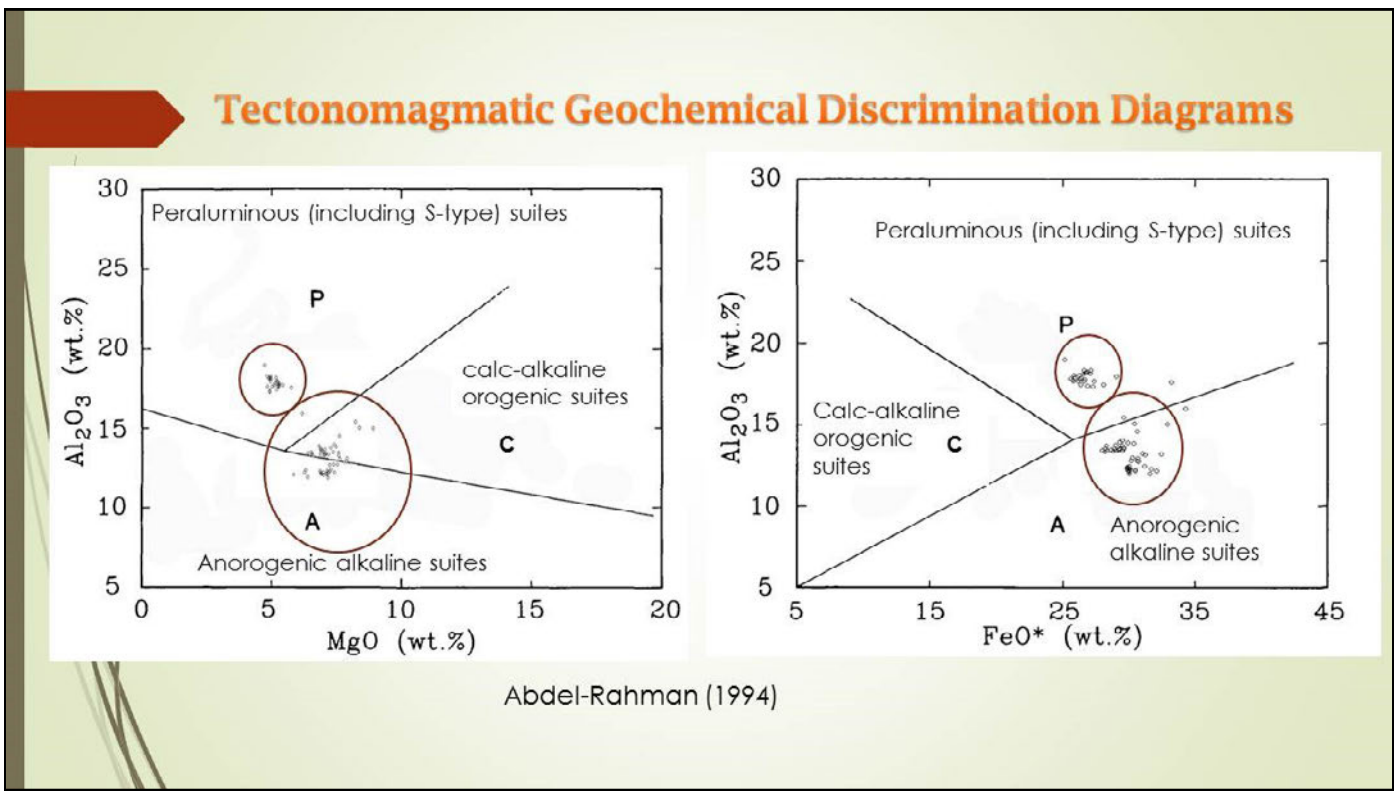
SDMEfi
MOUNT ELIZABETH GRANITE: Pink to white, fine- to coarse-grained biotite granite and granodiorite; minor pink to red equigranular aplite
Mount Mitchell MO
1340
Greisen and stockwork vein deposits (W, Sn, Mo, F, As, Cu, Pb, Zn)

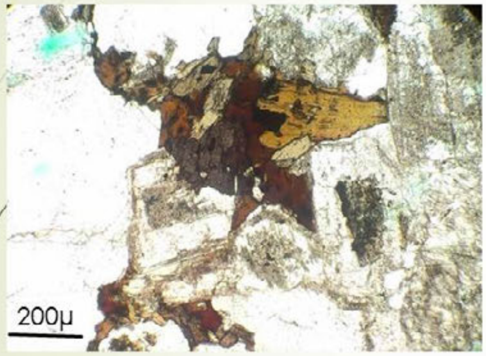

Whole rock Geochemistry
Alkaline Suite (SEag)
Alkaline Suite (SEaq)
Alkaline Suite (SEas)
granite (SEpg)
Middlemost (1985)
Tawite/Urtite/Italite
Foidolite
Foid syenite
Foid monzo-syenite
Foid monzo-gabbro
Foid gabbro
Syenite
Quartz monzonite
Monzonite
Monzo diorite
Monzo-gabbro
Peridot gabbro
Gabbro
Gabbroic diorite
Diorite
Granodiorite
Granite
Quartzolite
Na2O+K2O (wt%)
SiO2 (wt%)
0
5
10
15
40
50
60
70
80
90
AFM plot (Irvine and Baragar 1971)
F
Tholeiite Series
Calc-alkaline Series
A
M

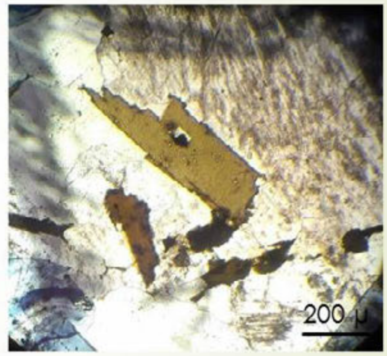

Whole rock Geochemistry
Alkaline Suite (SEag)
Alkaline Suite (SEaq)
Alkaline Suite (SEas)
granite (SEpg)
SiO2–K2O plot (Peccerillo and Taylor 1976)
Shoshonite Series
High-K calc-alkaline Series
Calc-alkaline Series
Tholeiite Series
K2O (wt%)
SiO2 (wt%)
A/CNK – A/NK plot (Shand 1943)
Metaluminous
Peraluminous
Peralkaline
A/NK
A/CNK


Tectonomagmatic Geochemical Discrimination Diagrams
Syn-collisional granitoid (s-type)
Within-plate granitoid (A-type)
Volcanic-arc granitoid (I-type)
Ocean-ridge granitoid (OR-type)
Rb (ppm)
Y+Nb (ppm)
Nb (ppm)
Y(ppm)
Ta+Yb (ppm)
Ta (ppm)
Yb(ppm)
Pearce et al. (1984) as modified by Christiansen and Keith (1996)


Tectonomagmatic Geochemical Discrimination Diagrams
Th/Yb (ppm)
Ta/Yb (ppm)
Oceanic Arcs
ACM
WPVZ
WPB
MORB
Th (ppm)
Ta (ppm)
Active Continental Margin
Within Plate Volcanic Zones
Th/Hf (ppm)
Ta/Hf (ppm)
Active Continental Margin
Within Plate Volcanic Zones
Th/Ta (ppm)
Yb (ppm)
Oceanic Arcs
Active Continental Margins
Within Plate Volcanic Zones
MORB
Schandl and Gorton(2002)


Tectonomagmatic Geochemical Discrimination Diagrams
Peraluminous (including S-type) suites
P
calc-alkaline orogenic suites
C
A
Anorogenic alkaline suites
Al_2O_3 (wt.%)
MgO (wt.%)
Peraluminous (including S-type) suites
Calc-alkaline orogenic suites
C
P
A
Anorogenic alkaline suites
FeO* (wt.%)
Abdel-Rahman (1994)





Lalonde and Bernard (1993)

Isotopic Characteristics of the Gander Granites

Zone	Al/(Na+K+Ca)	ε_{Nd}	ε_{Nd} (0.4 Ga)	T_{DM} (Ga)	$\delta^{18}O$	$^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$
Ordovician	1.02±0.06 (0.89/1.15)	-2.3±1.7 (-5.4/0.1)	-2.8±1.8 (-6.1/-0.2)	1.5±0.2 (1.1/1.7)	9.0±0.7 (8.2/10.1)	18.543±0.137 (18.353/18.770)	15.692±0.010 (15.675/15.709)	38.429±0.144 (38.232/38.707)
Silurian-Devonian	1.03±0.07 (0.85/1.17)	-1.09±1.0 (-4.2/-0.3)	-2.0±1.1 (-4.4/-0.4)	1.4±0.1 (1.1/1.7)	8.6±1.1 (5.6/10.4)	18.391±0.105 (18.276/18.708)	15.667±0.021 (15.628/15.702)	38.284±0.077 (38.089/38.420)

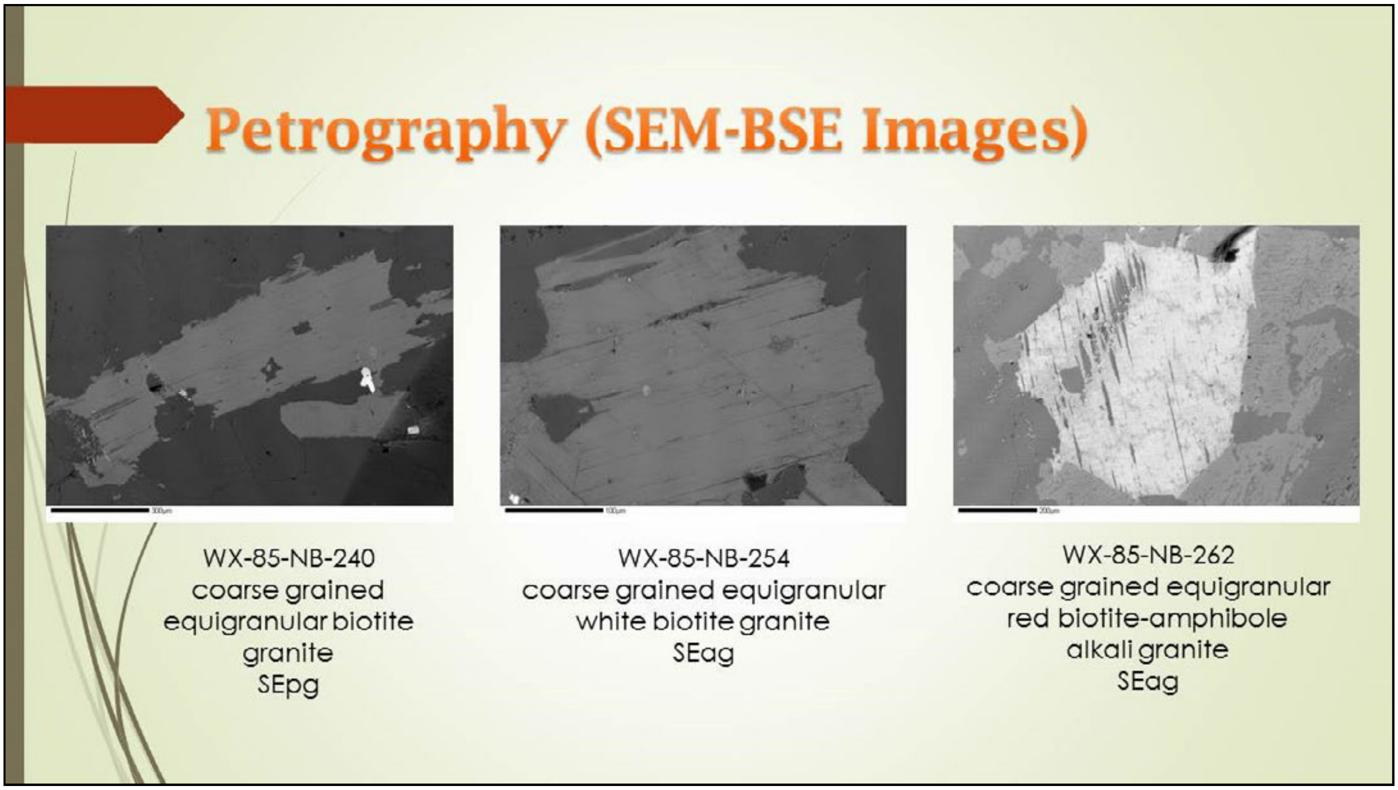
Old Continental crust or enriched mantle

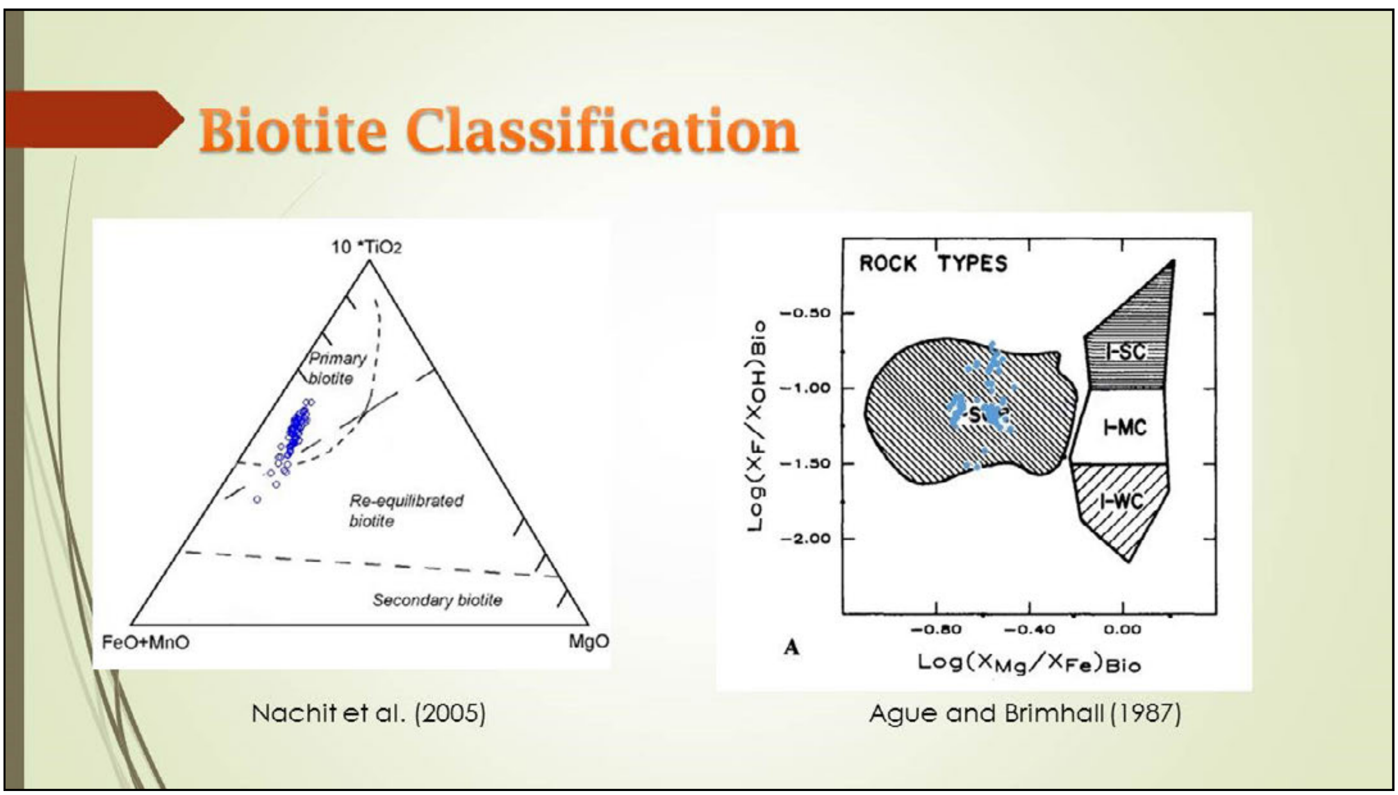
Supracrustal Source

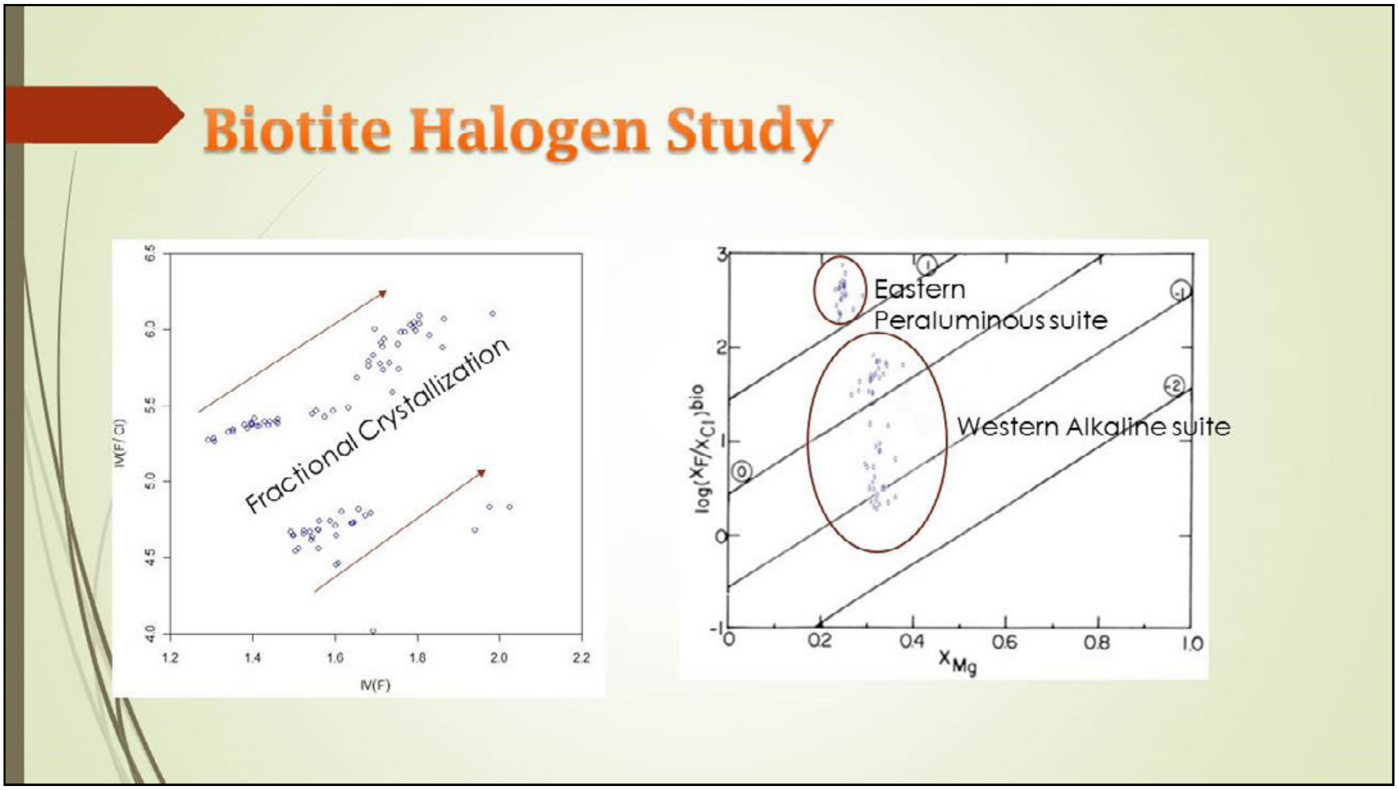
U-Pb monazite age of 418±1 Ma Eastern Peraluminous suite

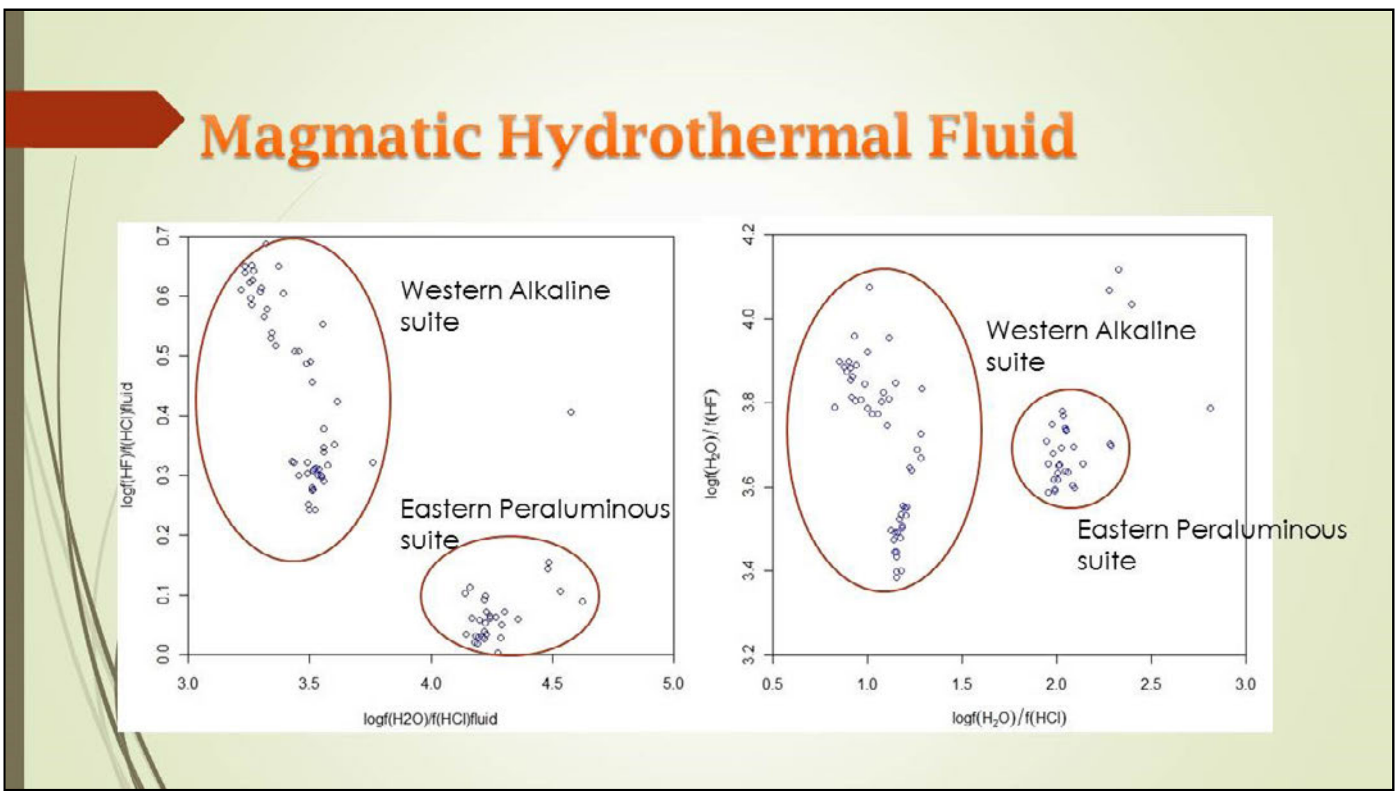
Negative ε_{Nd} (0.4 Ga) values indicates reworking of the same, significantly older (range in depleted mantle model ages, T_{DM}= 1.1-1.7 Ga), crustal protolith during a number of different partial melting events (Whalen 1993)

The isotopic data indicates that Gander zone granites were generated from older (1.5± 0.5 Ga) crustal source which included a major supracrustal component (Whalen 1993)


Petrography (SEM-BSE Images)
WX-85-NB-240
coarse grained
equigranular biotite
granite
SEpg
WX-85-NB-254
coarse grained equigranular
white biotite granite
SEag
WX-85-NB-262
coarse grained equigranular
red biotite-amphibole
alkali granite
SEag


Biotite Classification
10 *TiO2
Primary
biotite
Re-equilibrated
biotite
Secondary biotite
FeO+MnO
MgO
Nachit et al. (2005)
ROCK TYPES
I-SC
I-MC
I-WC
S
−0.50
−1.00
−1.50
−2.00
Log(XF/XOH)Bio
−0.80
−0.40
0.00
Log(XMg/XFe)Bio
A
Ague and Brimhall (1987)


Biotite Halogen Study
Fractional Crystallization
IV(F/Cl)
IV(F)
6.5
6.0
5.5
5.0
4.5
4.0
1.2
1.4
1.6
1.8
2.0
2.2
Eastern
Peraluminous suite
Western Alkaline suite
log(XF/XCl)bio
XMg
3
2
1
0
-1
0.2
0.4
0.6
0.8
1.0


Magmatic Hydrothermal Fluid
Western Alkaline
suite
Eastern Peraluminous
suite
logf(HF)/f(HCl)fluid
logf(H2O)/f(HCl)fluid
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
3.0
3.5
4.0
4.5
5.0
Western Alkaline
suite
Eastern Peraluminous
suite
logf(H2O)/f(HF)
logf(H2O)/f(HCl)
4.2
4.0
3.8
3.6
3.4
3.2
0.5
1.0
1.5
2.0
2.5
3.0

Trace Elements

Sample #	Suite	Mo (ppm)	Sn (ppm)	Sb (ppm)	W (ppm)
WX-85-NB-240	SEpg	2±1	130±10	0.3±0.1	9±2
WX-85-NB-254	SEag	2±1	8±2	1±0.5	2±1
WX-85-NB-262	SEag	2±1	24±5	0.5±0.1	10±2

Conclusion

- Mount Elizabeth Intrusive Complex seems to be fractionally crystalized
- It seems that different suites have been equilibrated with a different hydrothermal fluid (at least two different hydrothermal fluid
- Proof of concept that mica chemistry may aid in identification of fertile Acadian magma systems
- Systematic sampling
- U/Pb Zircon dating of different phases to study the time relationship between them
- Detail mapping of the area
- Geophysical survey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Jim Walker