Lithogeochemistry Constraints on Assimilation and Fractional Crystallization Processes in the South Mountain Batholith, Nova Scotia

Michael Whitbread, *ioGeochemistry, Brisbane, Queensland, Australia, mike.whitbread@ioglobal.net*

and:

Cliff Stanley, *Dept. of Geology, Acadia University, Wolfville, Nova Scotia, B4P 2R6, cliff.stanley@acadiau.ca*

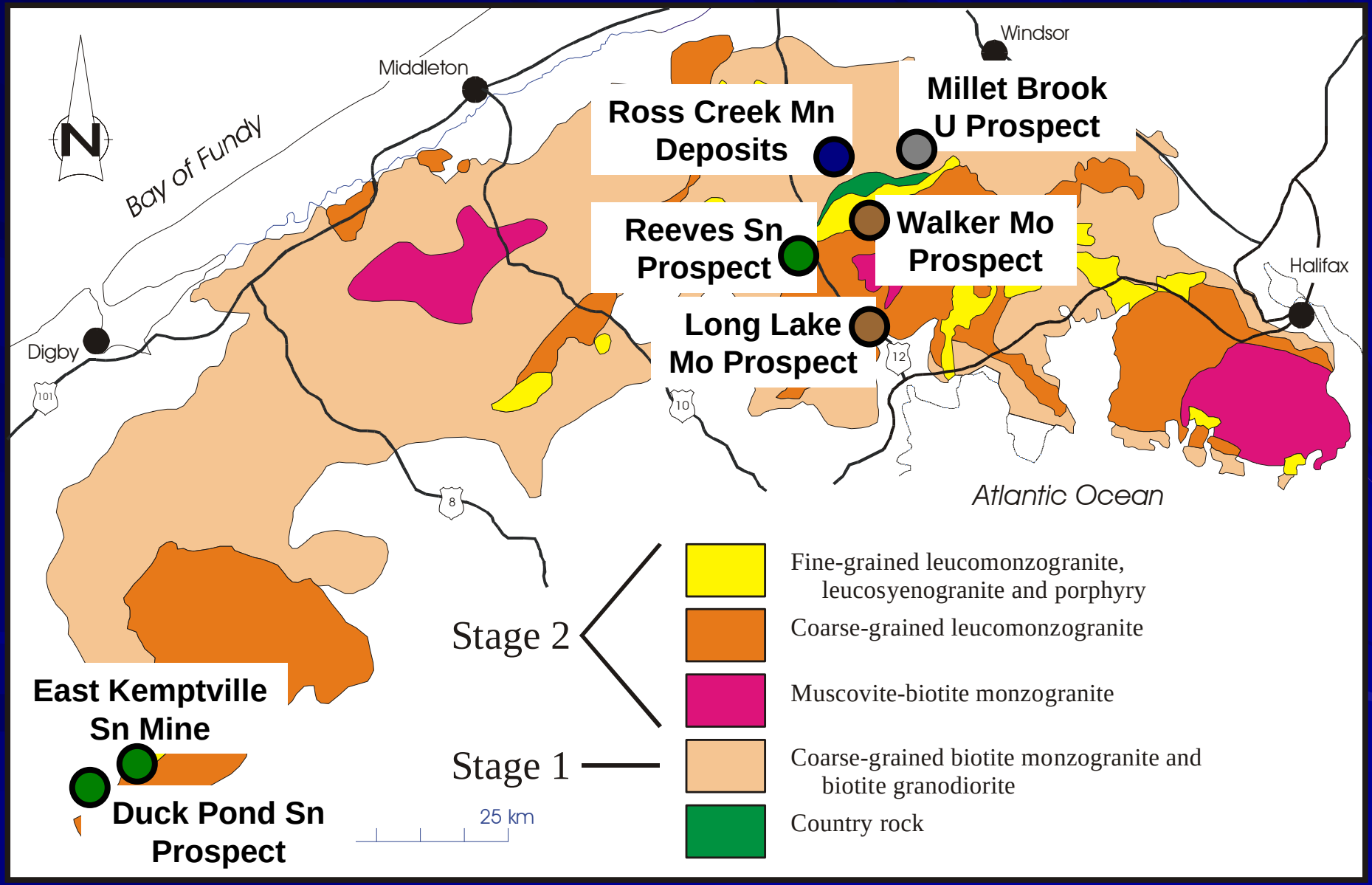
South Mountain Batholith, Nova Scotia

- largest peraluminous (*S-type, ilmenite series*) granitoid in the Appalachian orogen
- Devonian age, ~380 Ma
- megacrystic, porphyritic
- emplacement occurred in two stages
  - Stage 1: mafic porphyry, granodiorite & BT monzogranite
  - Stage 2: MS-BT monzogranite, leucomonzogranite & MS leucosyenogranite
- major minerals

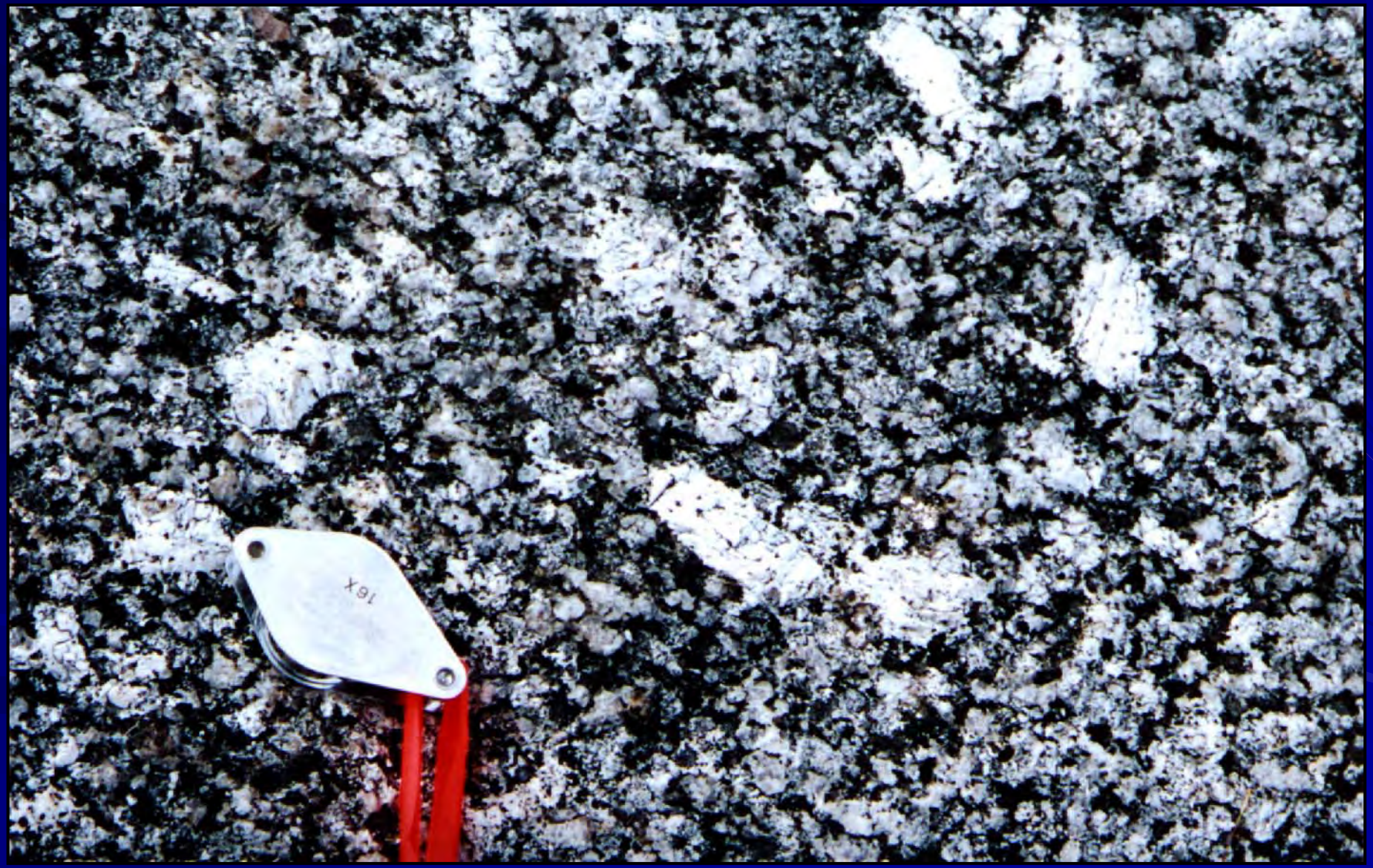
  quartz, plagioclase, alkali feldspar, biotite, muscovite
- accessory minerals

  aluminosilicate, cordierite, garnet, tourmaline, topaz
- *host to significant Sn, Mo, U & Mn mineralization!*

South Mountain Batholith, Nova Scotia



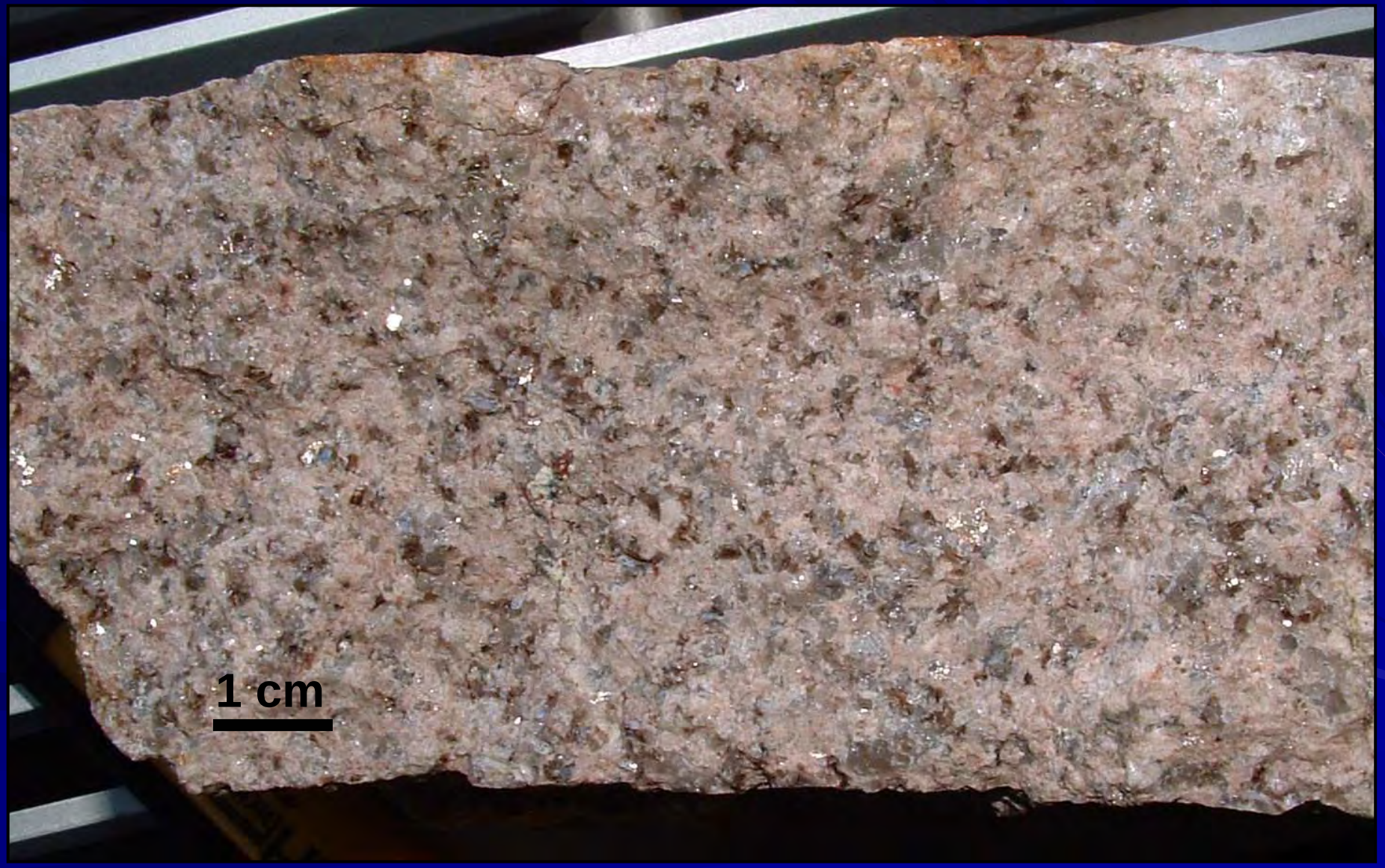
Coarse Grained, Porphyritic Stage 1 Gaspereau Lake BT Granodiorite



Medium Grained, Equigranular Stage 2 Murphy Lake Leucosyenogranite Dyke

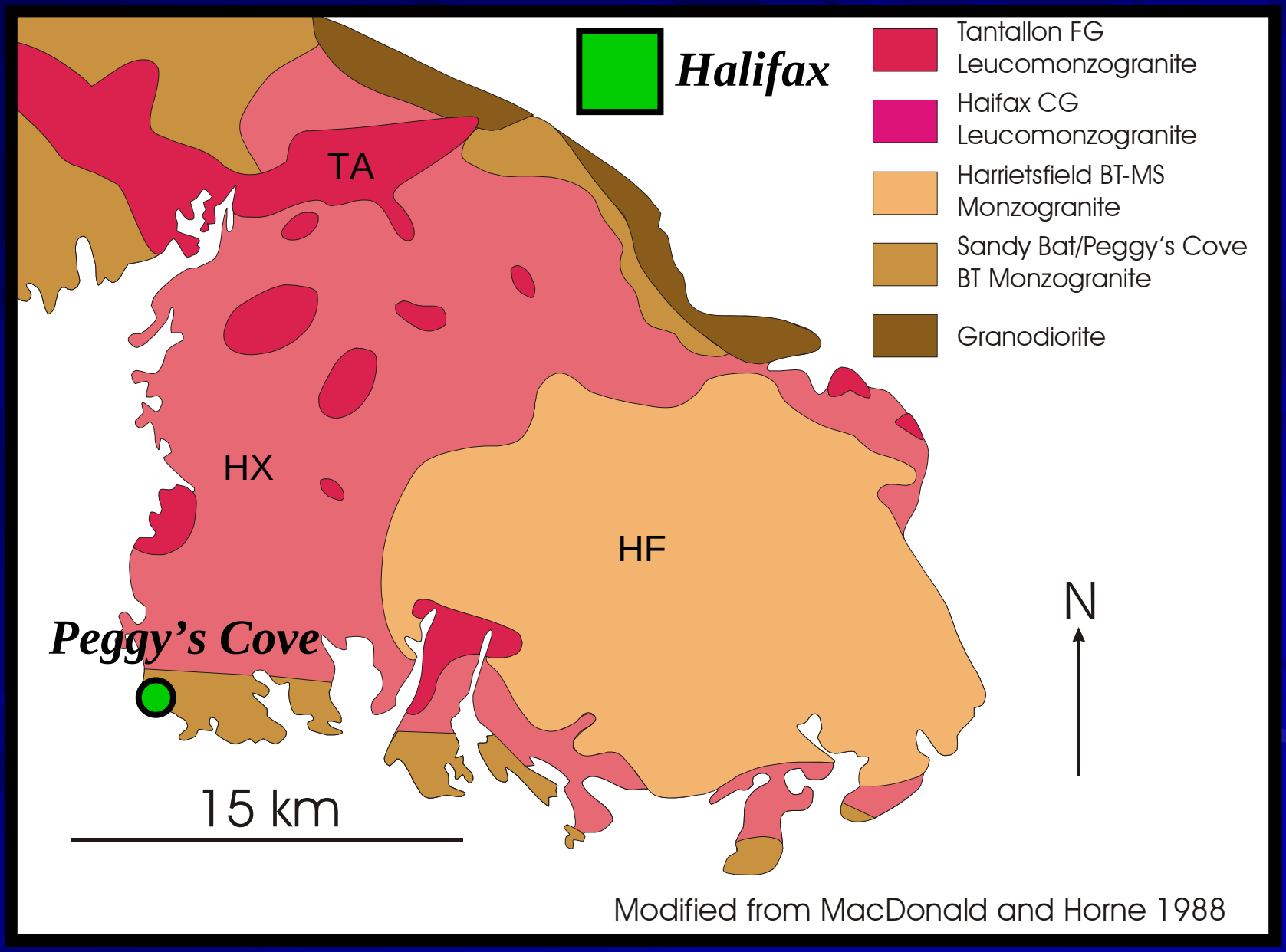
(intruding Stage 1 Gaspereau Lake BT granodiorite)

Fine Grained, Equigranular Stage 2 Lake Lewis MS Leucosyenogranite



Fine Grained, Equigranular Stage 2 Tantallon Leucomonzogranite

Halifax Pluton



Xenolith-Rich Portion of the South Mountain Batholith

Photo courtesy of Mike MacDonald, NSDNR

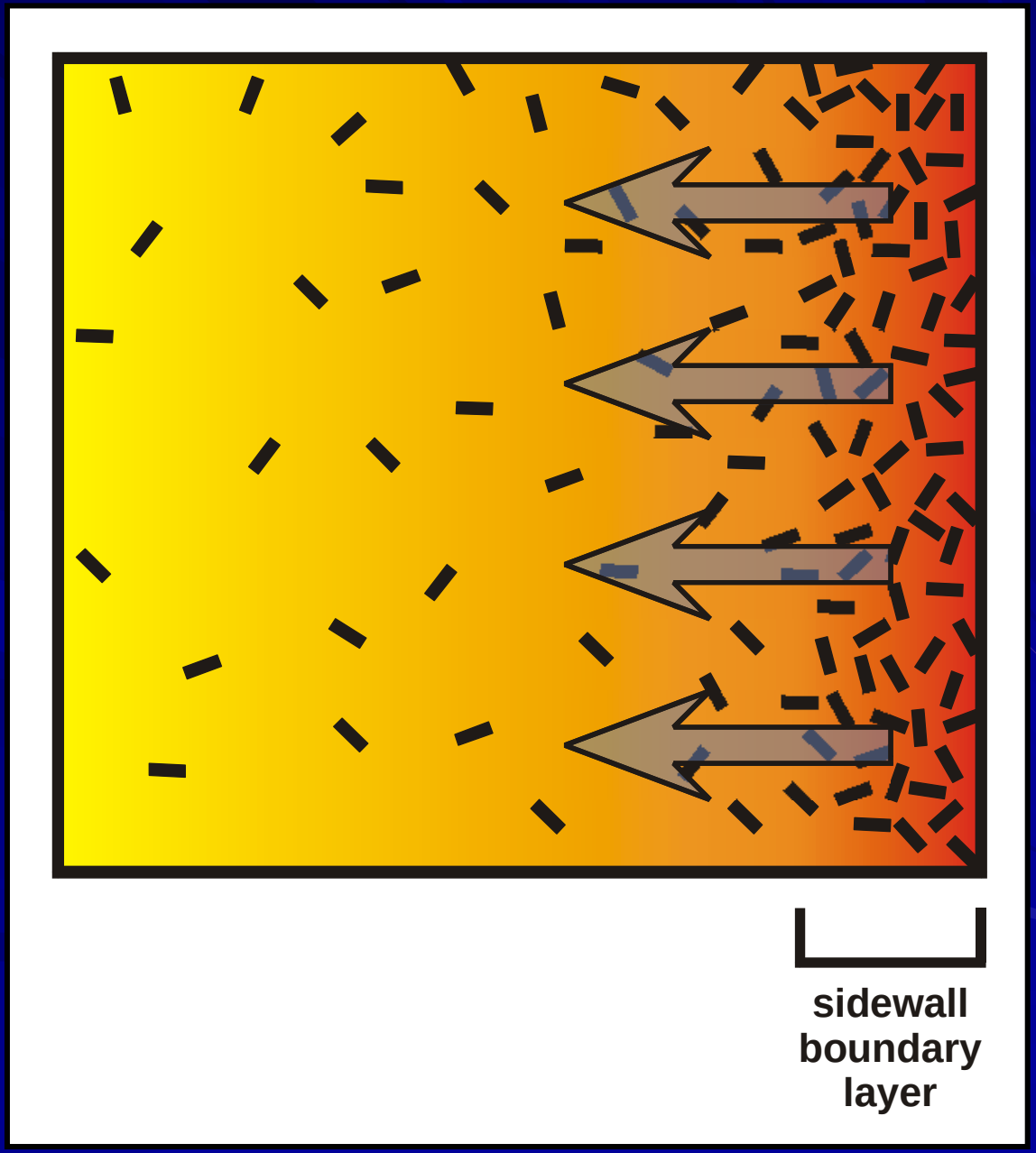
How did the various melts in the South Mountain Batholith become evolved?

AFC Processes

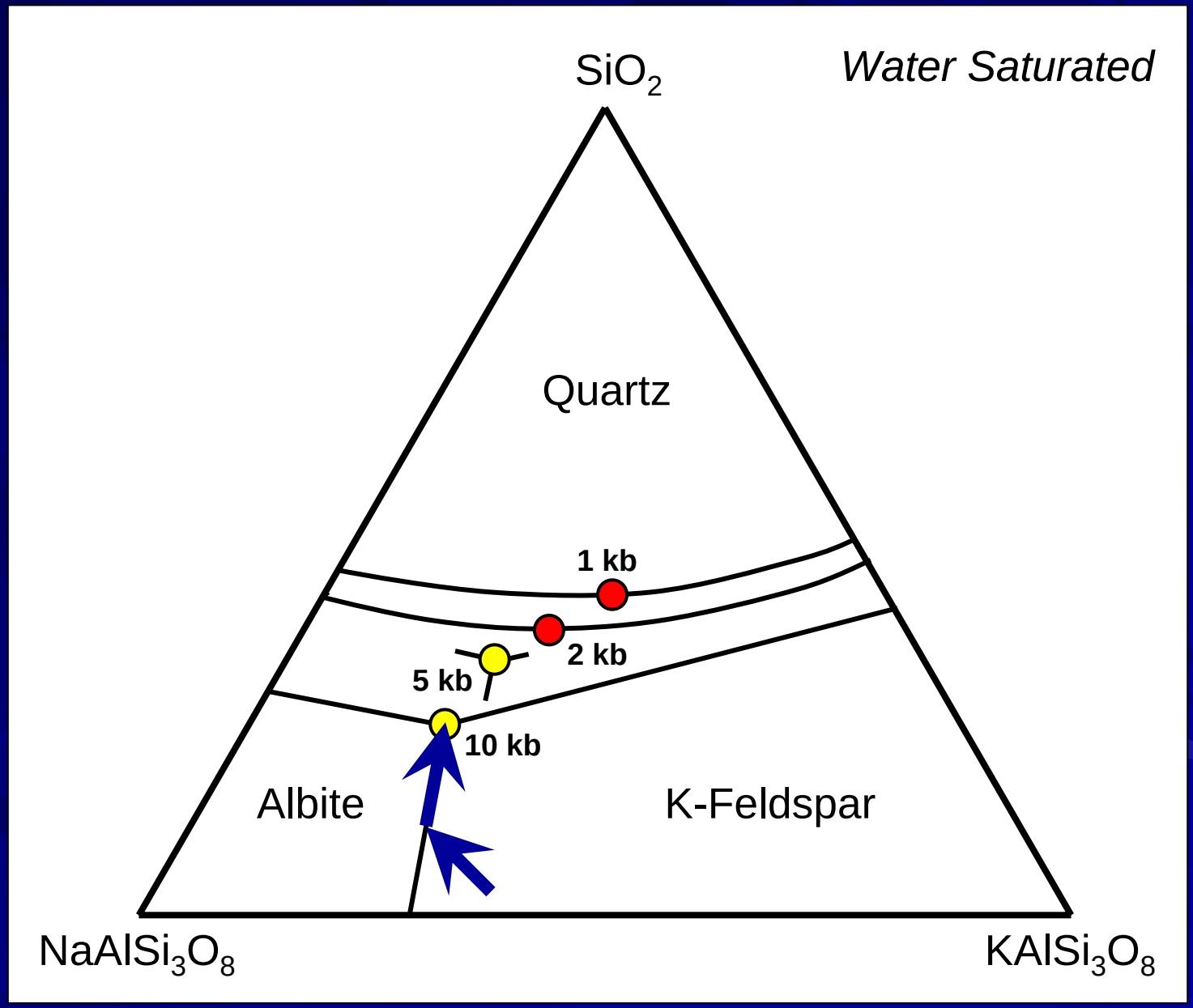
(assimilation & fractional crystallization)

Sidewall Boundary Layer Differentiation

- Crystallization takes place at cool intrusion margin
- Evolved residual melt forms between the crystals at this margin
- Residual melt migrates into centre of magma chamber, mixing with less evolved melt, making the mixed melt more evolved
- Additional crystallization leads to an even more evolved, mixed melt in the centre of the magma chamber
- Process continues …
- Magma chamber becomes concentrically zoned

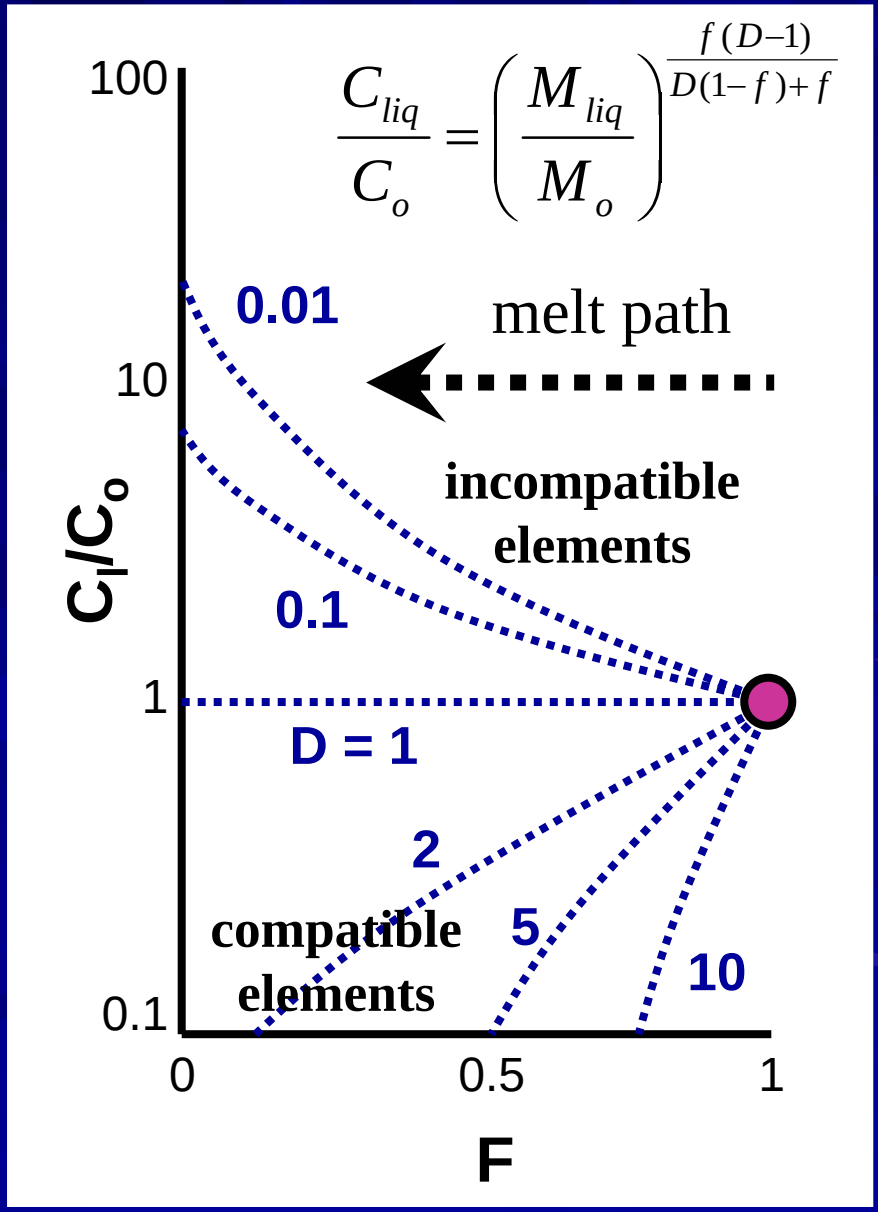


Residual Melt Composition



Fractionation During Crystallization

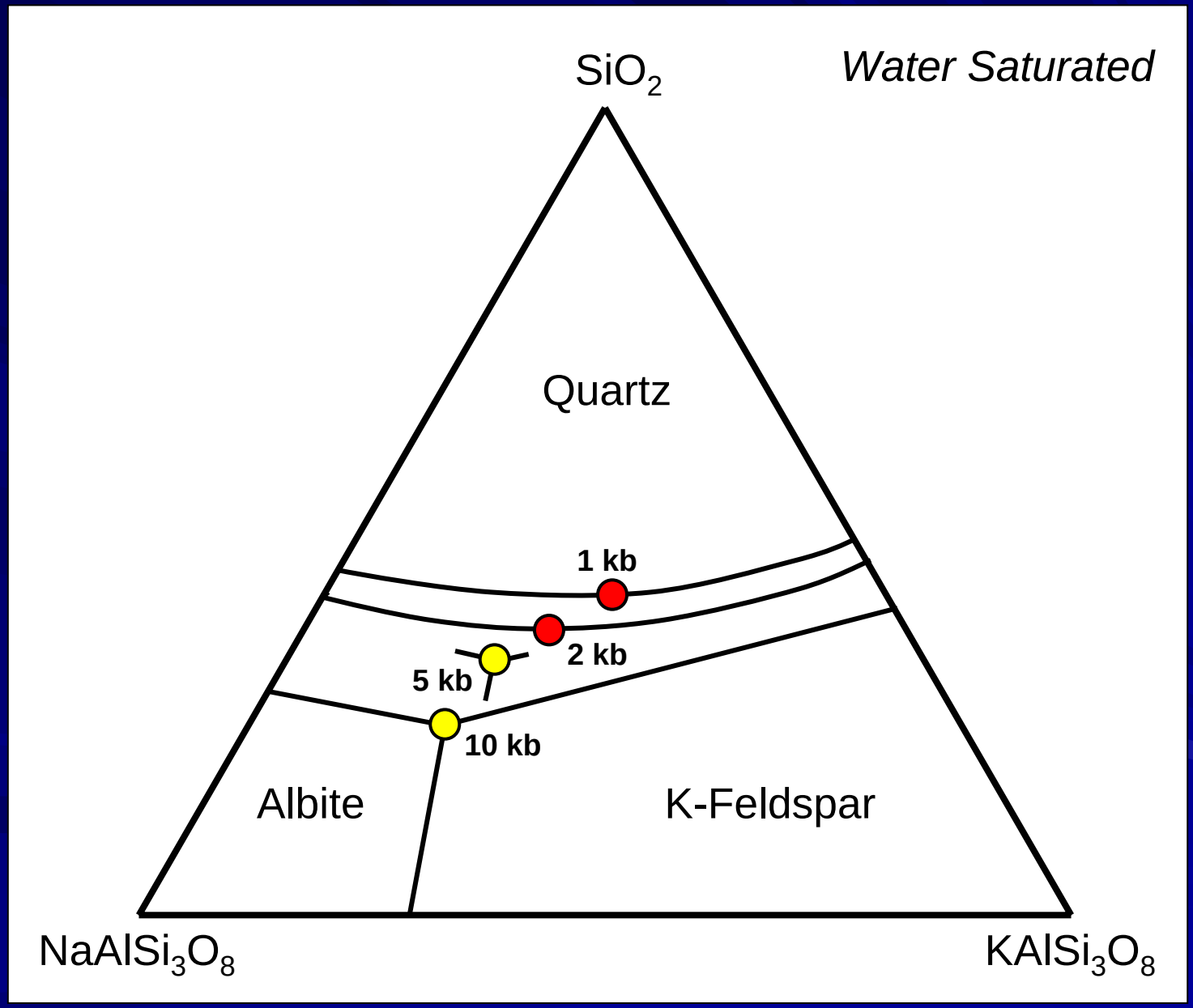
- *Enrichment of incompatible elements in the residual melt can occur during sidewall boundary layer crystallization*
- *Critical factor controlling mineral deposit genesis*



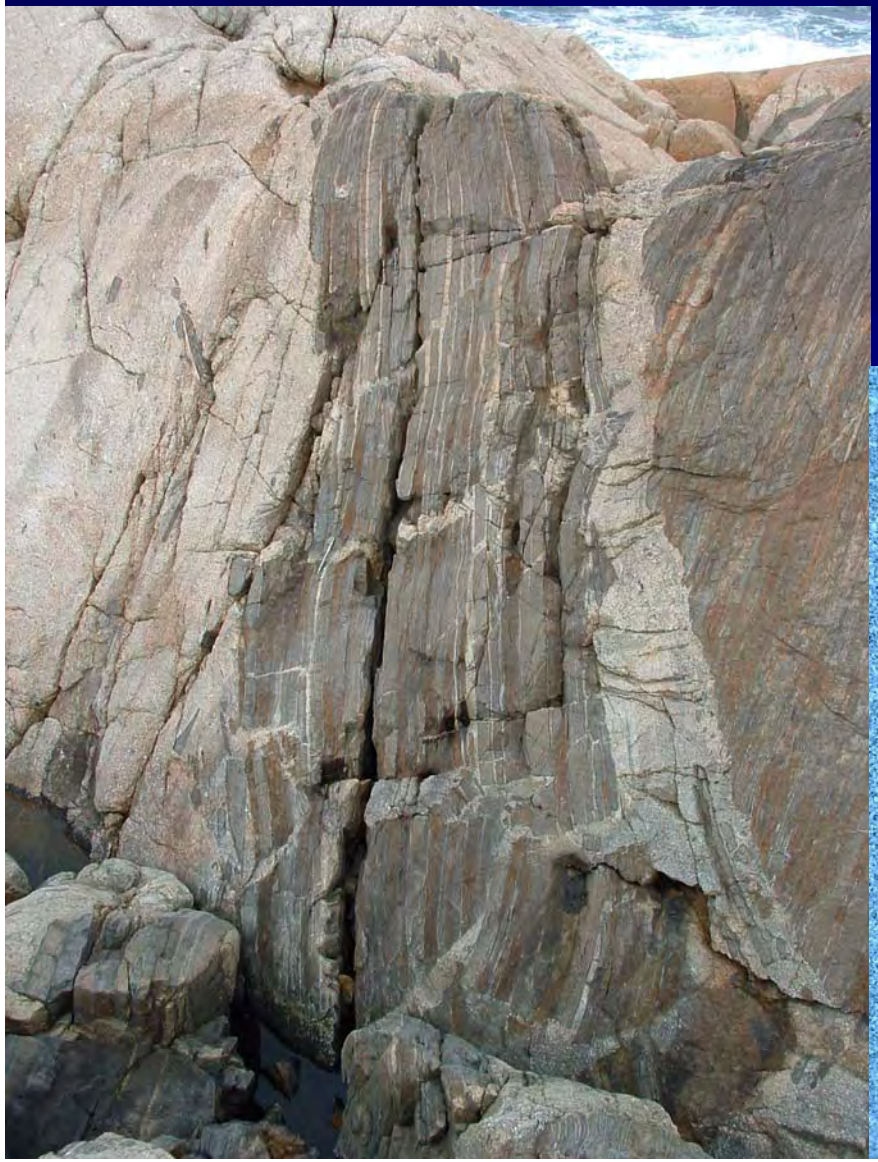
How did the various melts in the South Mountain Batholith become evolved?

- **(1) Sidewall Boundary Layer Differentiation (*Fractionation*)**
  - *addition of evolved melt (essentially QZ, ALB, KSP) to the original melt, causing it to become more evolved*
  - *enrichment of incompatible elements in the more evolved phases*

Partial Melt Composition



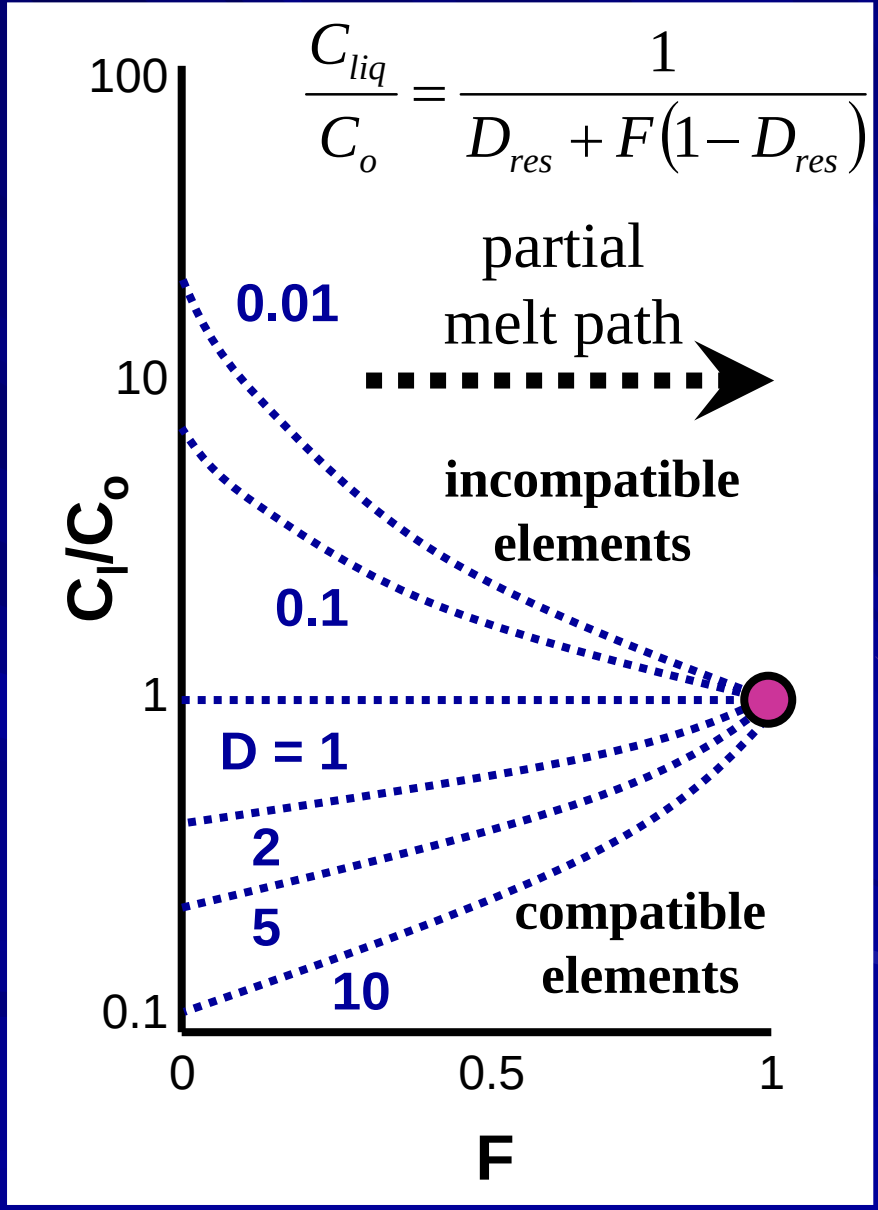
Assimilation



- – There is evidence for it, but much of it may be “physical”

Fractionation During Assimilation

- *Enrichment of incompatible elements can occur in the partial melt during assimilation, but only if assimilation if incomplete*
- *If assimilation is complete, no enrichment can occur unless the assimilant is enriched*
- *Critical factor preventing mineral deposit genesis!*



Average concentrations (ppm) of Meguma Group Pelites & Psammites, and the granodiorite/monzogranite phases of the SMB

	Pelite	Psammite	SMB
Rb	533	398	187
F	2440	1050	620
Li	122	81	76
U	24	6	4
Sn	21	17	7
Nb	14	9	12
Ta	4	1	1
W	7	5	1

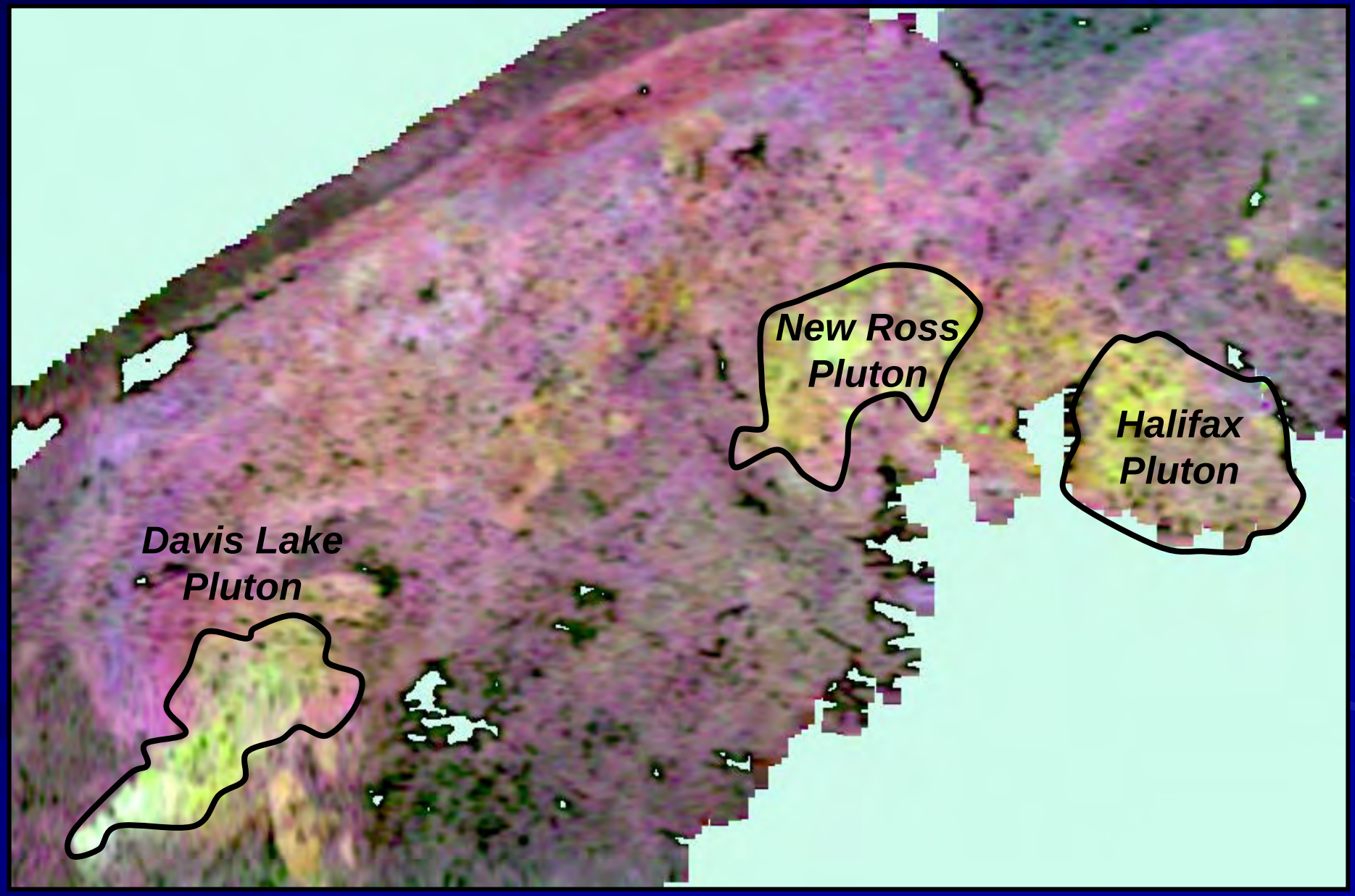
Meguma Group average concentrations courtesy of Paul Smith, NSDNR

How did the various melts in the South Mountain Batholith become evolved?

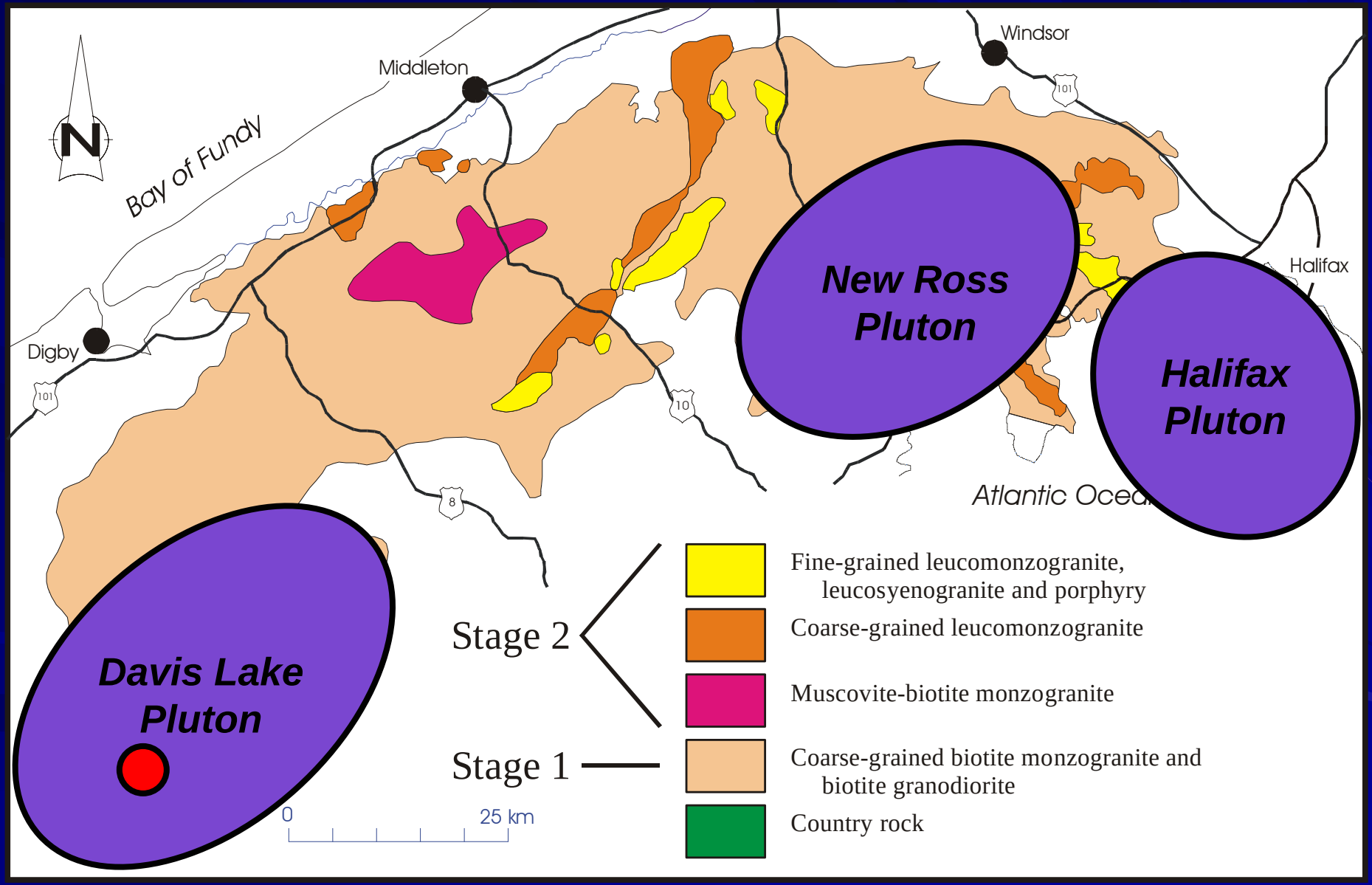
- **(2) Assimilation**
  - *partial melting of host rock (essentially QZ, ALB, KSP) and subsequent addition of this granite minimum melt composition*
  - *incompatible elements in host rock can partition into partial melt, but likely won't become enriched because partial melting is usually complete (and thus fractionation is limited)*
  - *addition of assimilated host rock can increase incompatible element concentrations by simple mixing, but this enrichment will be limited by the host rock composition*

Can one distinguish between evolved granites that have undergone predominantly fractional crystallization from those that have undergone predominantly assimilation?

Nova Scotia Radiometric Map

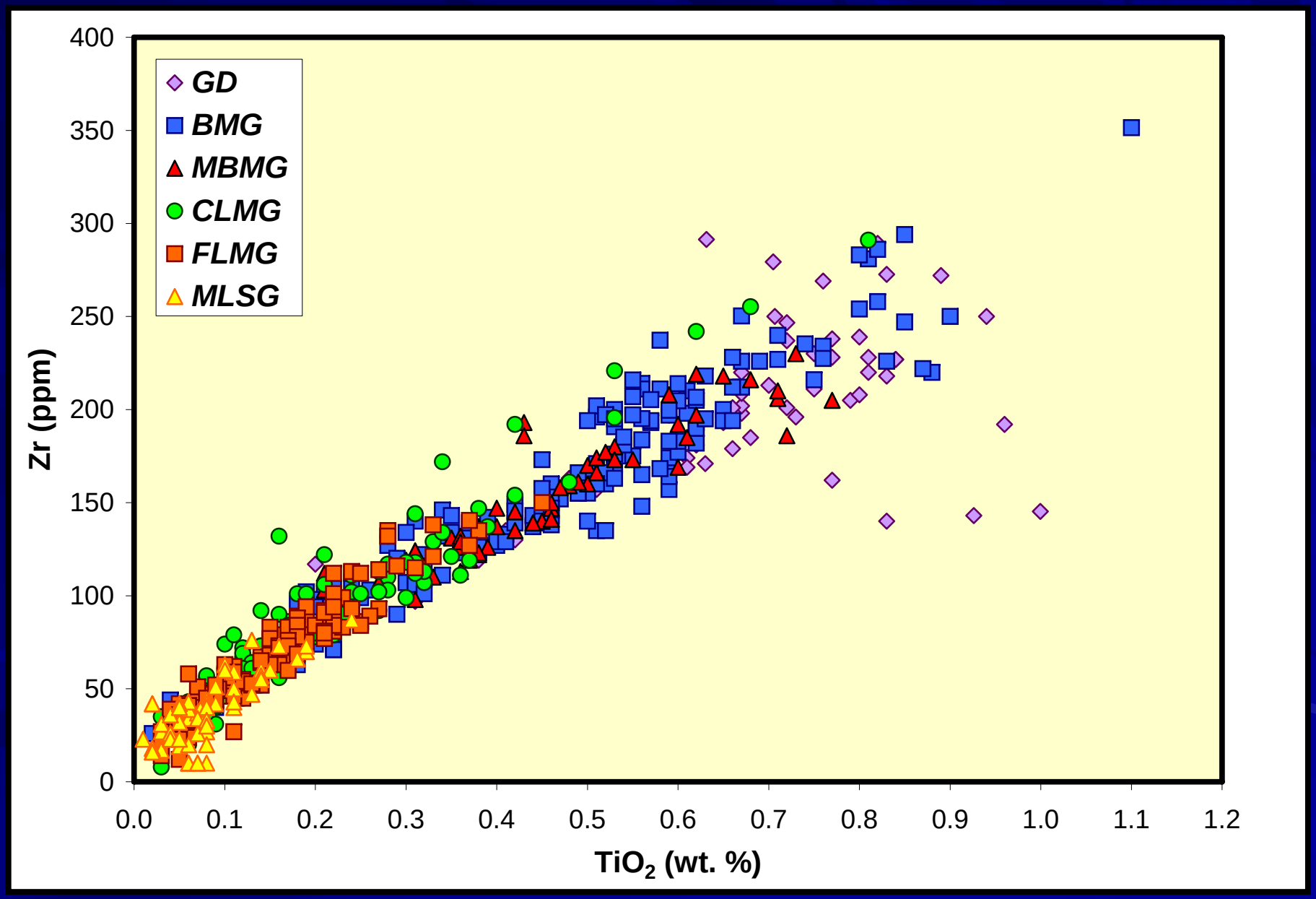


South Mountain Batholith, Nova Scotia

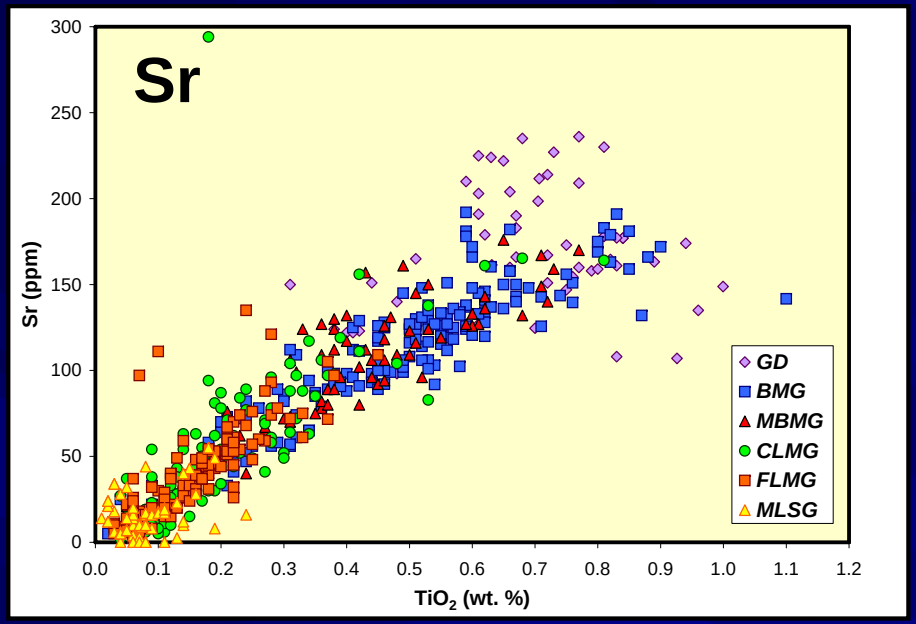


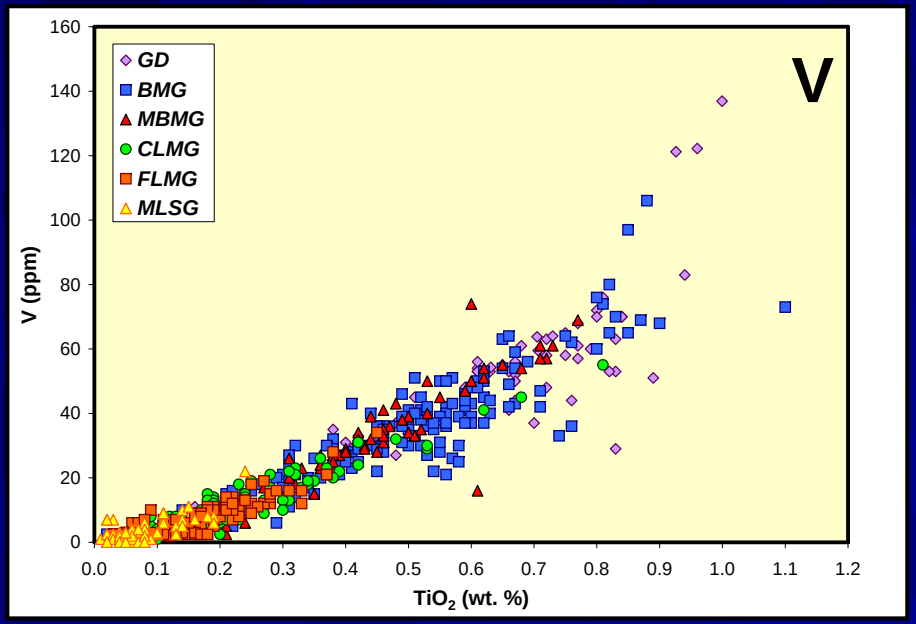
NSDNR Lithogeochemical Database

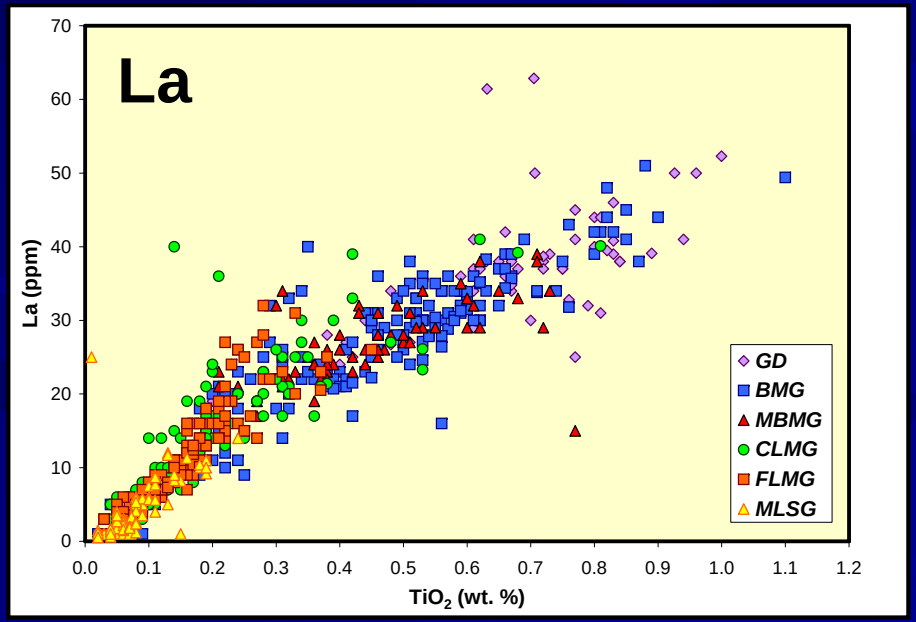
South Mountain Batholith, Nova Scotia

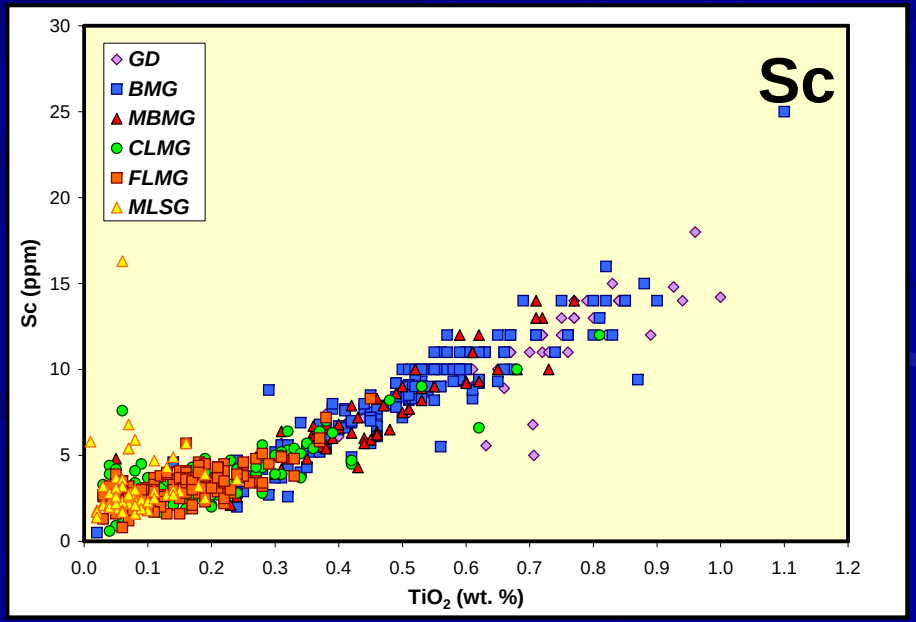


South Mountain Batholith, Nova Scotia

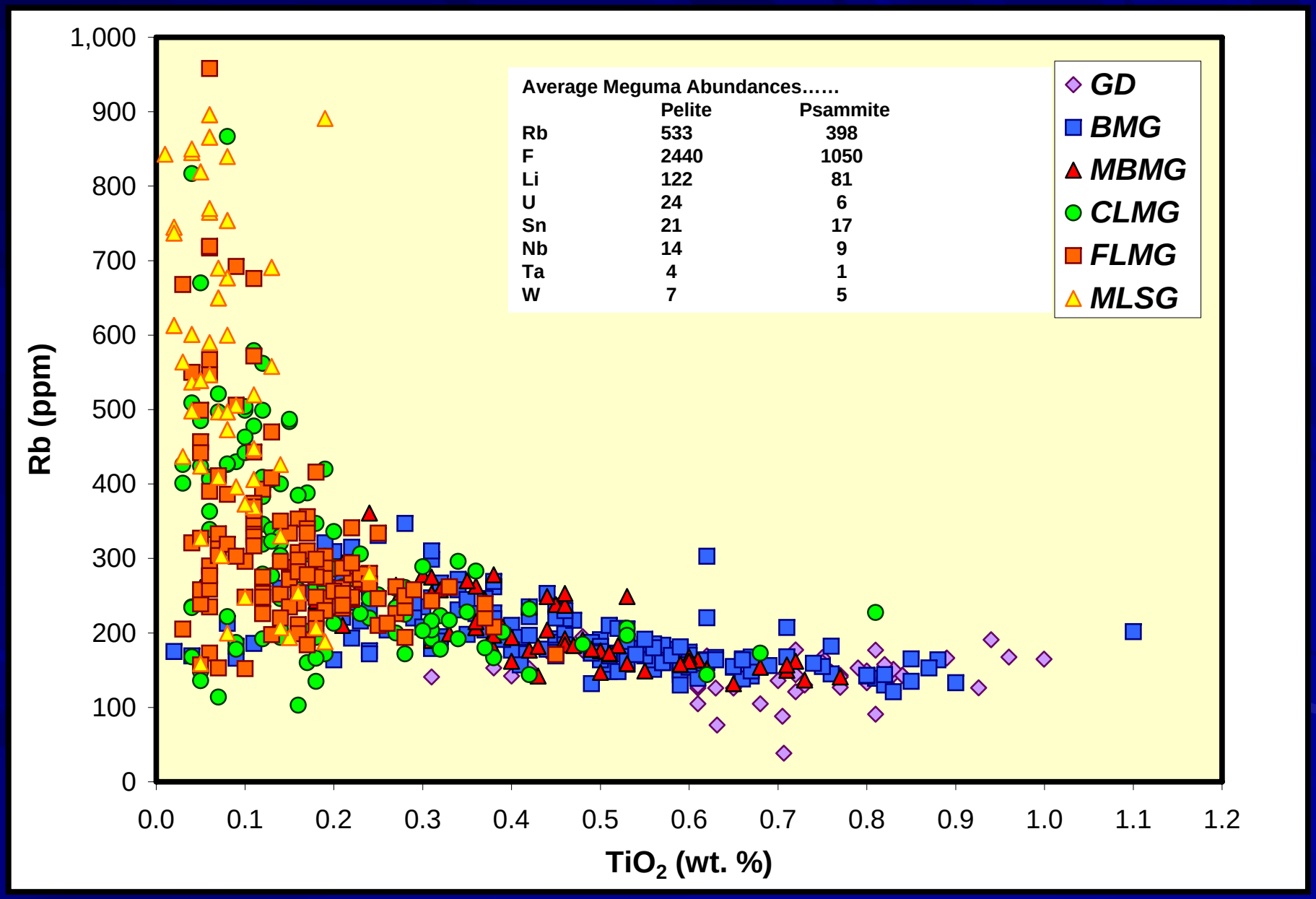




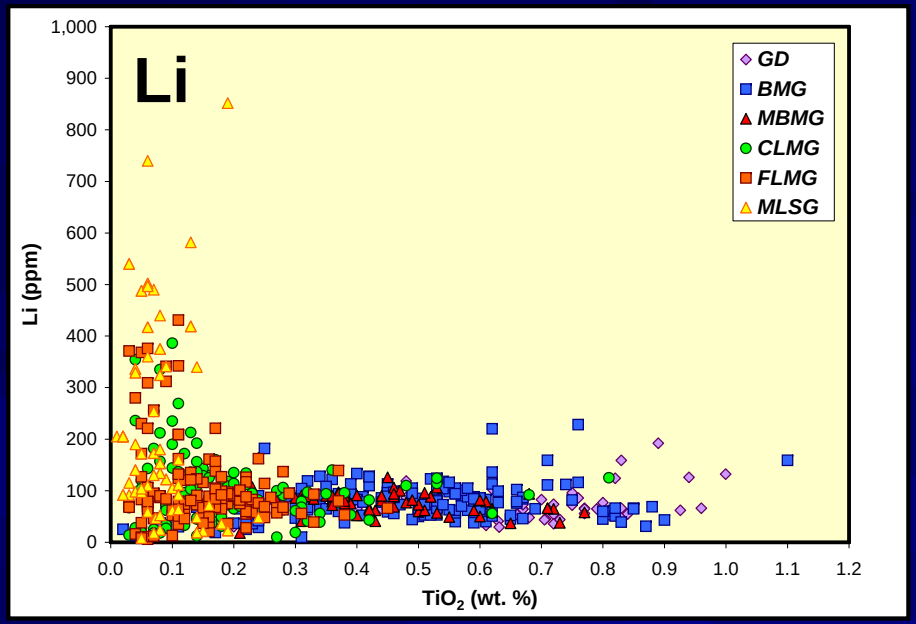


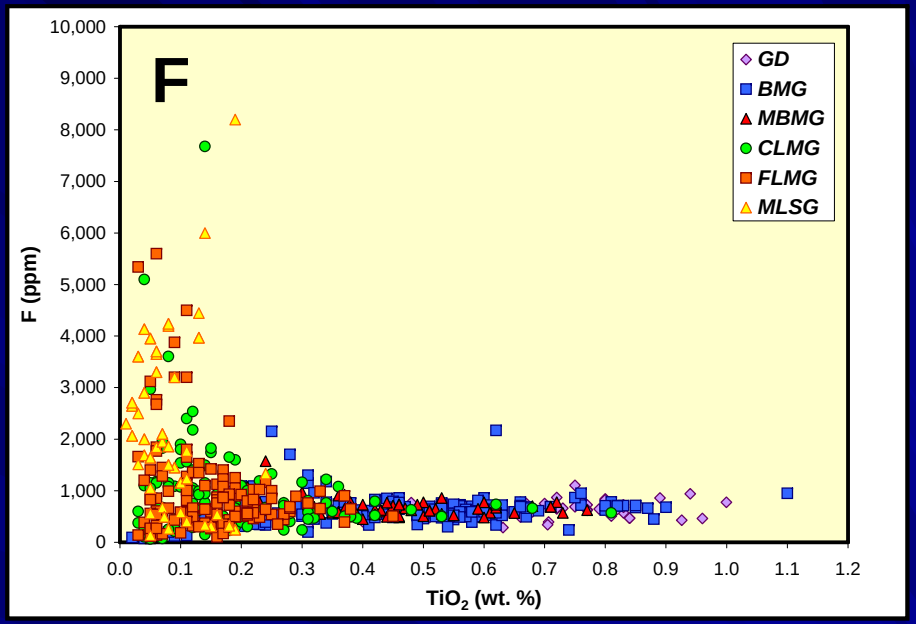


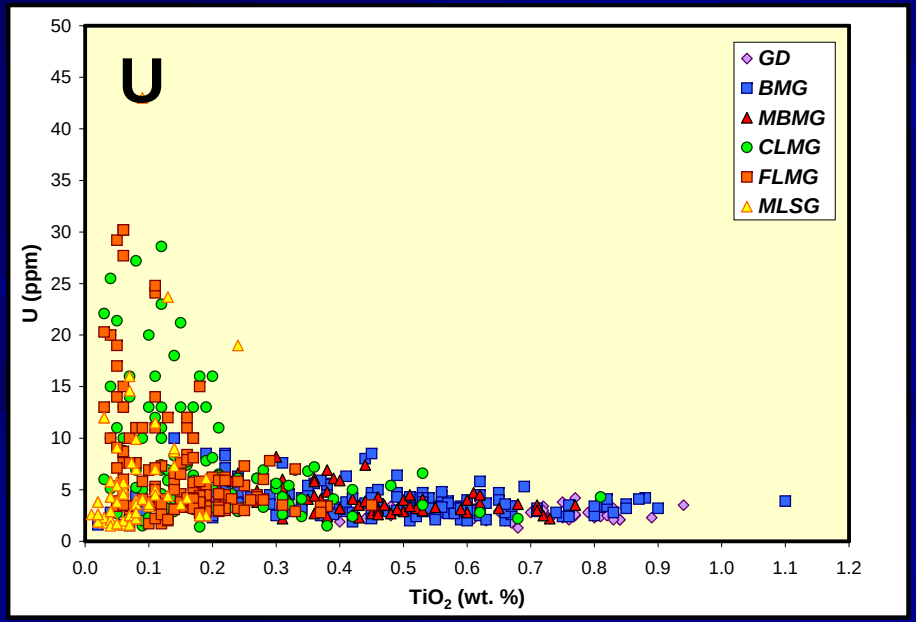
South Mountain Batholith, Nova Scotia

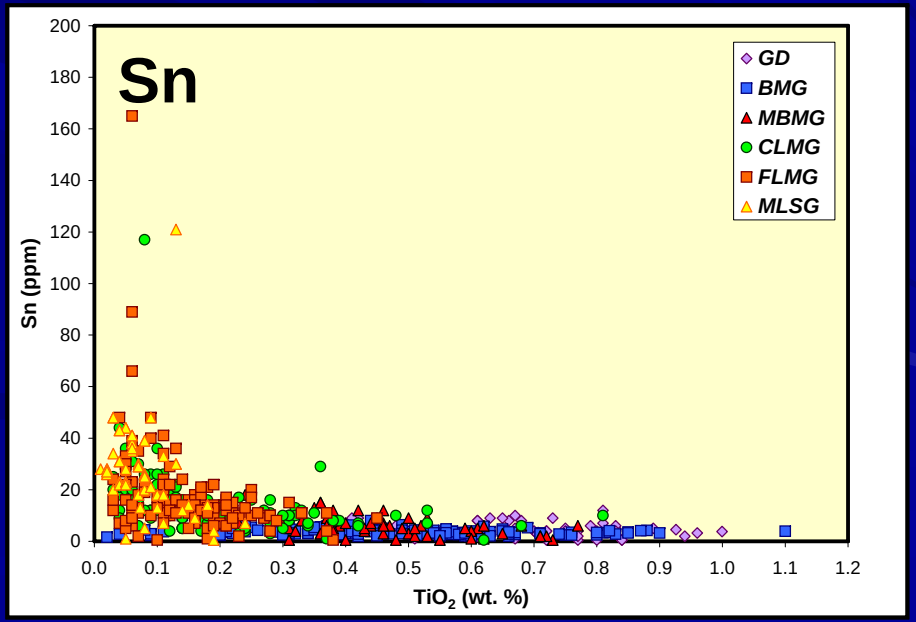


South Mountain Batholith, Nova Scotia

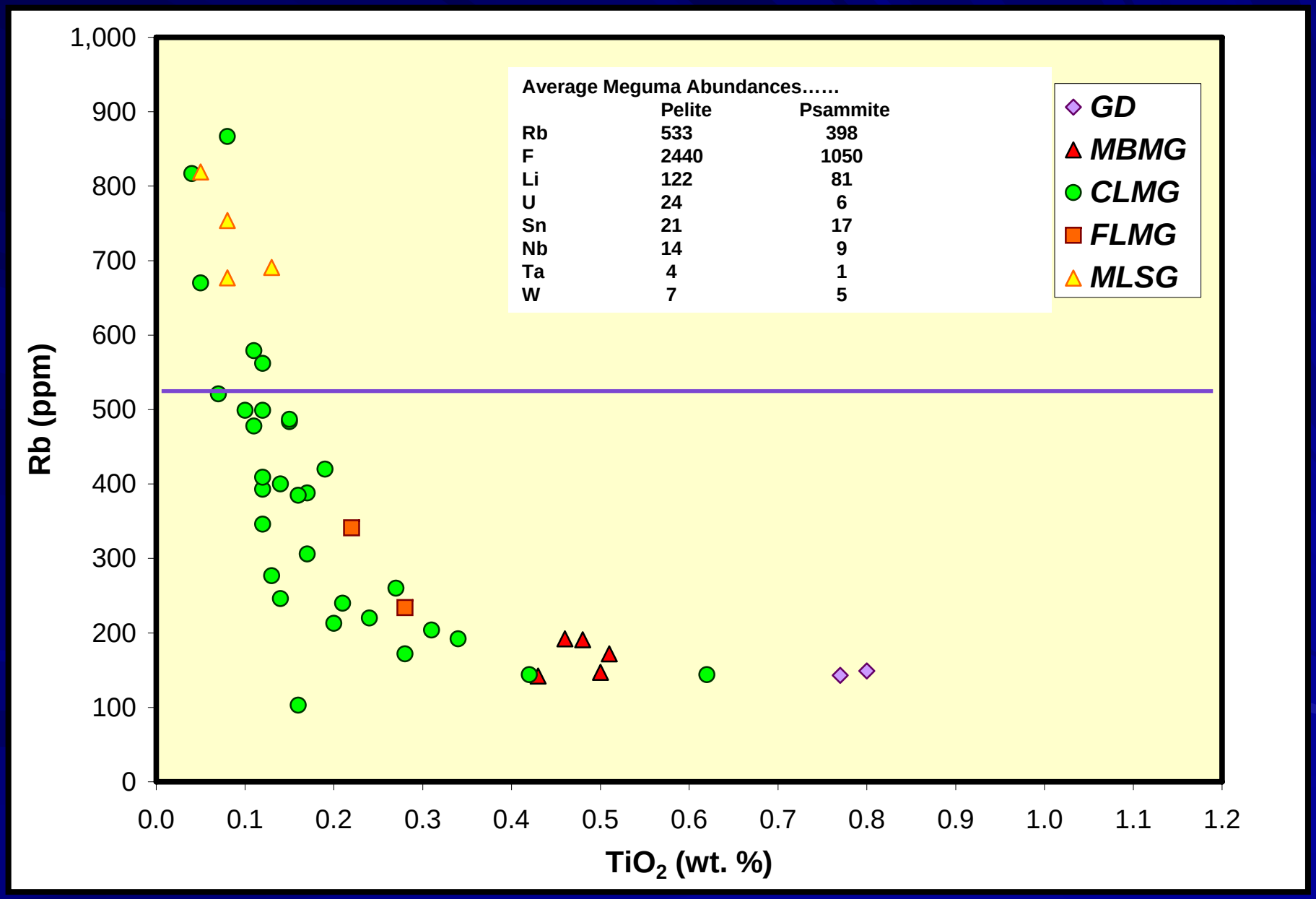




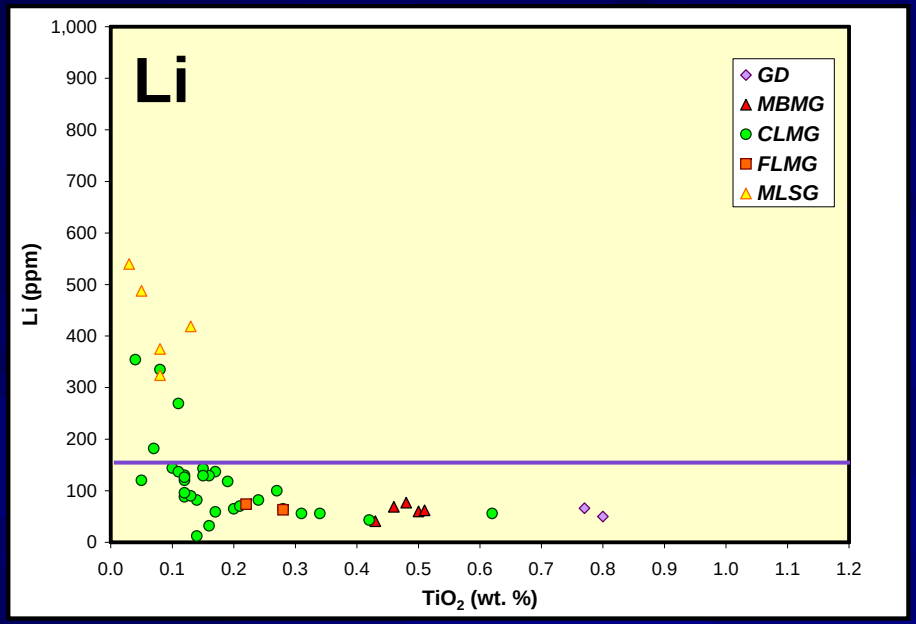


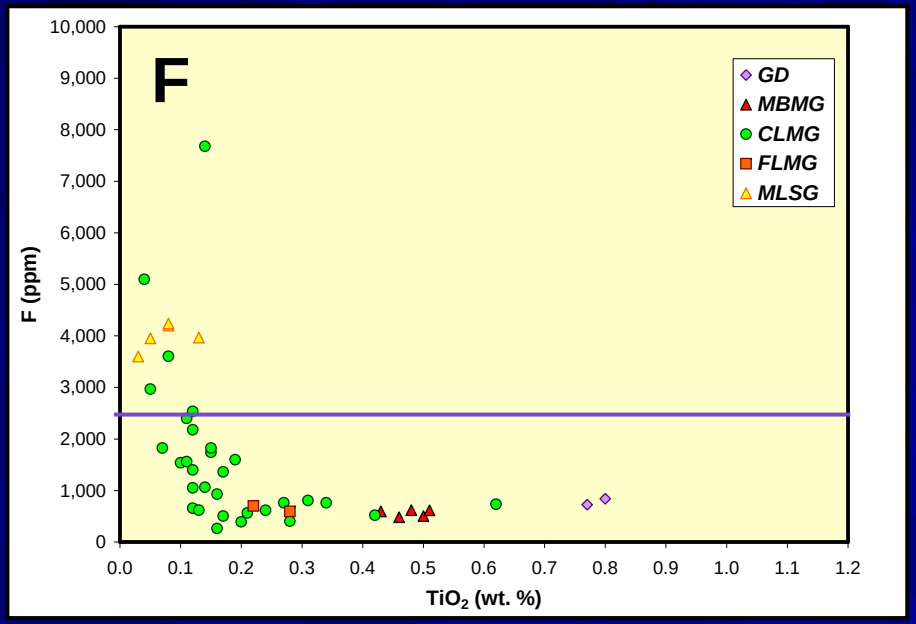


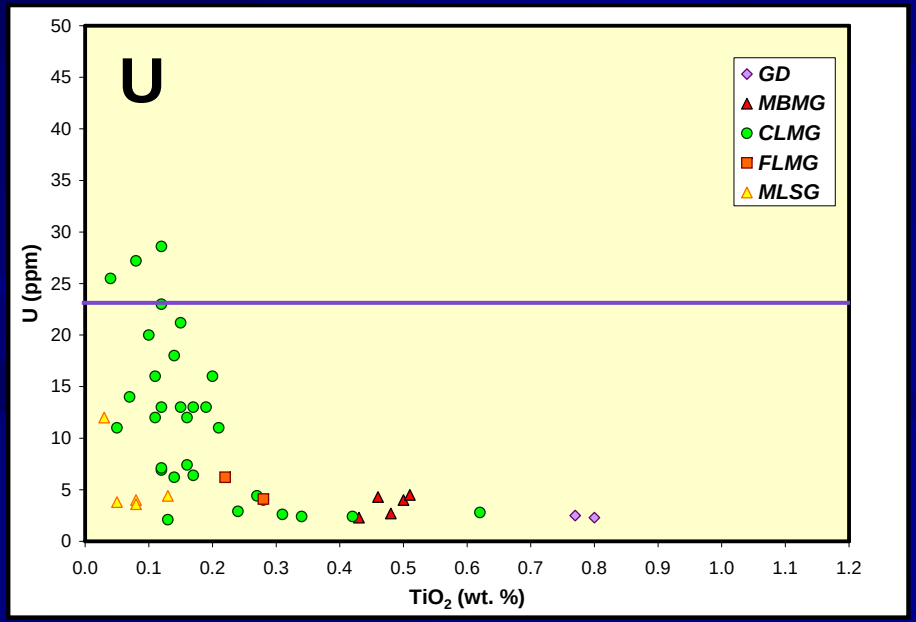
Davis Lake Pluton, Nova Scotia

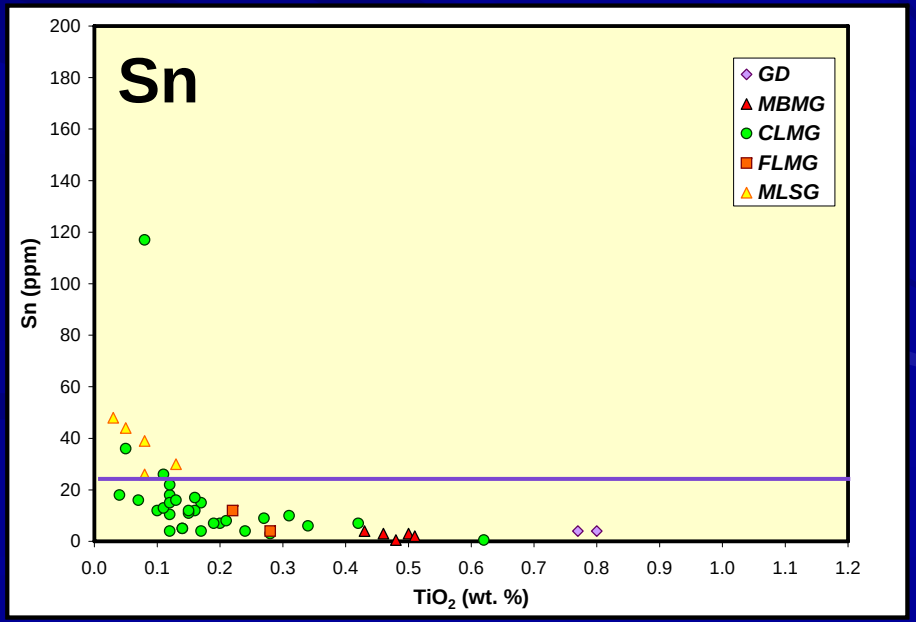


Davis Lake Pluton, Nova Scotia

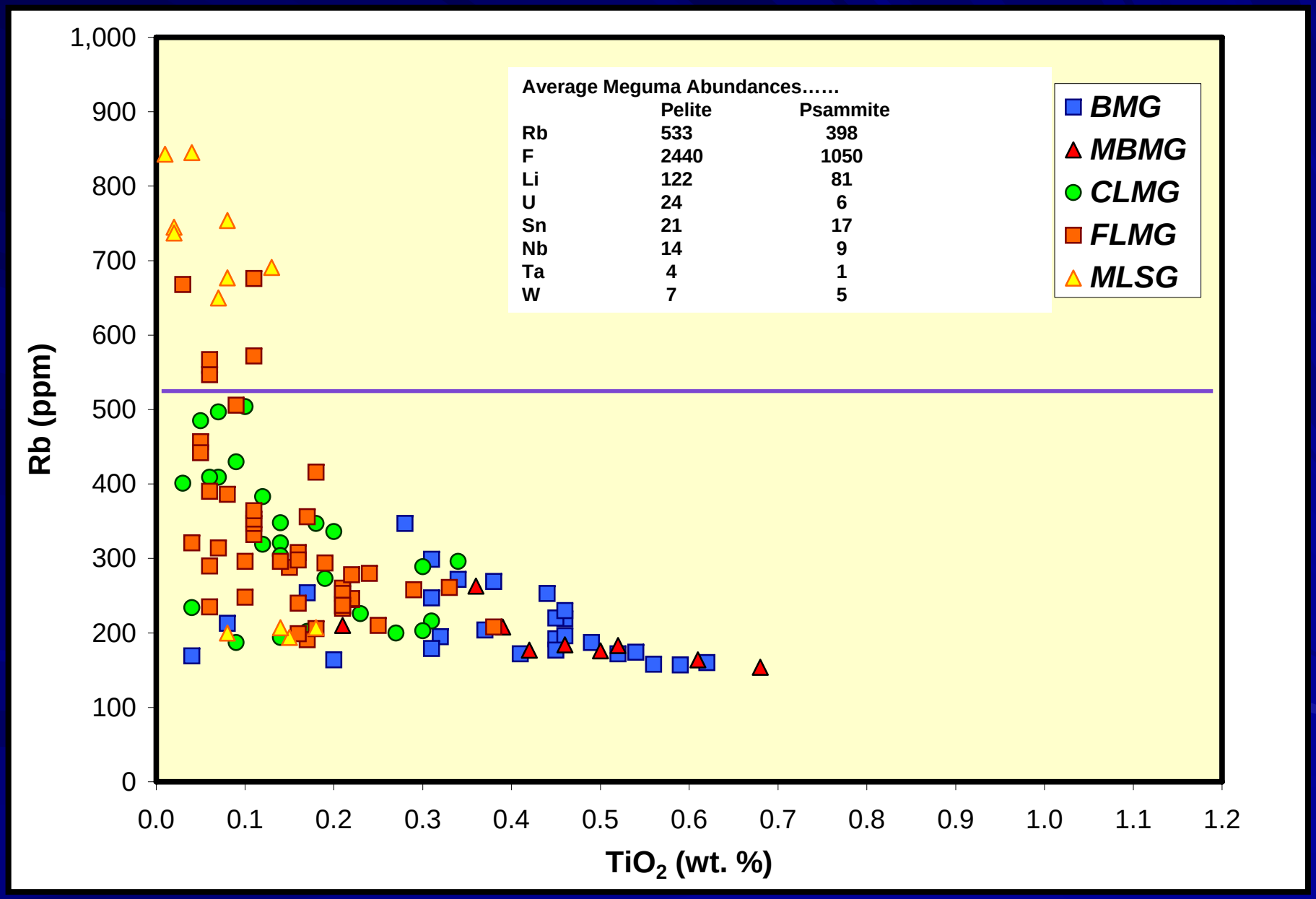




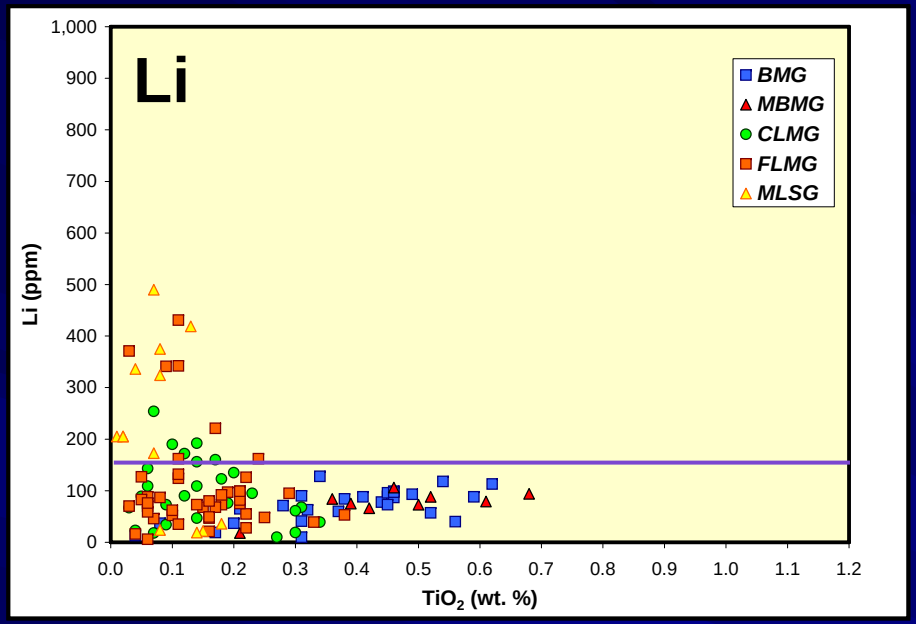


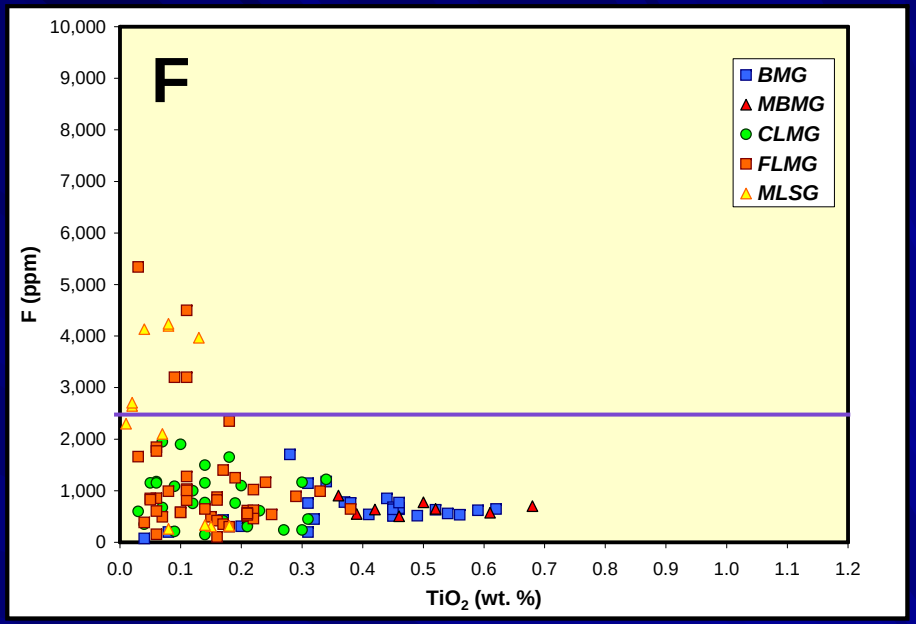


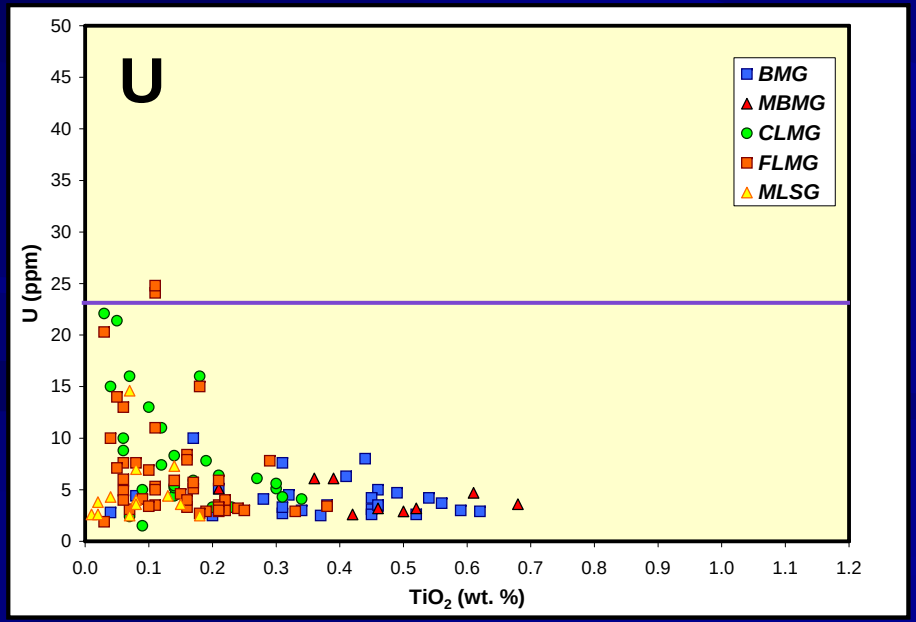
New Ross Pluton, Nova Scotia

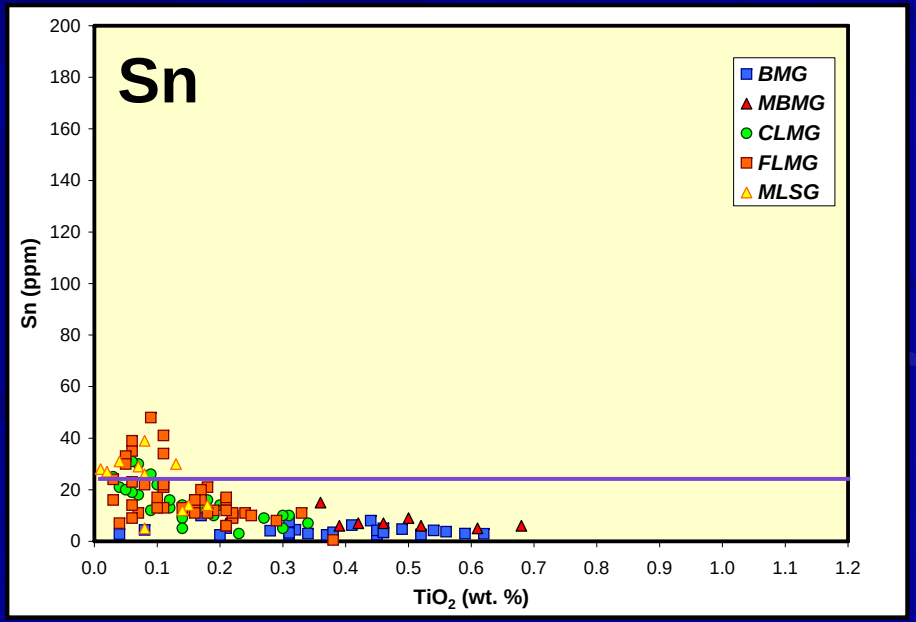


New Ross Pluton, Nova Scotia

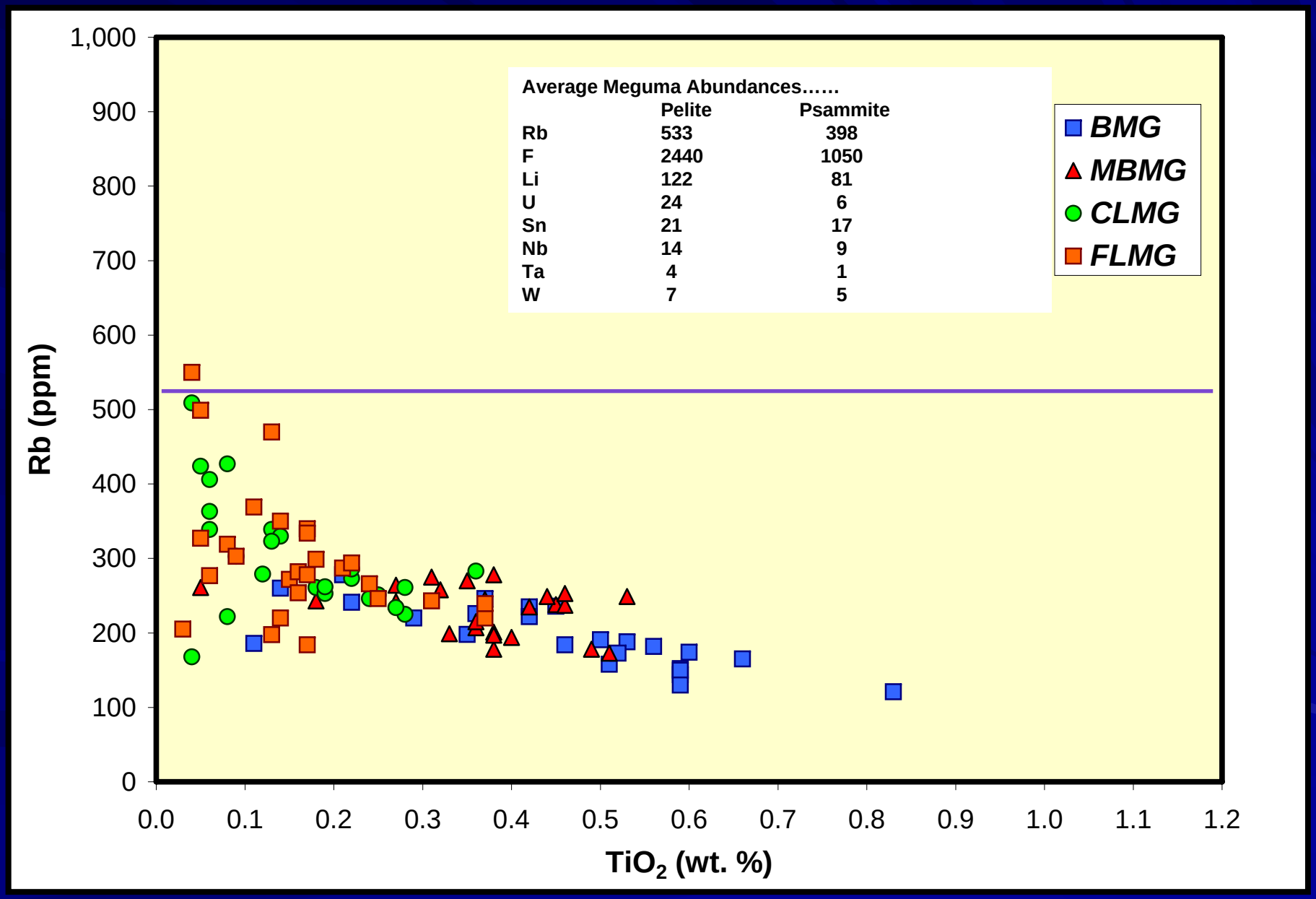




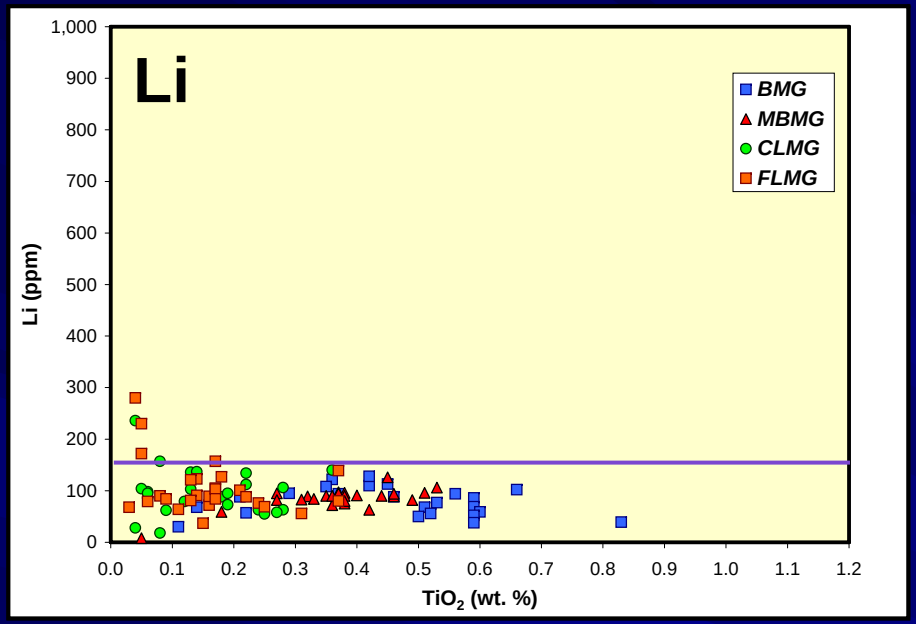


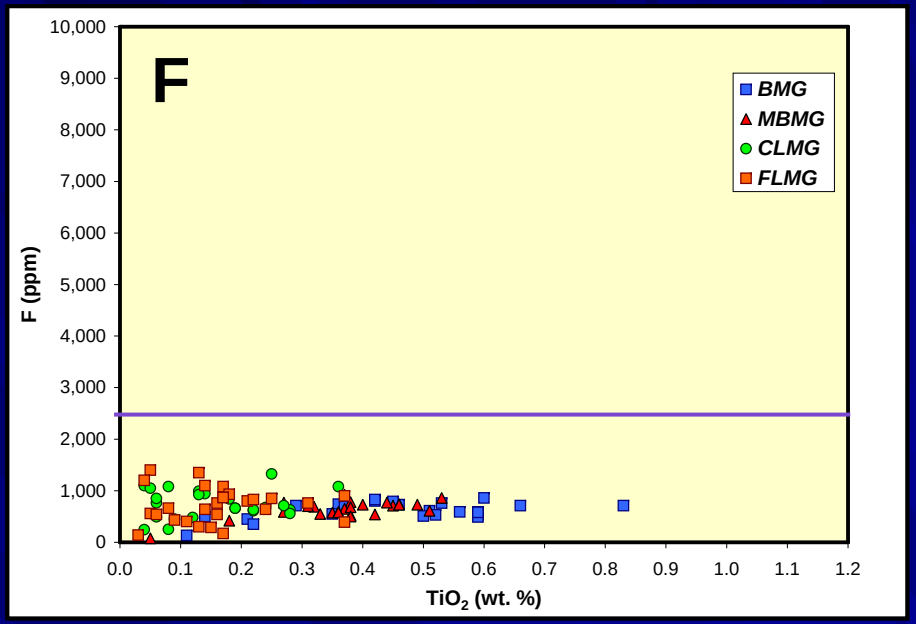


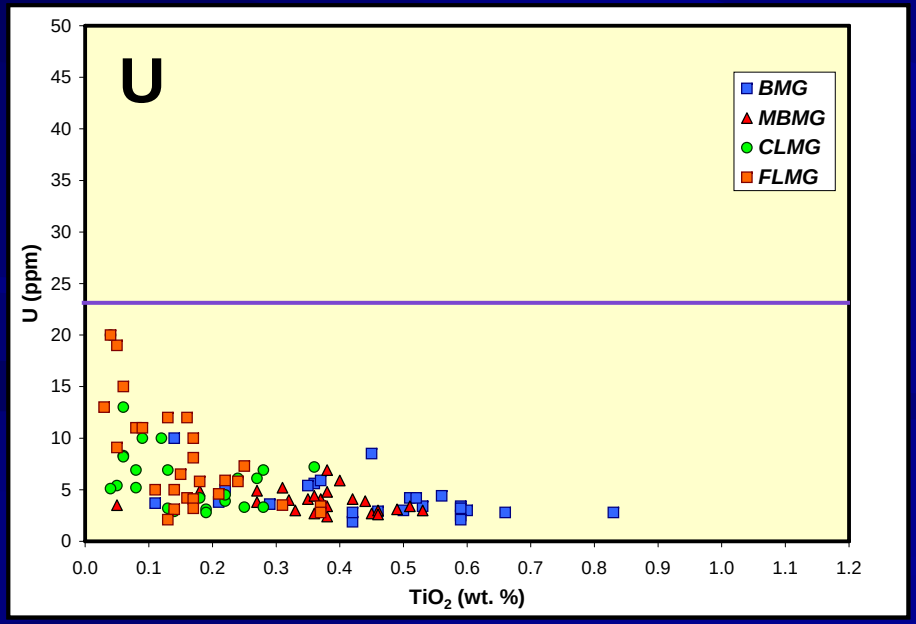
Halifax Pluton, Nova Scotia

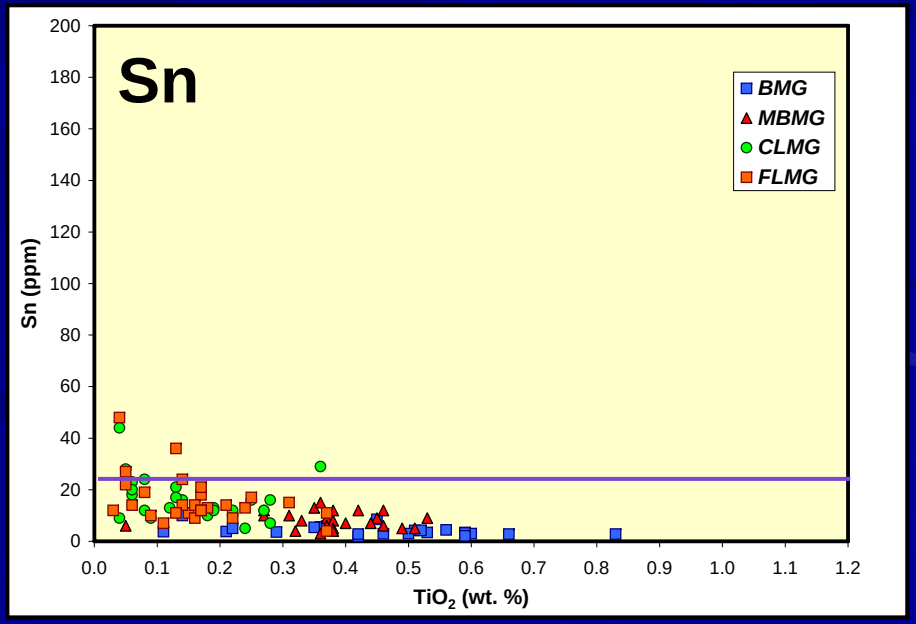


Halifax Pluton, Nova Scotia

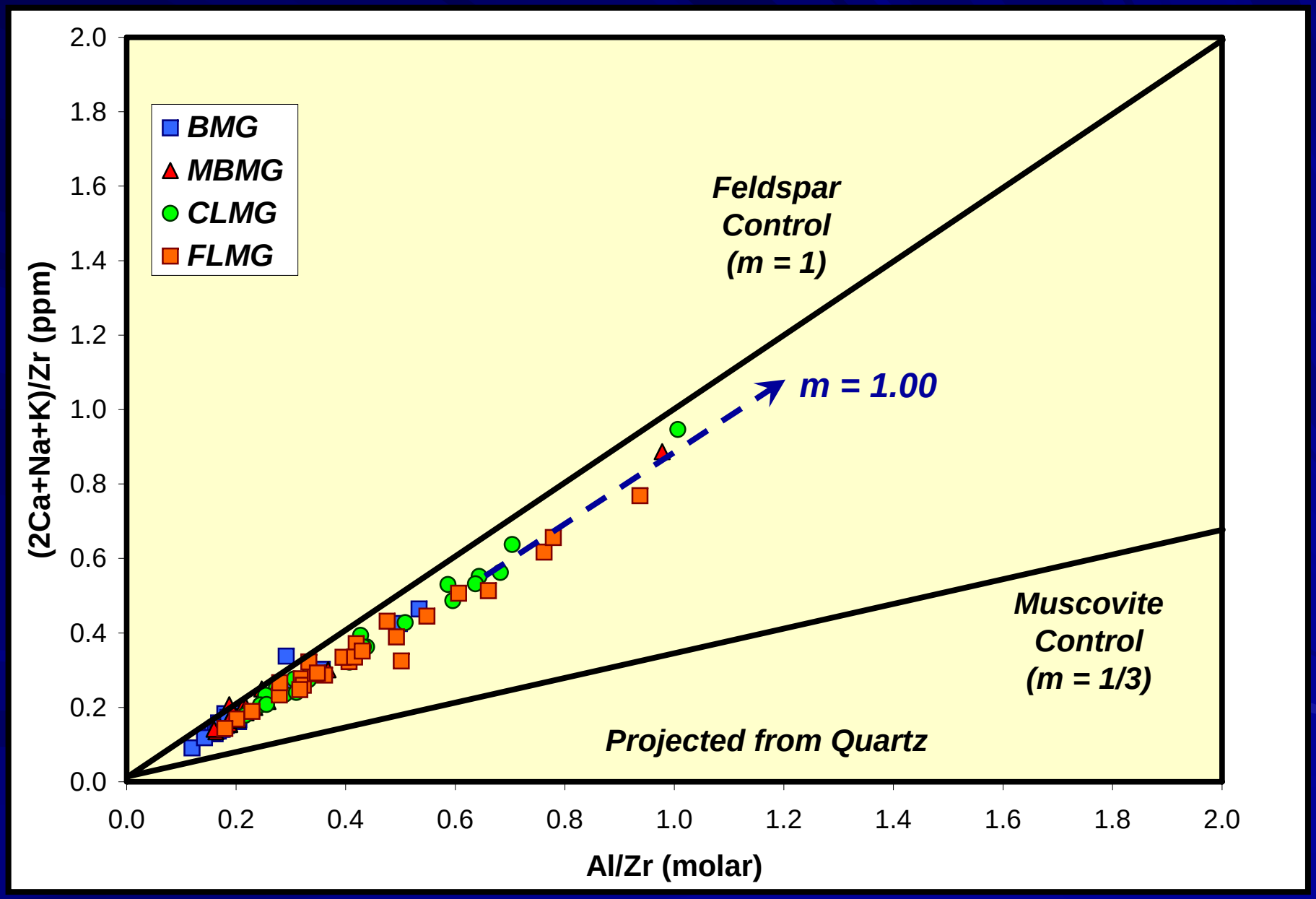




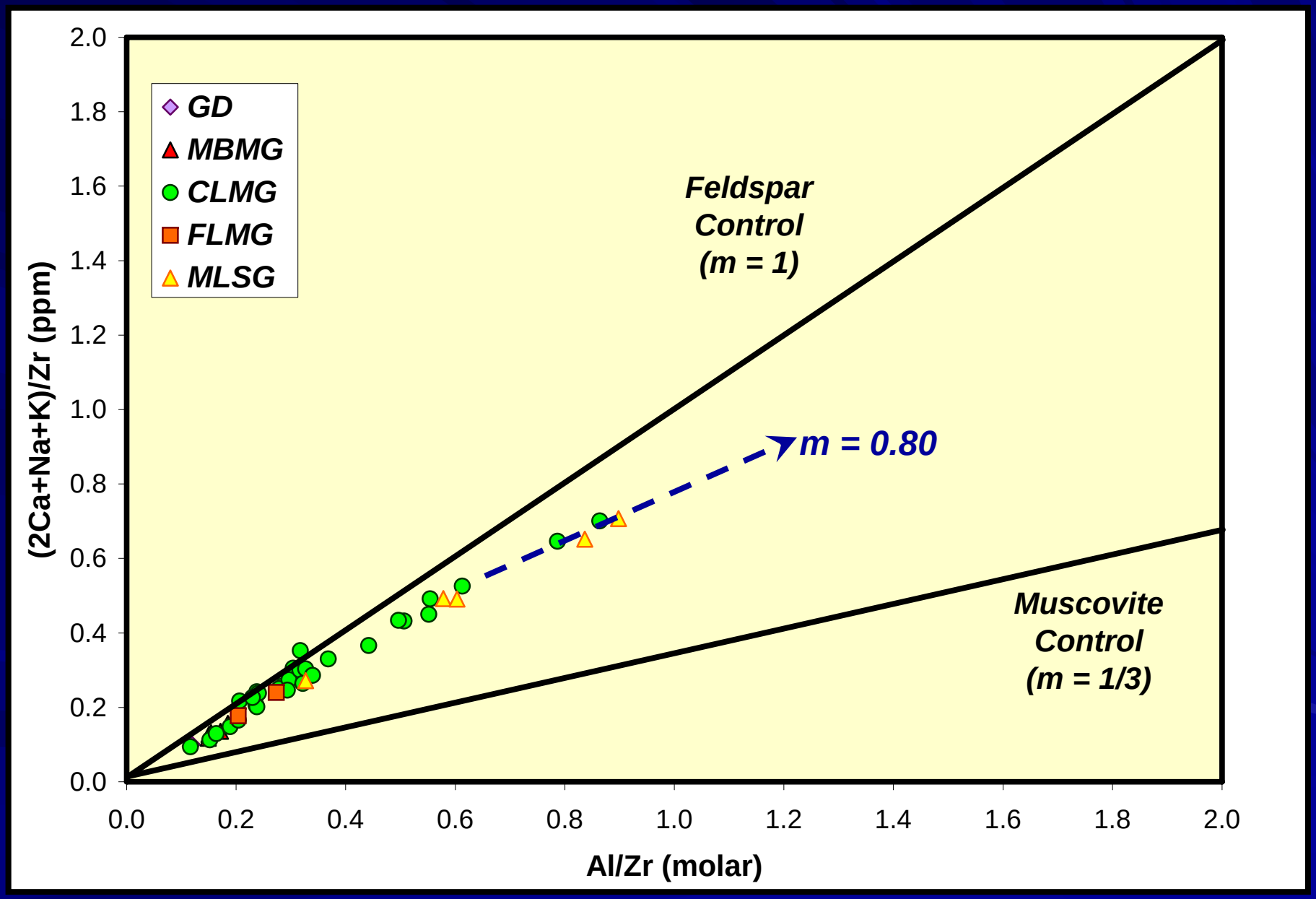




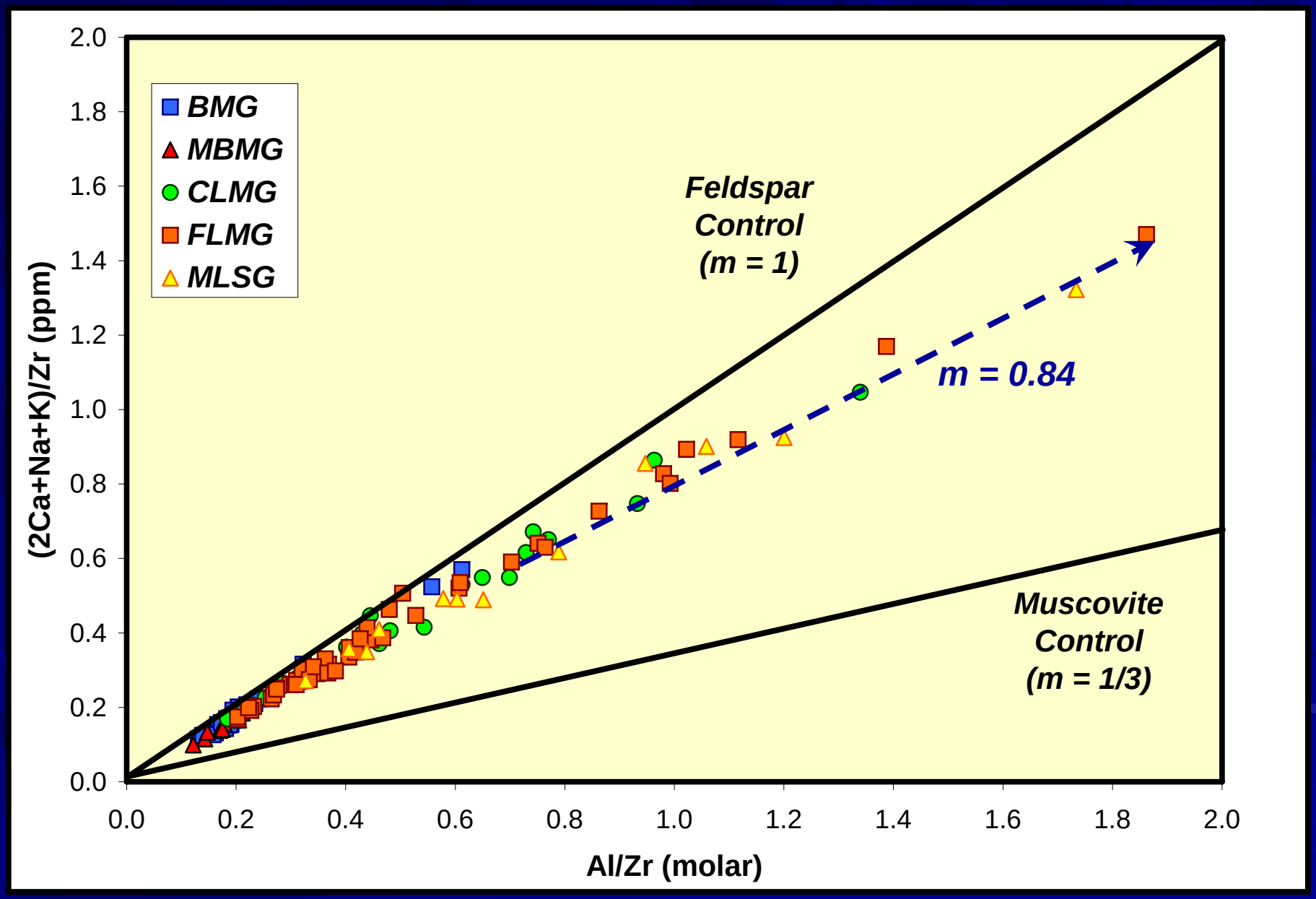
Halifax Pluton, Nova Scotia

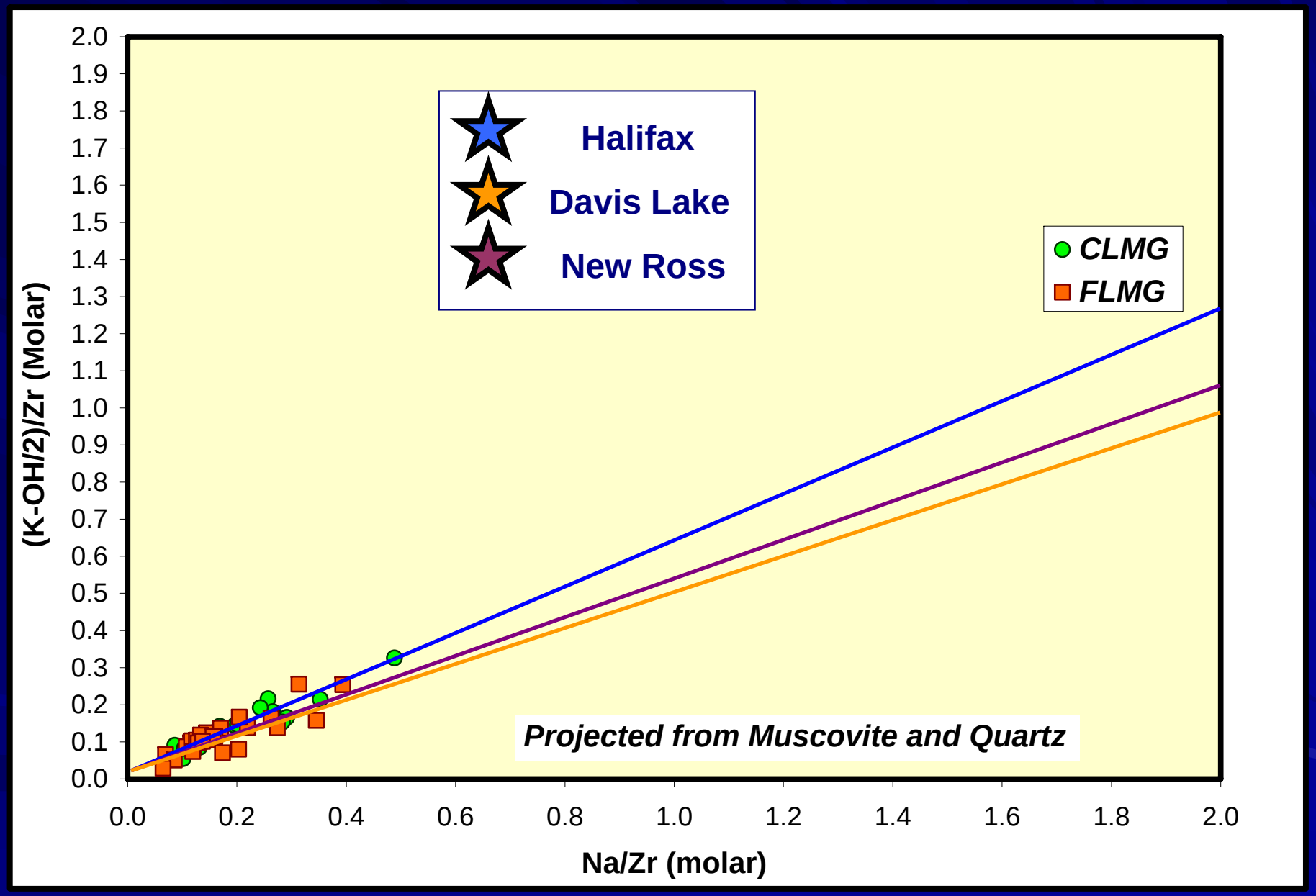


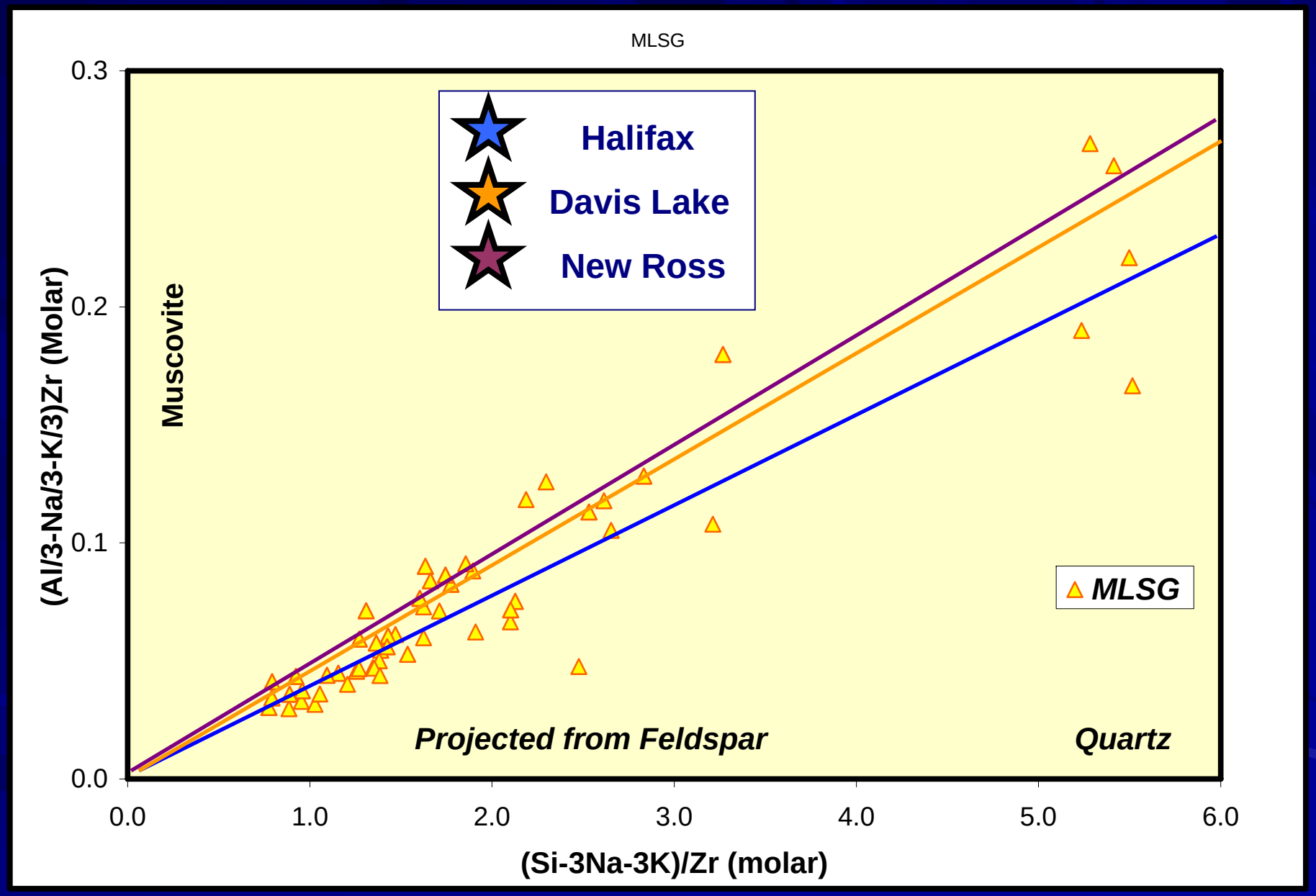
Davis Lake Pluton, Nova Scotia

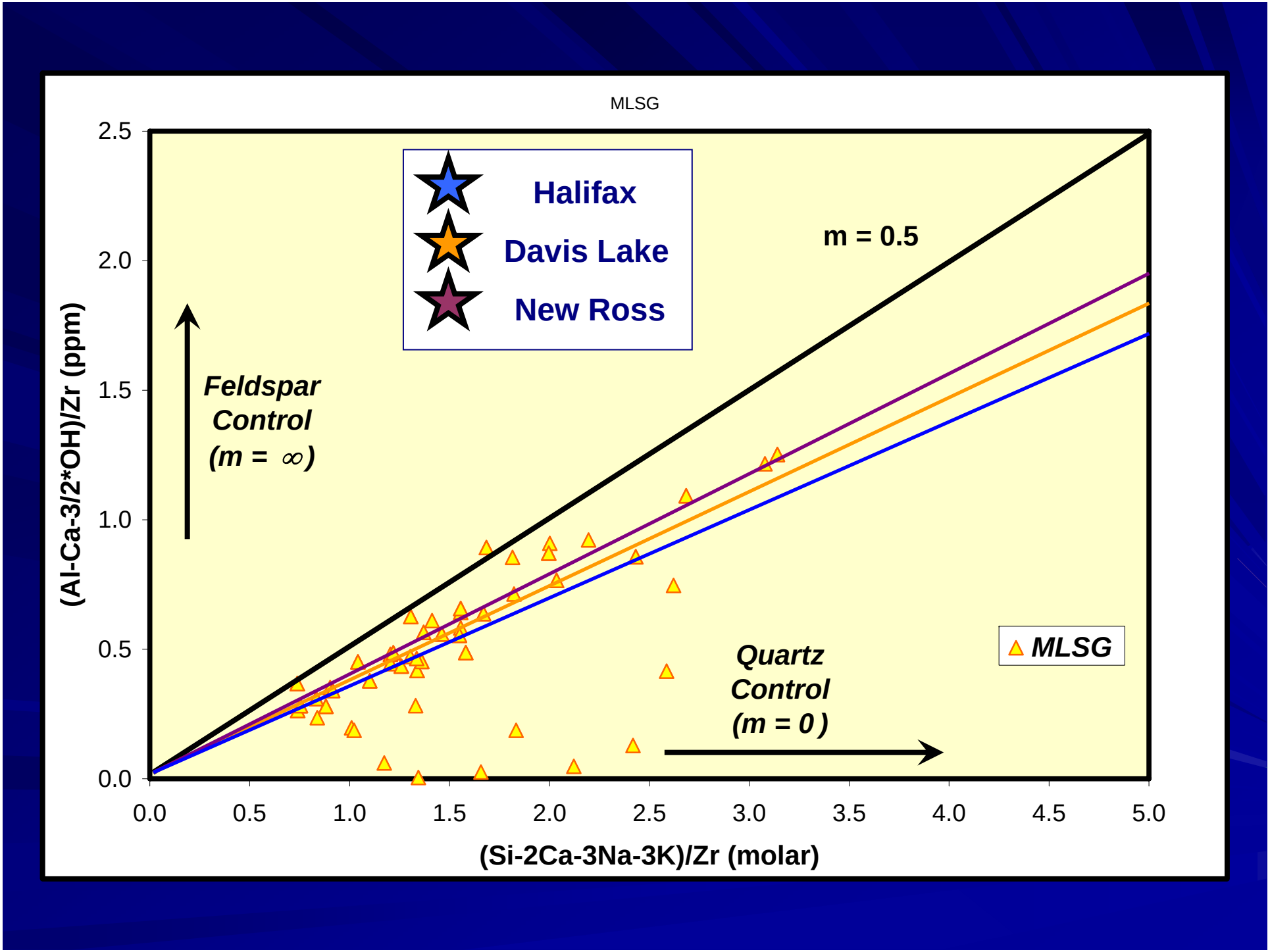


New Ross Pluton, Nova Scotia

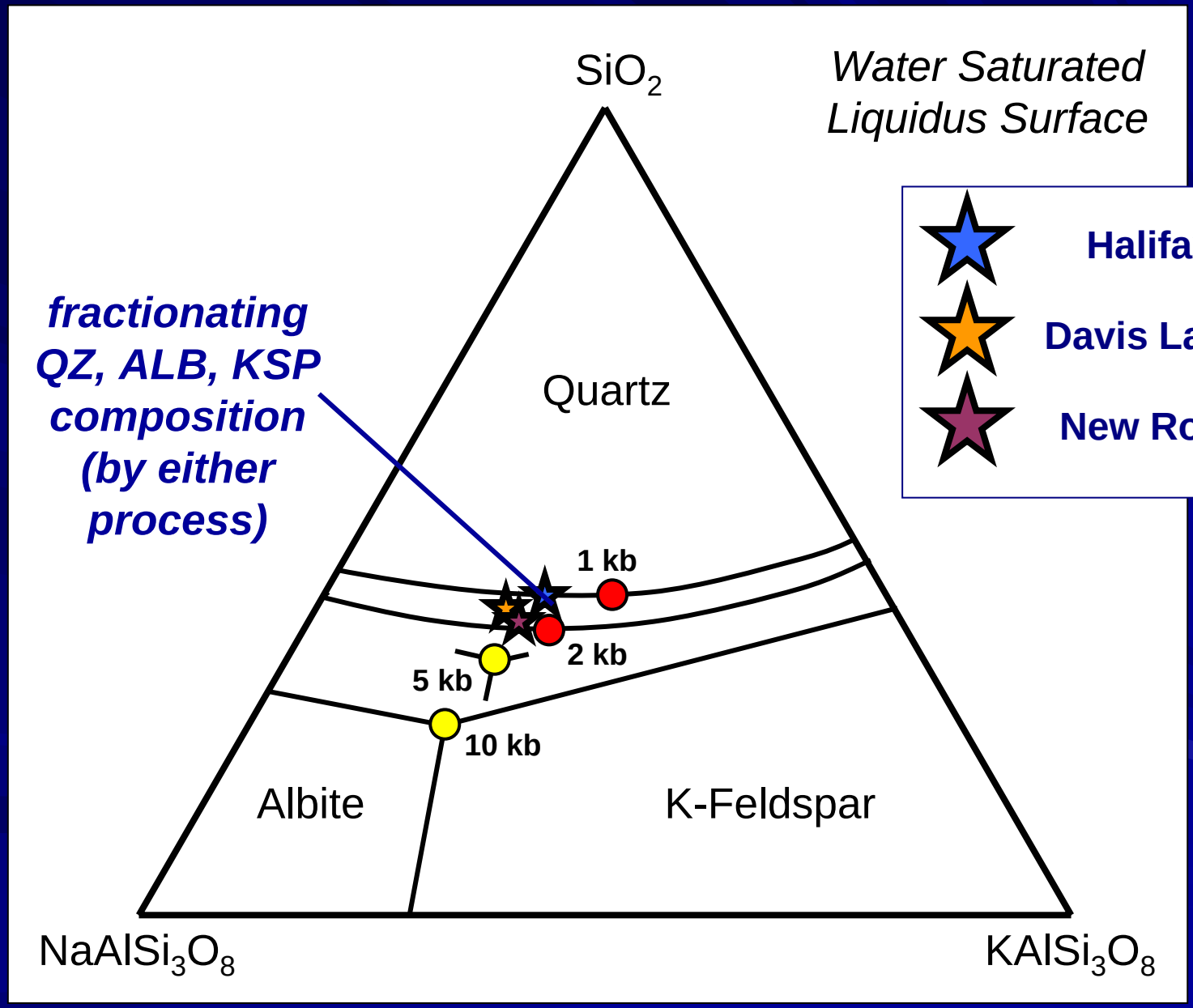



Halifax
Davis Lake
New Ross
CLMG
FLMG
Projected from Muscovite and Quartz
(K-OH/2)/Zr (Molar)
Na/Zr (molar)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0

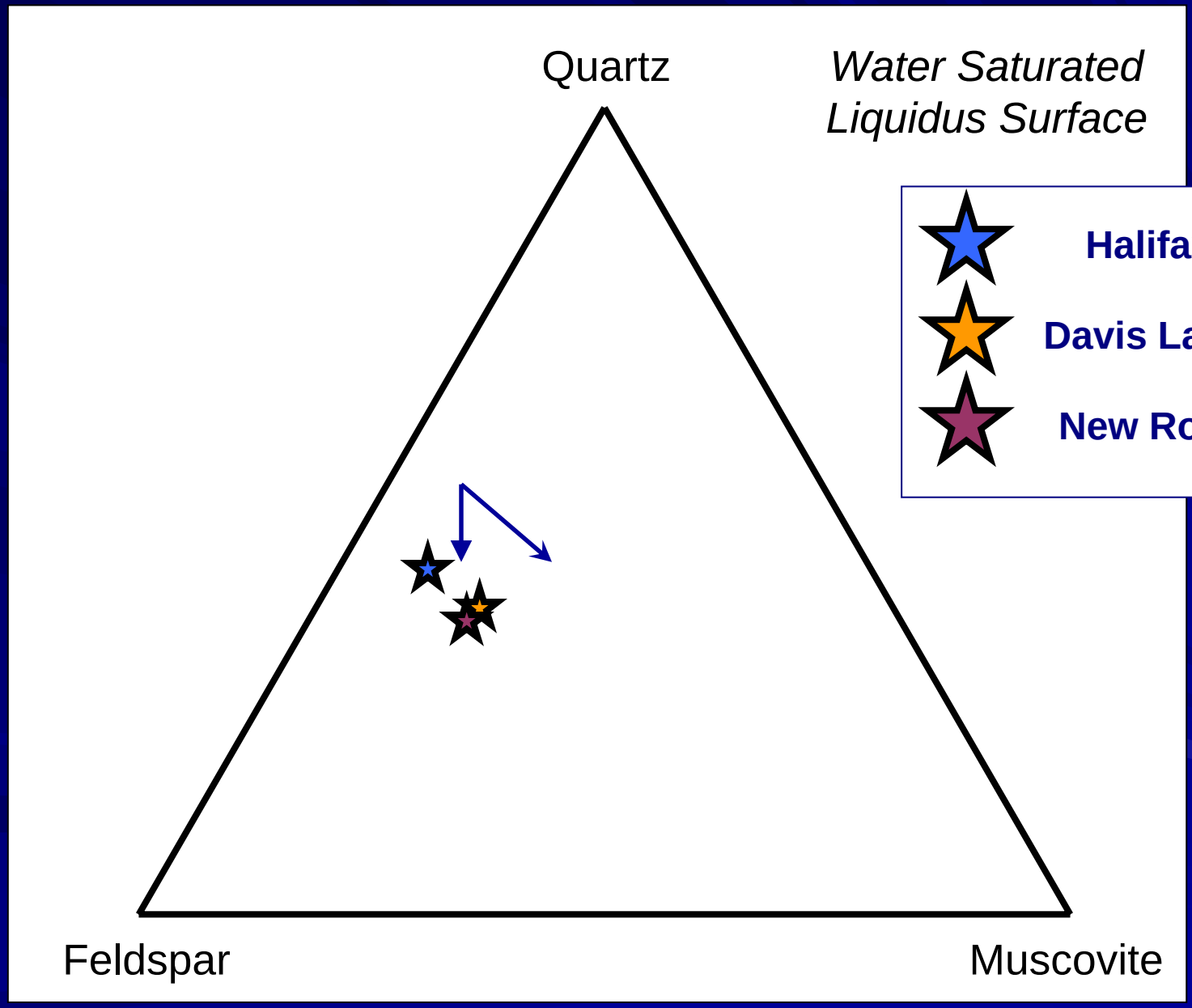

MLSG
Halifax
Davis Lake
New Ross
Muscovite
Projected from Feldspar
Quartz
MLSG
(Al/3-Na/3-K/3)Zr (Molar)
(Si-3Na-3K)/Zr (molar)
0.0
0.1
0.2
0.3
0.0
1.0
2.0
3.0
4.0
5.0
6.0


MLSG
Halifax
Davis Lake
New Ross
m = 0.5
Feldspar Control (m = ∞)
Quartz Control (m = 0)
MLSG
(Al-Ca-3/2*OH)/Zr (ppm)
(Si-2Ca-3Na-3K)/Zr (molar)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0

Fractionation Composition



Fractionation Composition



Some Key Points

- Major element, and therefore mineralogical, differences are subtle
- However, even utilising a ‘poor man’s water’, we can demonstrate repeatable differences between ‘fertile’ and ‘barren’ plutons within the SMB by examining their most evolved components
- Major and trace elements are telling us the same story! Gives more confidence in the interpretation
- Proper water analyses would have helped greatly, and might allow interpretation of major element data against mineral phase boundaries
- Structural water…. Analyse for it! If you are looking for variations in hydrous minerals!
- Point Counting might help… but time consuming and is it really more reliable? Use the whole rock traces and majors to rapidly assess many samples

Conclusions

- two processes operated to cause magma evolution in the South Mountain batholith:
  - *fractional crystallization, and*
  - *assimilation*
- Only the former leads to significant lithophile element enrichment
- Think PROCESS
- The Halifax pluton hosts no significant known mineralization, does not exhibit significant lithophile element enrichment, and did not become very peraluminous during evolution (probably as a result of assimilation)
- The New Ross and Davis Lake plutons have significant mineralization, exhibit lithophile element enrichment, and became very peraluminous during evolution (probably as a result of fractional crystallization)

Thanks to:

NSERC Discovery Grant to CRS
Mike MacDonald & Linda Ham, NS-DNR
Christina Giles
Barrie Clarke and Saskia Erdmann, Dalhousie

Questions?