Petrographic observations and evaporate mound analysis of quartz-hosted fluid inclusions: Applications to assess metal fertility in granites

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3. Geological Survey of Canada, 601 Booth St., Ottawa, Ontario

Abstract: The 380 Ma South Mountain Batholith (SMB), Nova Scotia, is a large (~7300 km^2), contiguous, mesozonal granitoid intrusion consisting of 13 coalesced plutons hosting a variety of mineralized zones (e.g., Sn-Zn-Cu-Ag, Mn-Fe-P, U, Cu-Ag). Given the hydrothermal nature of this mineralization, it is expected that a geochemical fingerprint of the mineralizing fluids might be preserved both petrographically and as secondary fluid inclusions (FIs) in the granites on a scale equal to or larger than the mineralized zones. In this unique study, we investigate the possibility of integrating petrographic observations that reflect fluid:rock interaction and the chemistry of secondary, quartz-hosted FIs in samples from the SMB to assess granite fertility and also the scale of this potential vectoring tool. The protocol involved: (1) detailed petrographic study of >500 archived samples and focused on the extent and degree of alteration (e.g., perthite textures, chlorite alteration of biotite, plagioclase alteration, percent of secondary muscovite, abundance of FI in quartz); and (2) determining fluid chemistry of quartz- hosted FIs in >100 samples collected from a 10 × 10 km grid superimposed on the SMB. The petrographic data record highly variable degrees of alteration and the results are being used to design an alteration algorithm that can be used to map the extent of fluid:rock interaction throughout the batholith. The chemistry of FIs, determined using the evaporate mound method, is being used as a proxy for both the mineralizing and altering fluids. At present, results for >600 mounds determined for 68 samples indicate the fluids are dominated by Na-K-Ca-Cl-F, with traces of Fe, Mn, and S, and that two distinct types are present, one Na-rich and the other Ca-rich. Two intriguing results to date include: (1) the pervasive occurrence of F in the mound analysis with up to 40 wt% when normalized to 100%, even in samples distal to known mineralization; and (2) elevated Ca in many samples, including those from chemically evolved, hence Ca-depleted rocks. This latter feature may reflect extensive albitization of plagioclase, hence liberation of Ca, during fluid-mediated alteration. Thus, our preliminary findings clearly indicate that mappable variation in the degree and extent of alteration is retained in the main mineral phases of the granites and that fluid chemistry, preserved as secondary FIs in quartz, is a potential proxy for fluid:rock interaction and hence a measure of metal fertility.

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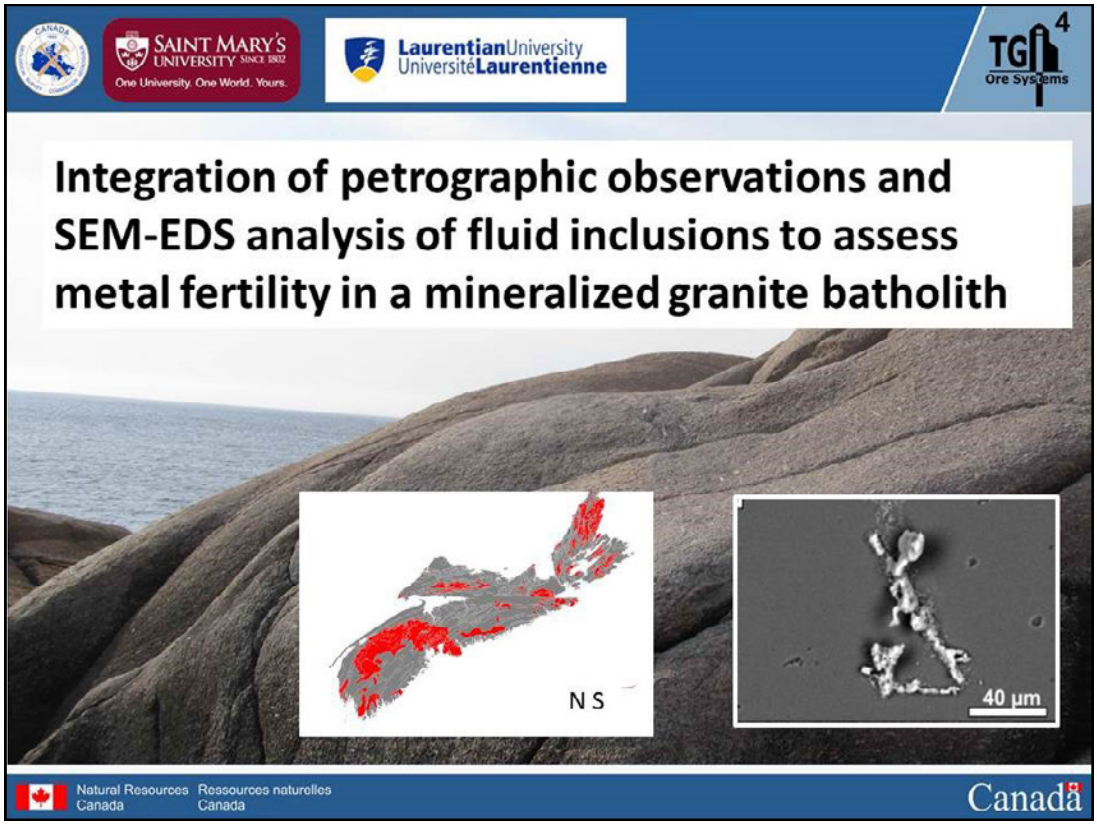


Research objectives

1) Evaluate (i) alteration textures preserved in granitic rocks from the study area and (ii) fluid chemistry of quartz-hosted fluid inclusions.

2) Evaluate the application of alteration indices and fluid chemistry to determine metal fertility of a mineralized batholith (i.e., South Mountain Batholith (SMB)).

As mandated by TGI-4 federal government program, this research provides a protocol and case study that can be exported to assess metal fertility of any mineralized batholith,

Presentation Outline

1) Study area

2) Methods and Analytical Considerations

3) Results

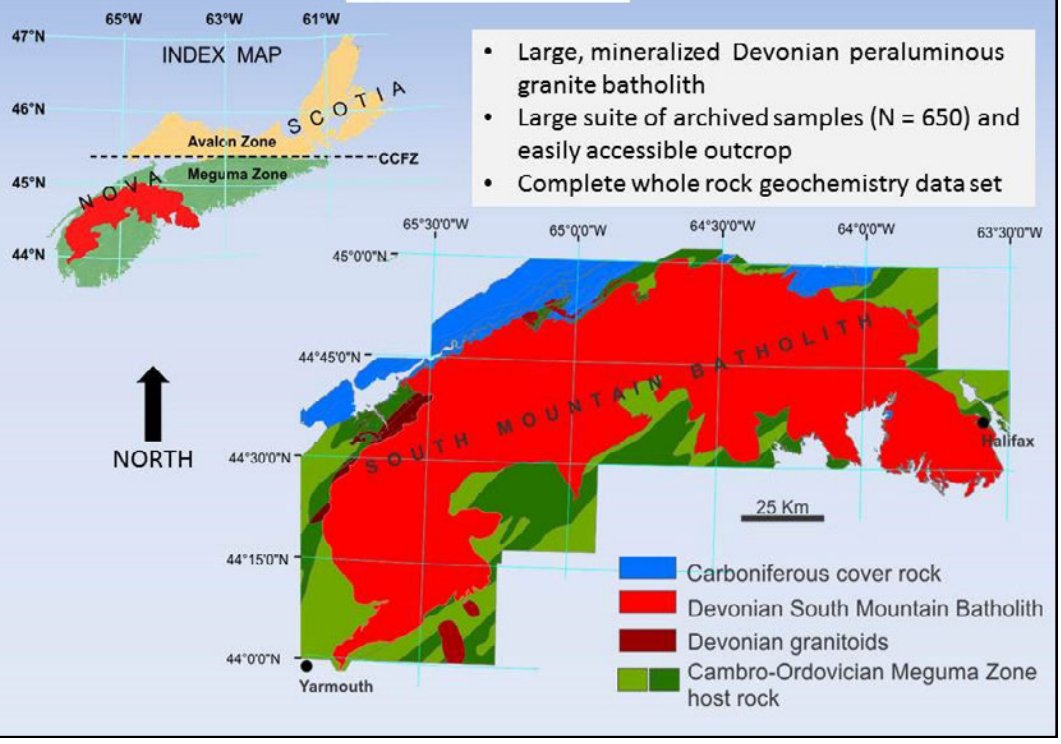
4) Evaluation of results

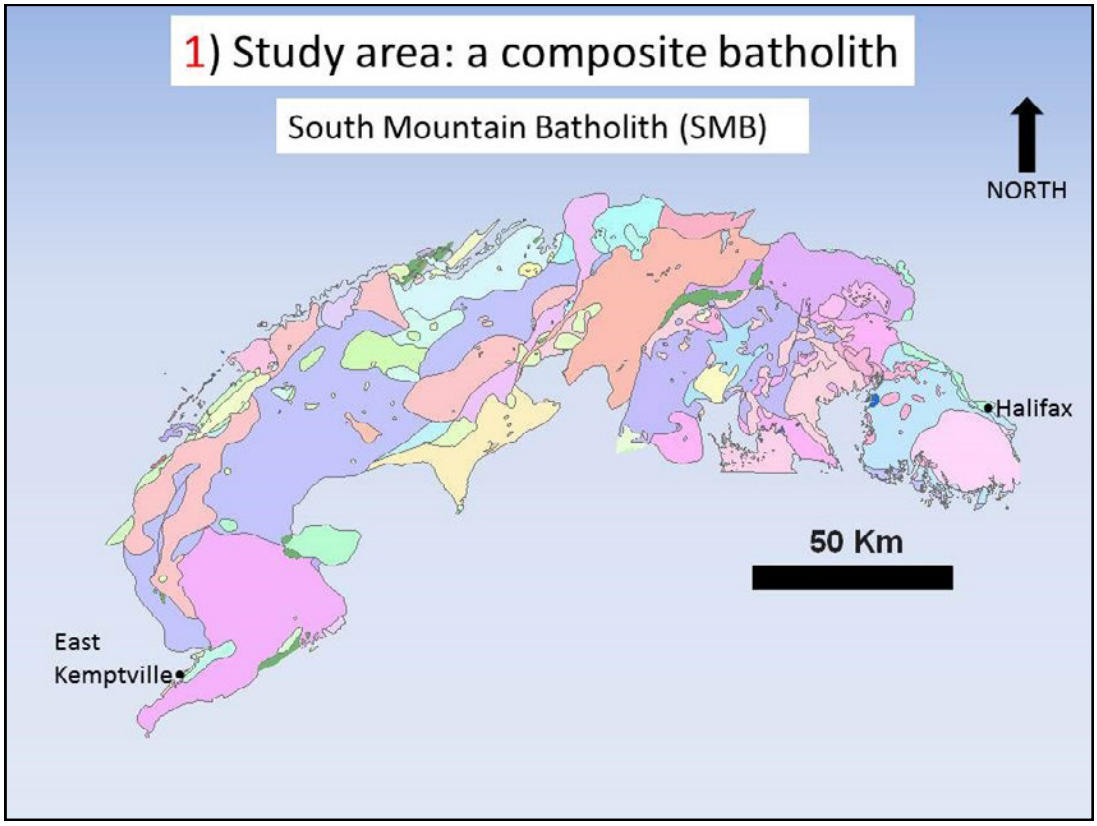
5) Conclusion

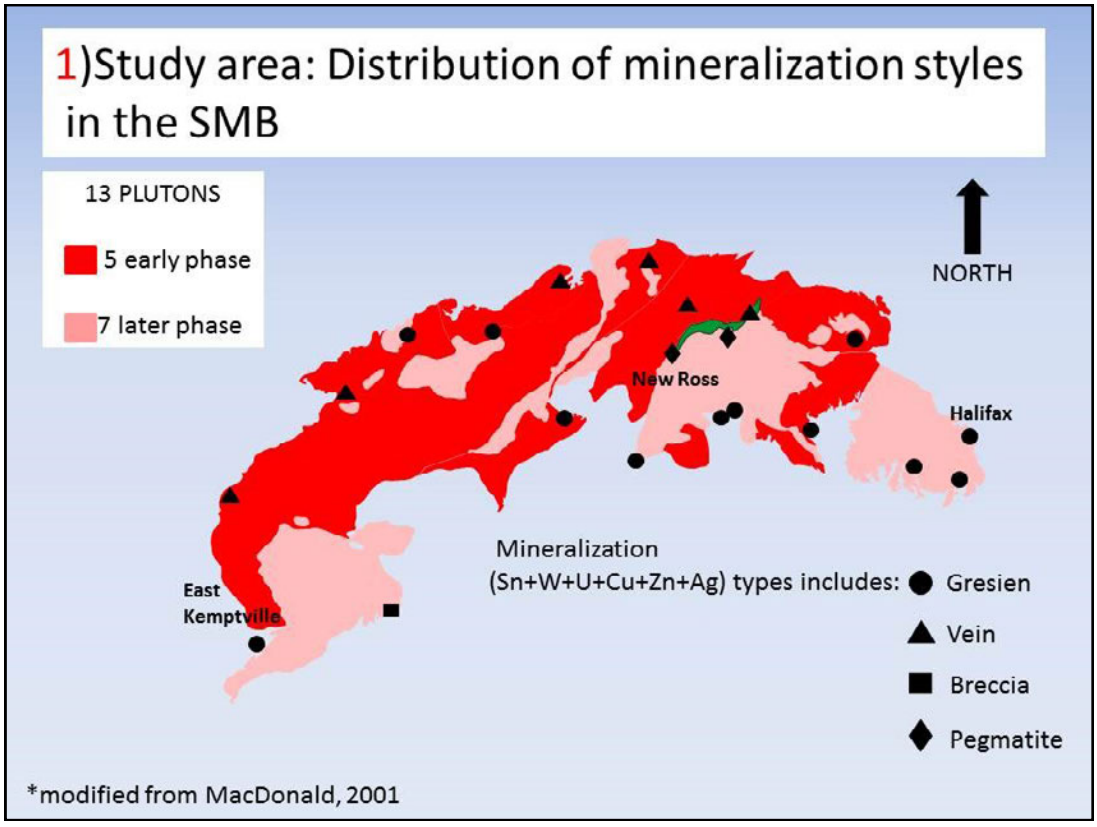
6) References

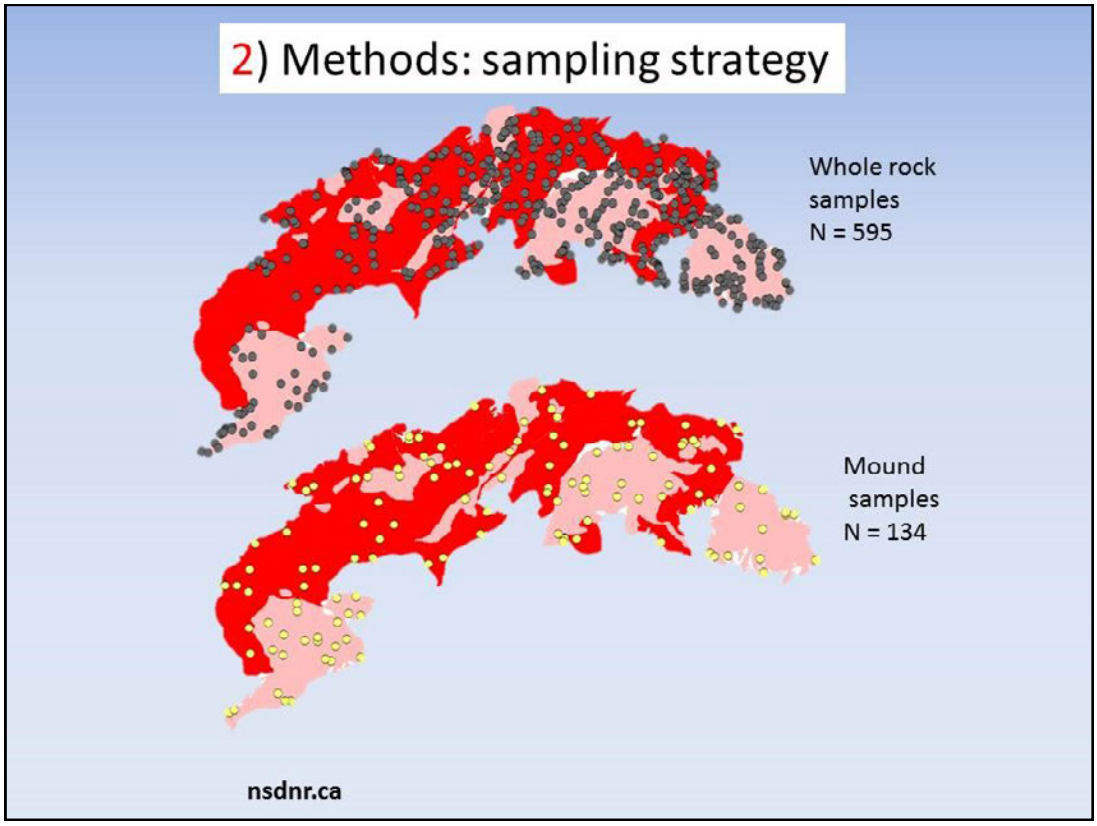
7) Acknowledgements

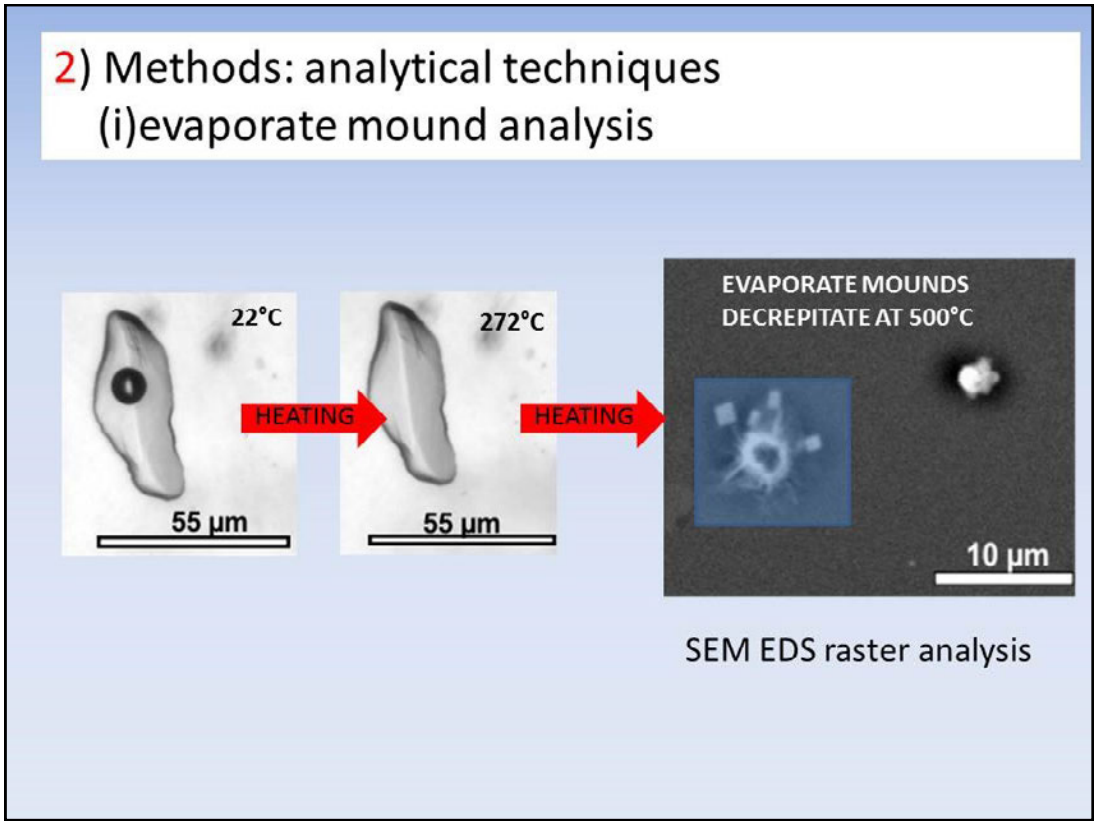
1) Study area

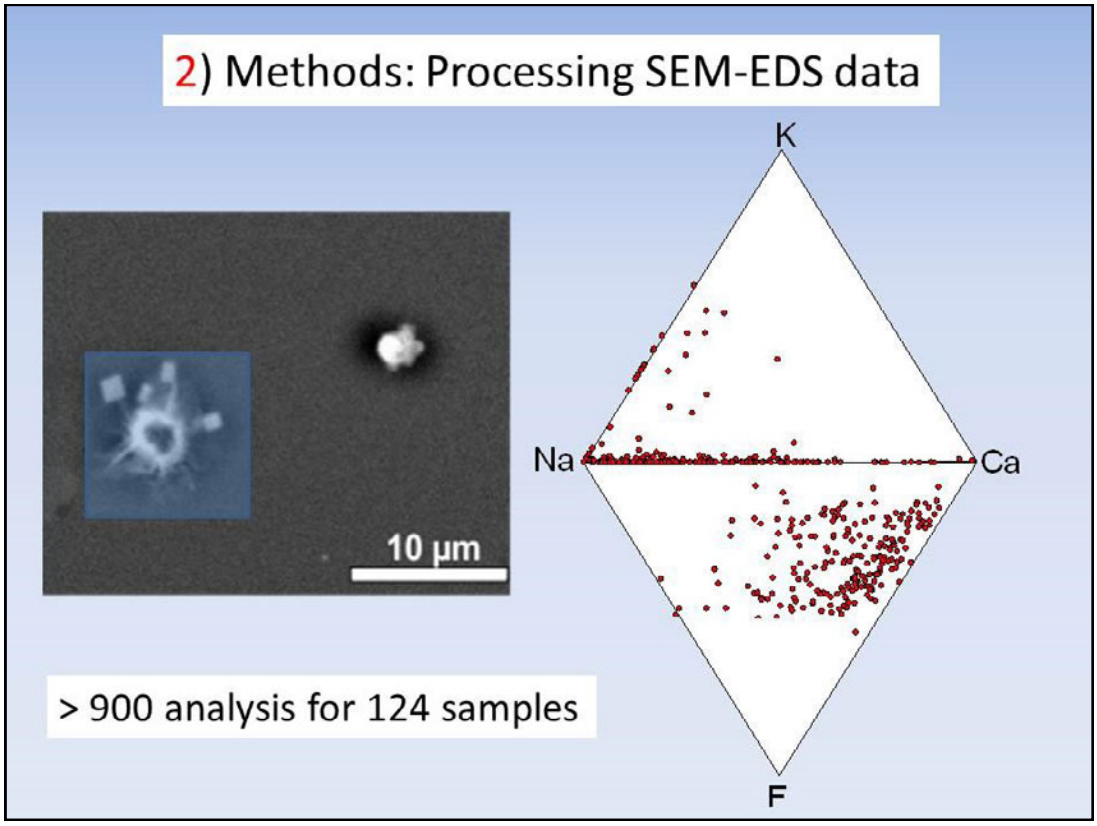


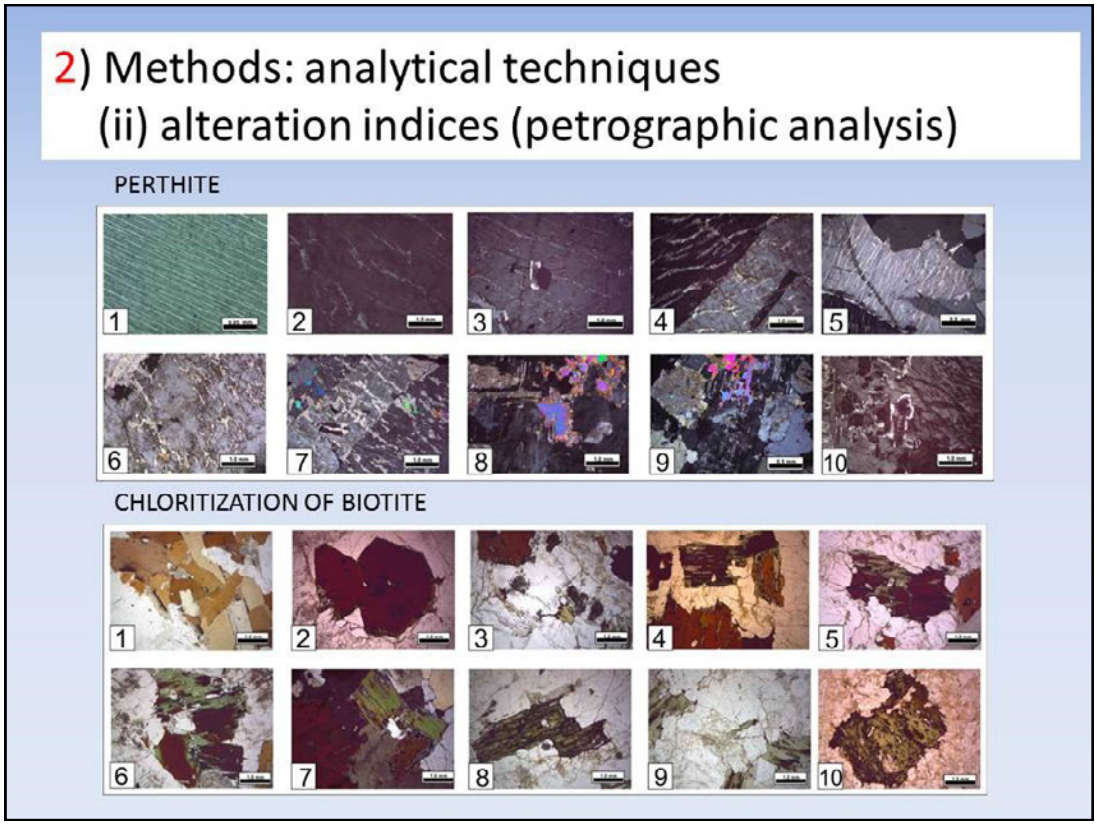

1) Study area: a composite batholith
South Mountain Batholith (SMB)
NORTH
Halifax
50 Km
East
Kemptville

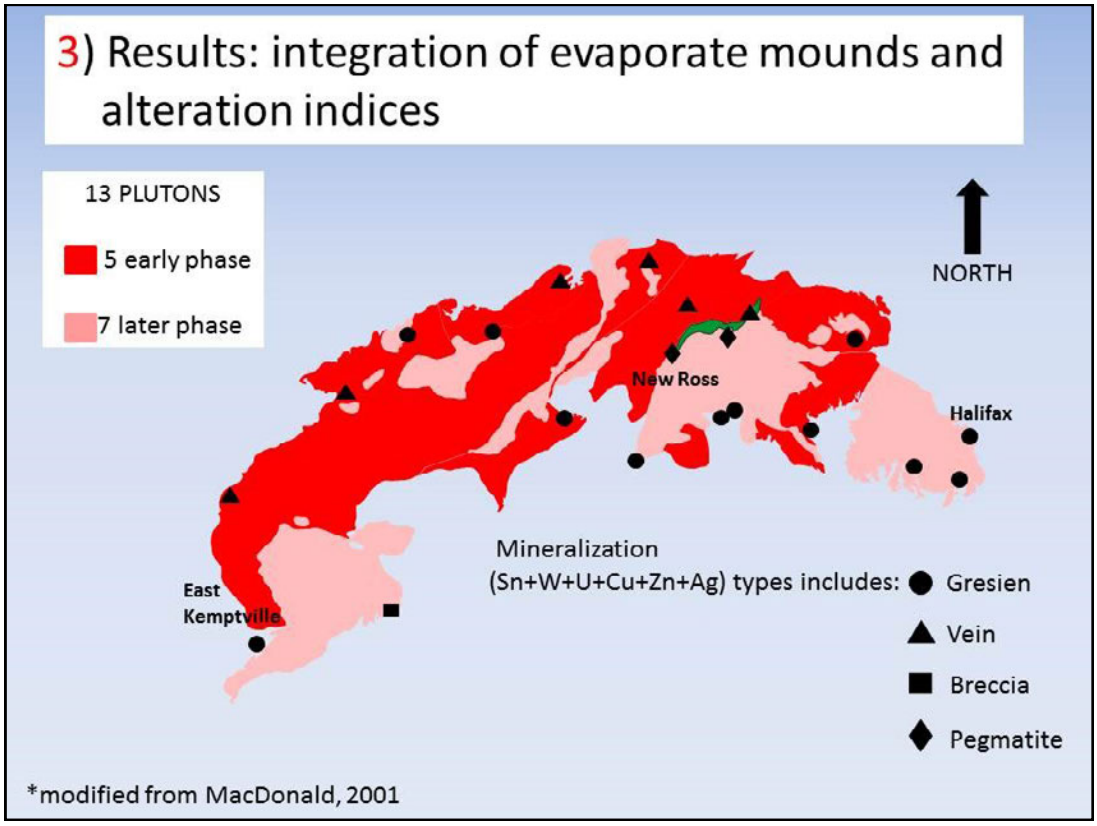

1)Study area: Distribution of mineralization styles in the SMB
13 PLUTONS
5 early phase
7 later phase
NORTH
New Ross
Halifax
East
Kemptville
Mineralization
(Sn+W+U+Cu+Zn+Ag) types includes:
Gresien
Vein
Breccia
Pegmatite
*modified from MacDonald, 2001

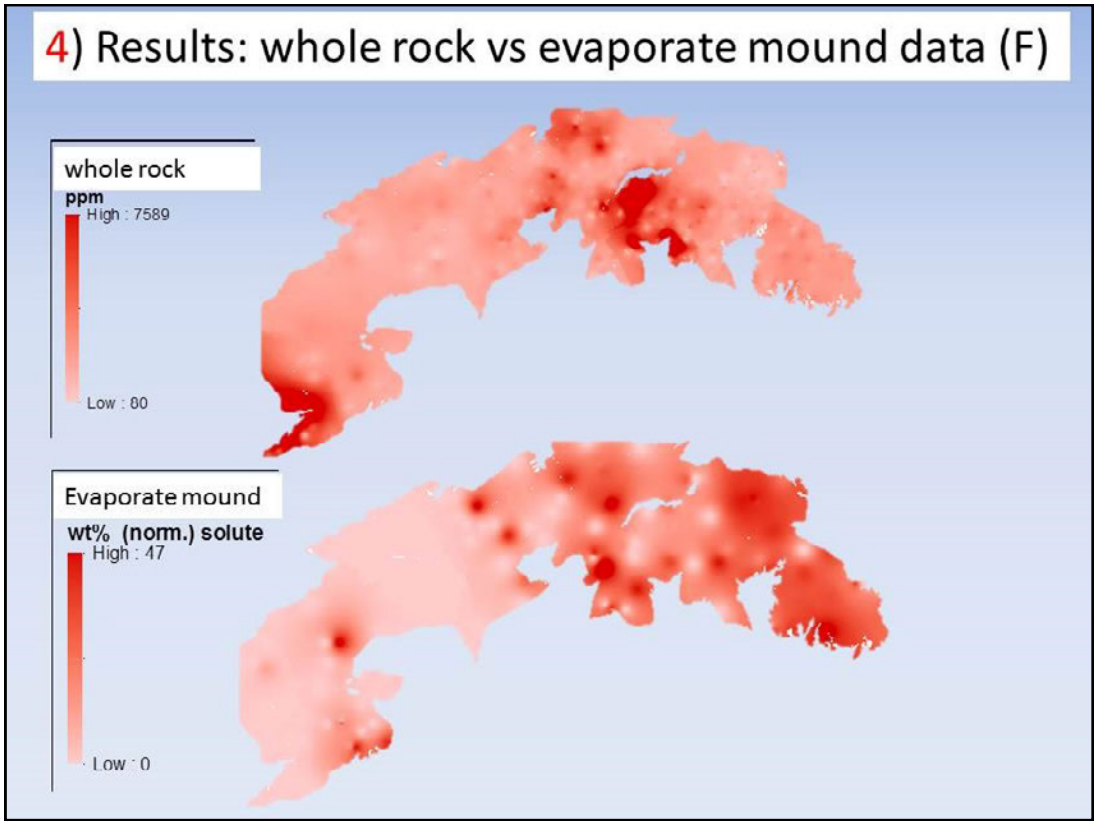

2) Methods: sampling strategy
Whole rock samples N = 595
Mound samples N = 134
nsdnr.ca

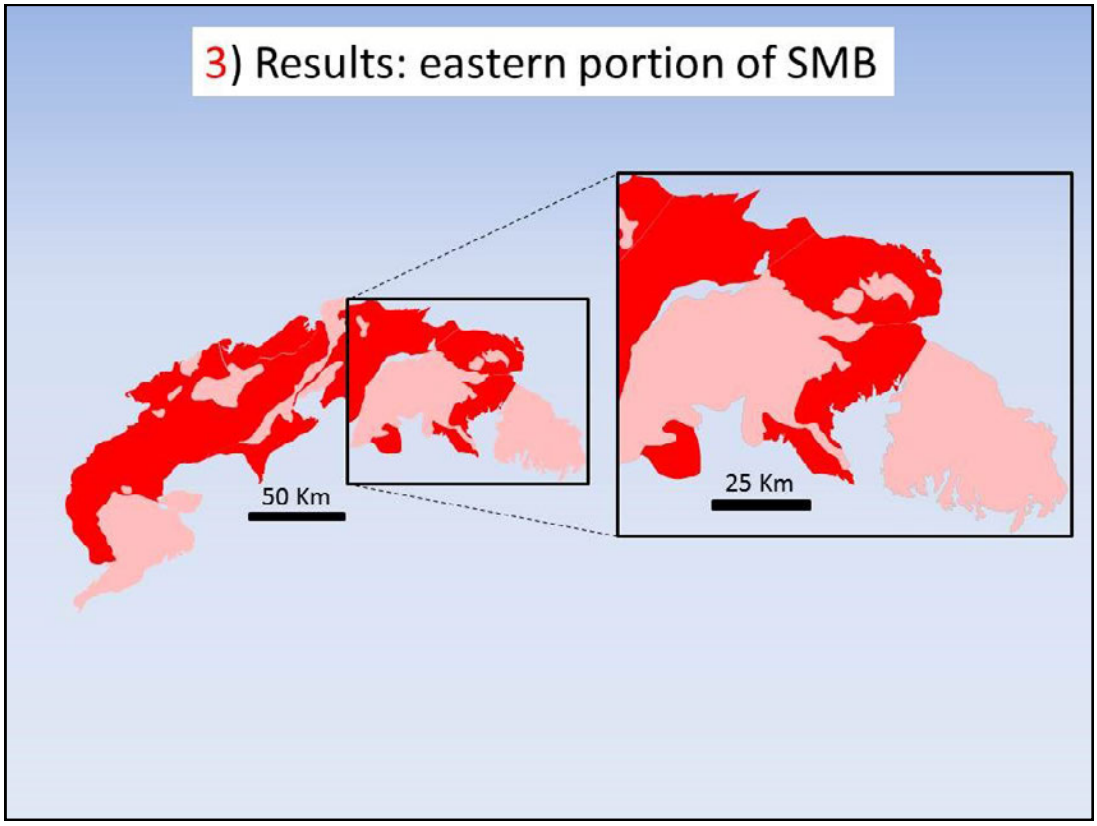

2) Methods: analytical techniques
(i)evaporate mound analysis
22°C
55 µm
HEATING
272°C
55 µm
HEATING
EVAPORATE MOUNDS DECREPITATE AT 500°C
10 µm
SEM EDS raster analysis

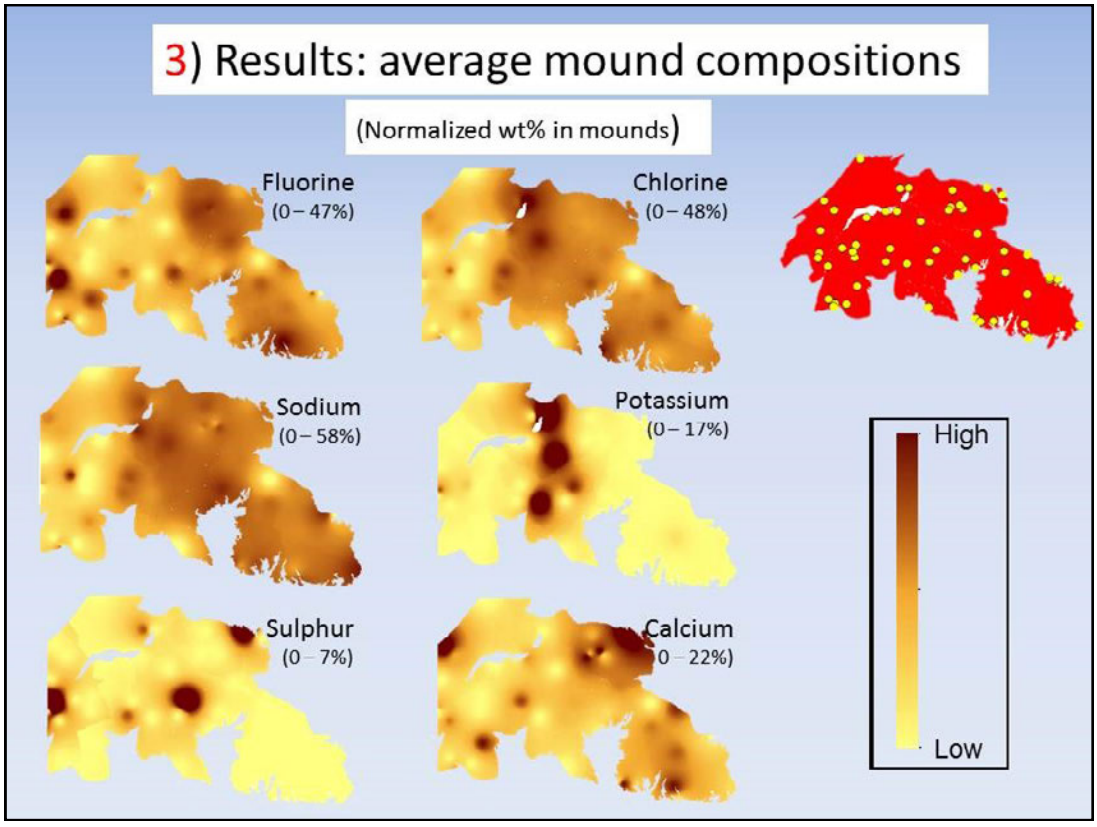

2) Methods: Processing SEM-EDS data
10 µm
K
Na
Ca
F
> 900 analysis for 124 samples

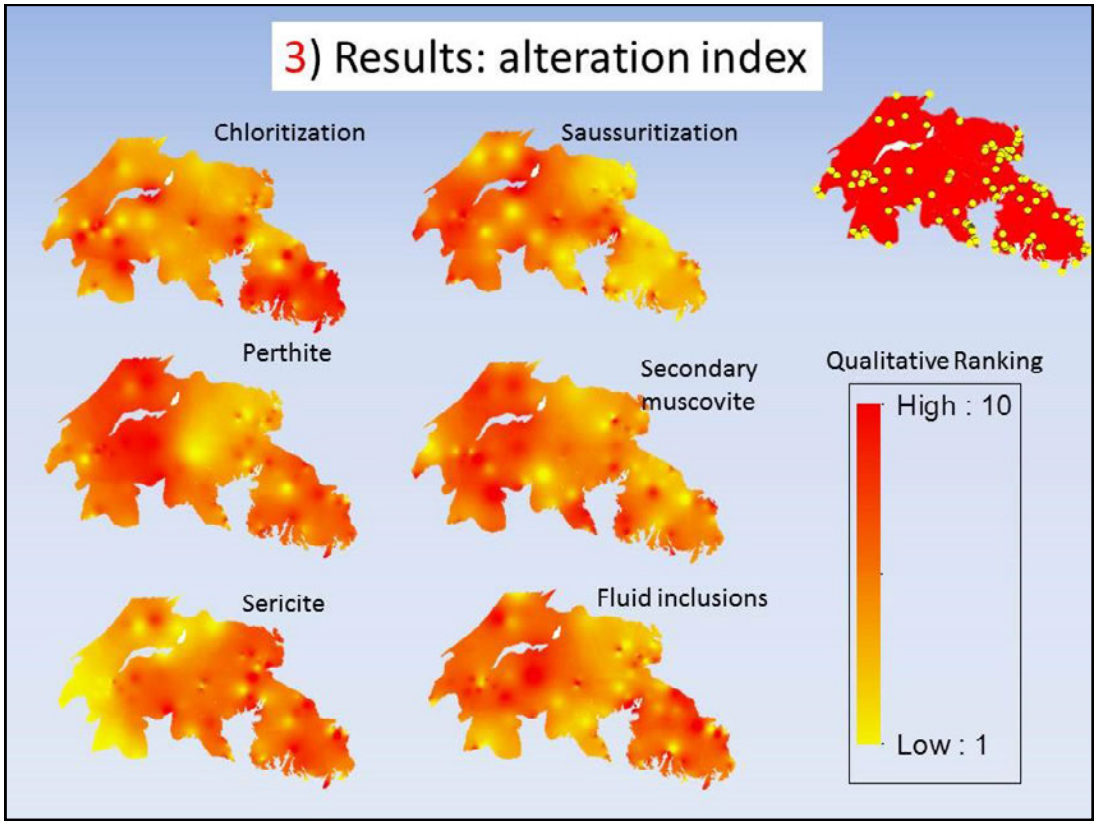

2) Methods: analytical techniques
(ii) alteration indices (petrographic analysis)
PERTHITE
1
2
3
4
5
6
7
8
9
10
CHLORITIZATION OF BIOTITE
1
2
3
4
5
6
7
8
9
10

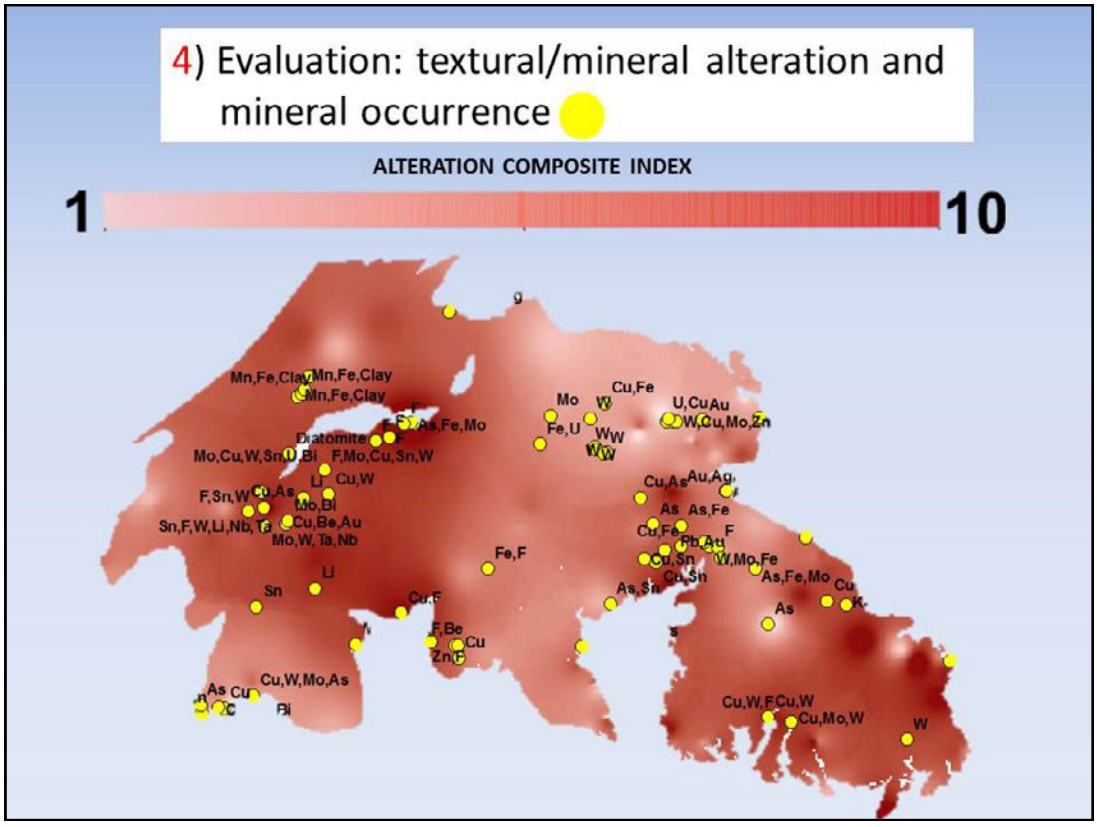

3) Results: integration of evaporate mounds and alteration indices
13 PLUTONS
5 early phase
7 later phase
NORTH
New Ross
Halifax
East Kemptville
Mineralization
(Sn+W+U+Cu+Zn+Ag) types includes:
Gresien
Vein
Breccia
Pegmatite
*modified from MacDonald, 2001

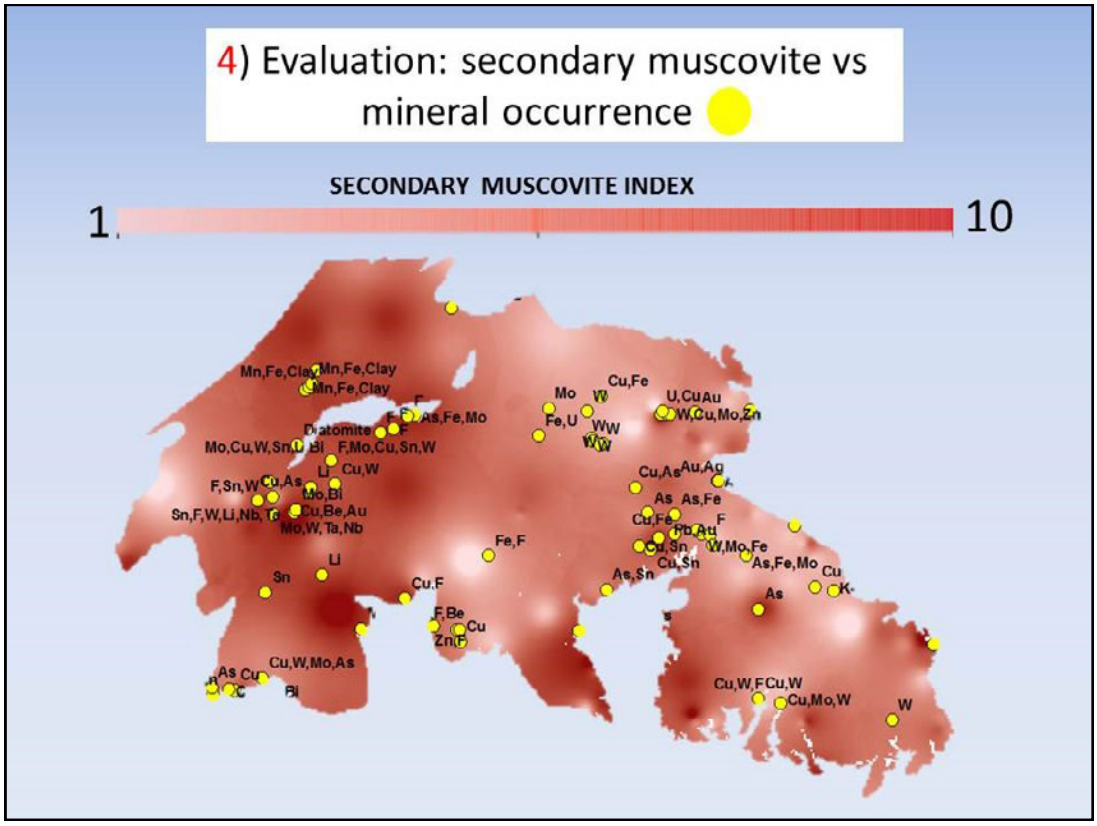

4) Results: whole rock vs evaporate mound data (F)
whole rock
ppm
High : 7589
Low : 00
Evaporate mound
wt% (norm.) solute
High : 47
Low : 0

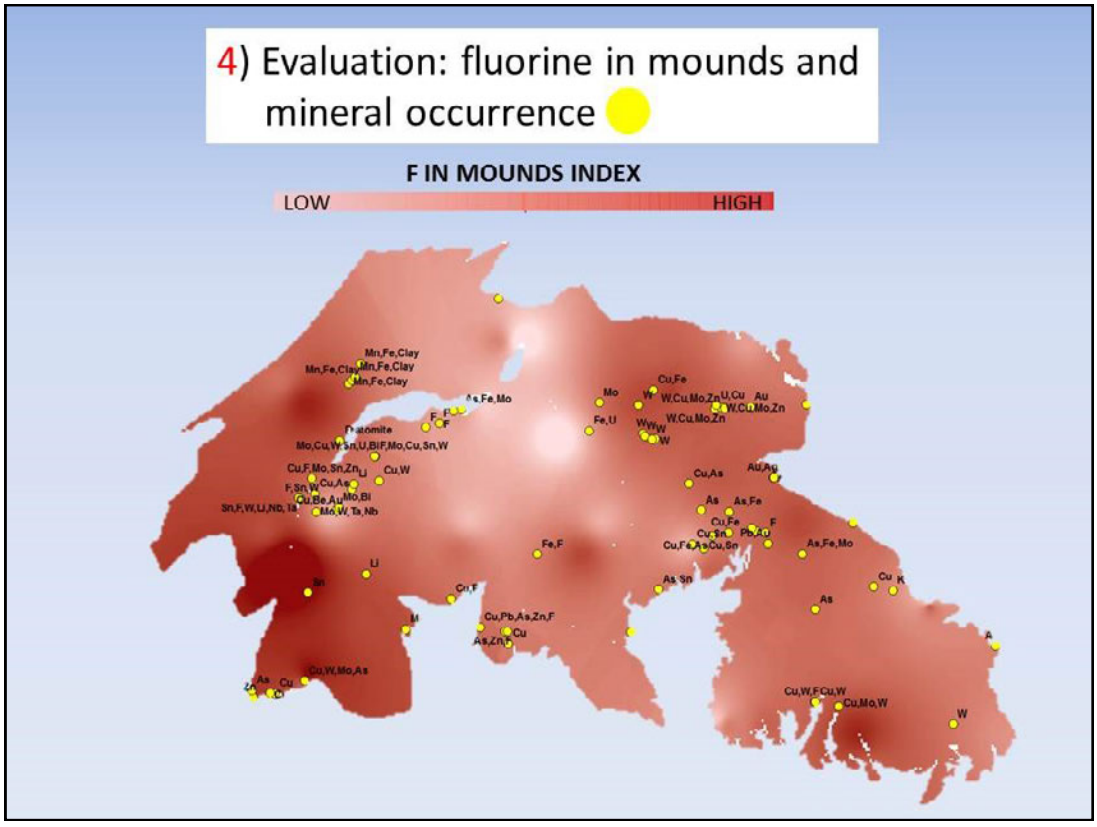

3) Results: eastern portion of SMB
50 Km
25 Km

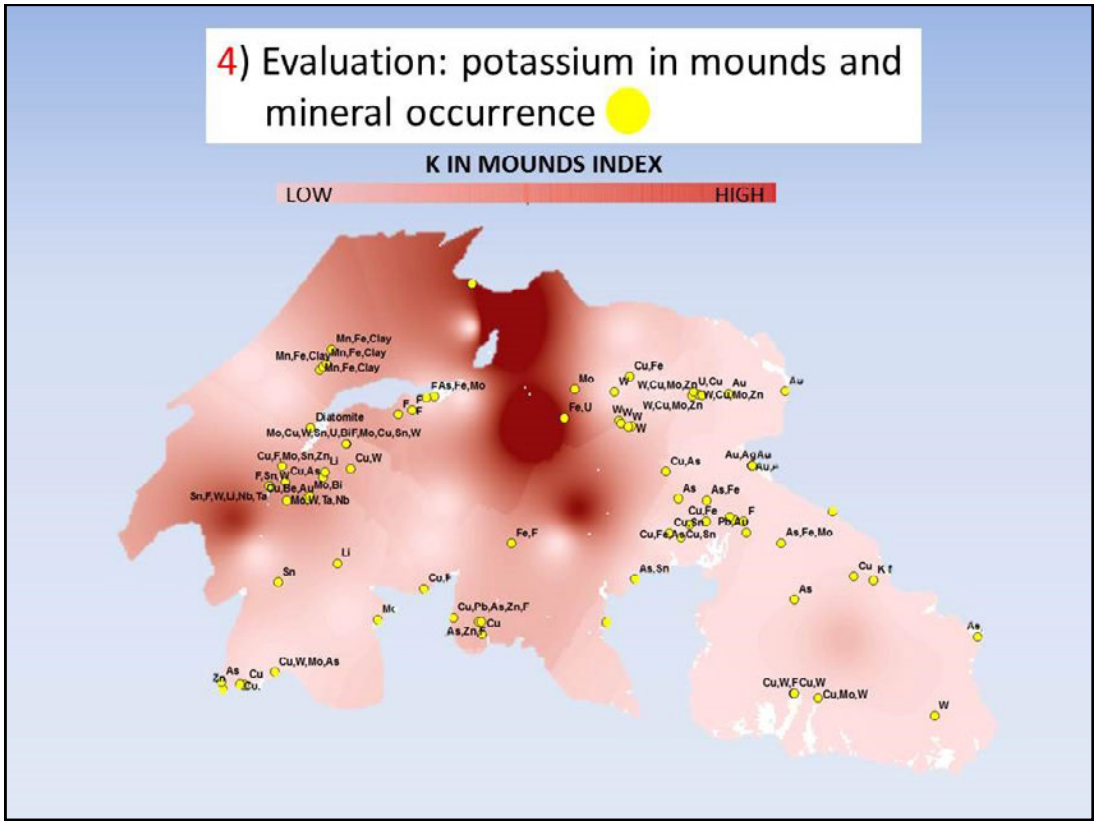

3) Results: average mound compositions
(Normalized wt% in mounds)
Fluorine
(0 – 47%)
Chlorine
(0 – 48%)
Sodium
(0 – 58%)
Potassium
(0 – 17%)
Sulphur
(0 – 7%)
Calcium
(0 – 22%)
High
Low

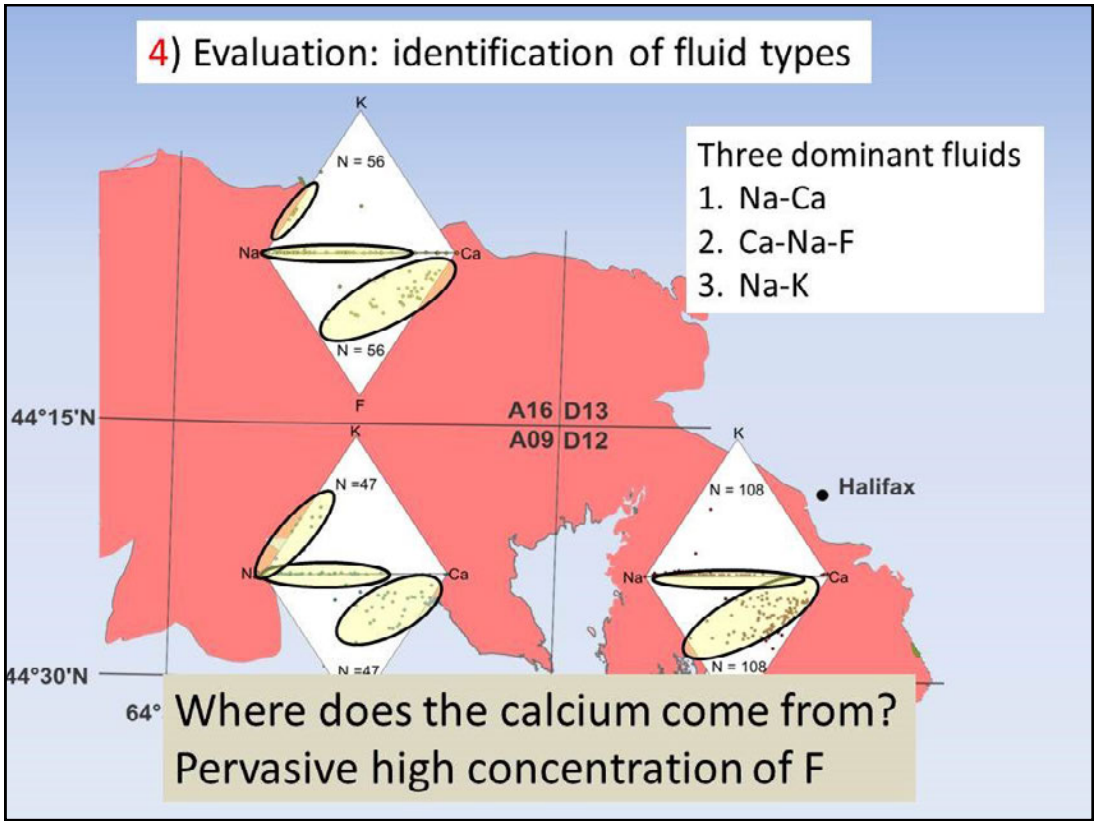

3) Results: alteration index
Chloritization
Saussuritization
Perthite
Secondary muscovite
Sericite
Fluid inclusions
Qualitative Ranking
High : 10
Low : 1


4) Evaluation: textural/mineral alteration and mineral occurrence
ALTERATION COMPOSITE INDEX
1
10


4) Evaluation: secondary muscovite vs mineral occurrence
SECONDARY MUSCOVITE INDEX
1
10
Mn,Fe,Clay
Mn,Fe,Clay
Mn,Fe,Clay
Diatomite
Mo,Cu,W,Sn,U,Bi
F,Mo,Cu,Sn,W
Li
Cu,W
F,Sn,W
Cu,As
Mo,Bi
Sn,F,W,Li,Nb,Ta
Cu,Be,Au
Mo,W,Ta,Nb
Li
Sn
Cu,F
F,Be
Cu
Zn,F
As,Cu
Cu,W,Mo,As
Bi
Fe,F
Mo
Cu,Fe
U,Cu,Au
W,Cu,Mo,Zn
Fe,U
Cu,As
Au,Ag
As
As,Fe
Cu,Fe
F
Pb,Au
W,Mo,Fe
Cu,Sn
As,Fe,Mo
Cu
As,Sn
As
K
Cu,W,F
Cu,W
Cu,Mo,W
W


4) Evaluation: fluorine in mounds and mineral occurrence
F IN MOUNDS INDEX
LOW
HIGH
Mn,Fe,Clay
Mn,Fe,Clay
Mn,Fe,Clay
Diatomite
Mo,Cu,W,Sn,U,Bi
F,Mo,Cu,Sn,W
Cu,F,Mo,Sn,Zn
Li
Cu,W
F,Sn,W
Cu,As
Mo,Bi
Sn,F,W,Li,Nb,Ta
Cu,Be,Au
Mo,W,Ta,Nb
Li
Sn
Cu,F
Cu,Pb,As,Zn,F
Cu
As,Zn
As,Cu
Cu,W,Mo,As
Fe,F
Mo
Cu,Fe
W,Cu,Mo,Zn
Li,Cu
Au
W,Cu,Mo,Zn
Fe,Li
W,Cu,Mo,Zn
Cu,As
Au,Ag
As
As,Fe
Cu,Fe
F
Cu,Sn
Pb,Au
Cu,Fe,As,Cu,Sn
As,Fe,Mo
Cu
K
As,Sn
As
A
Cu,W,F
Cu,W
Cu,Mo,W
W


4) Evaluation: potassium in mounds and mineral occurrence
K IN MOUNDS INDEX
LOW
HIGH


4) Evaluation: identification of fluid types
Three dominant fluids
1. Na-Ca
2. Ca-Na-F
3. Na-K
K
N = 56
Na
Ca
N = 56
F
44°15'N
A16 D13
A09 D12
K
K
N =47
N
Ca
N = 108
Halifax
Na
Ca
44°30'N
N =47
N = 108
64°
Where does the calcium come from?
Pervasive high concentration of F

5) CONCLUSIONS

- Evaluation of metal fertility of a batholith using integration of evaporate mound analysis and alteration indices is feasible
- Strong correlations between mineralized centres and alteration and evaporate mound compositions
- Abundance of calcium-rich fluids suggest batholith-wide albitization
- Abundance of F-rich fluids suggests presence of buried evolved intrusions below current level of exposure

6) References

MacDonald, M.A., 2001, Geology of the South Mountain Batholith, Southwestern Nova Scotia, Nova Scotia Department of Natural Resources, Open File Report ME 2001-2.

7) Acknowledgments

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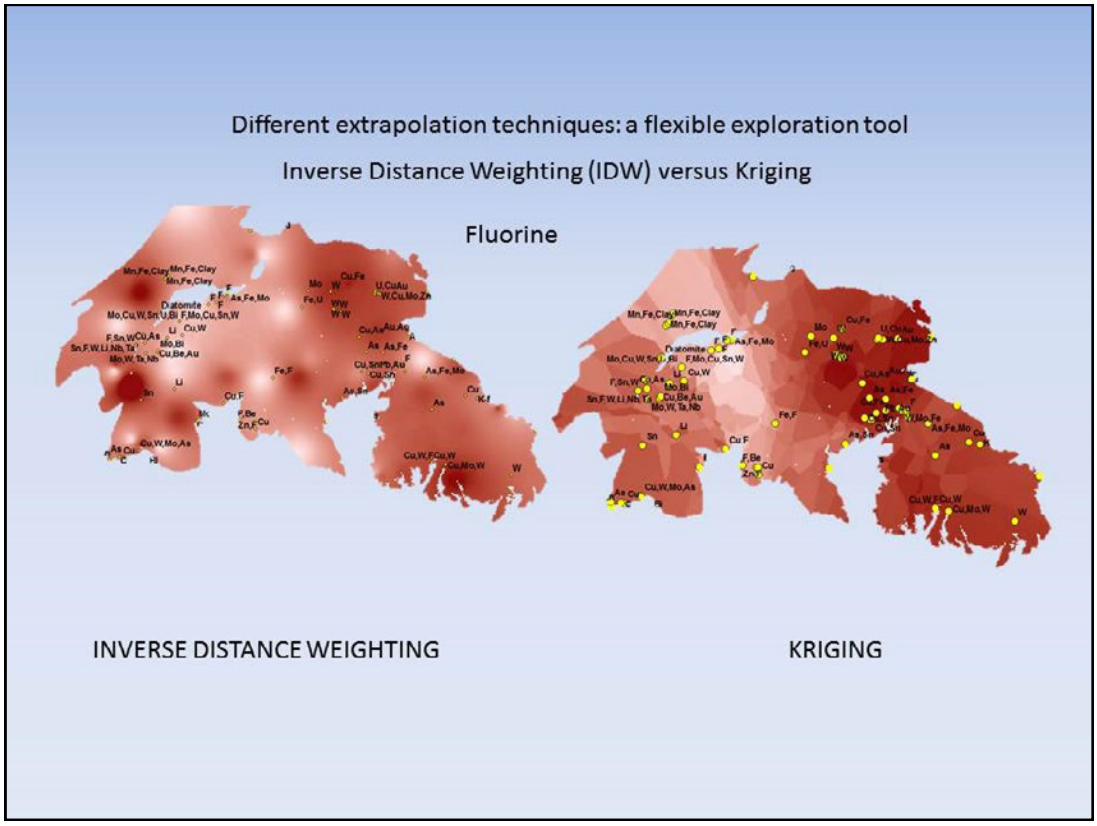
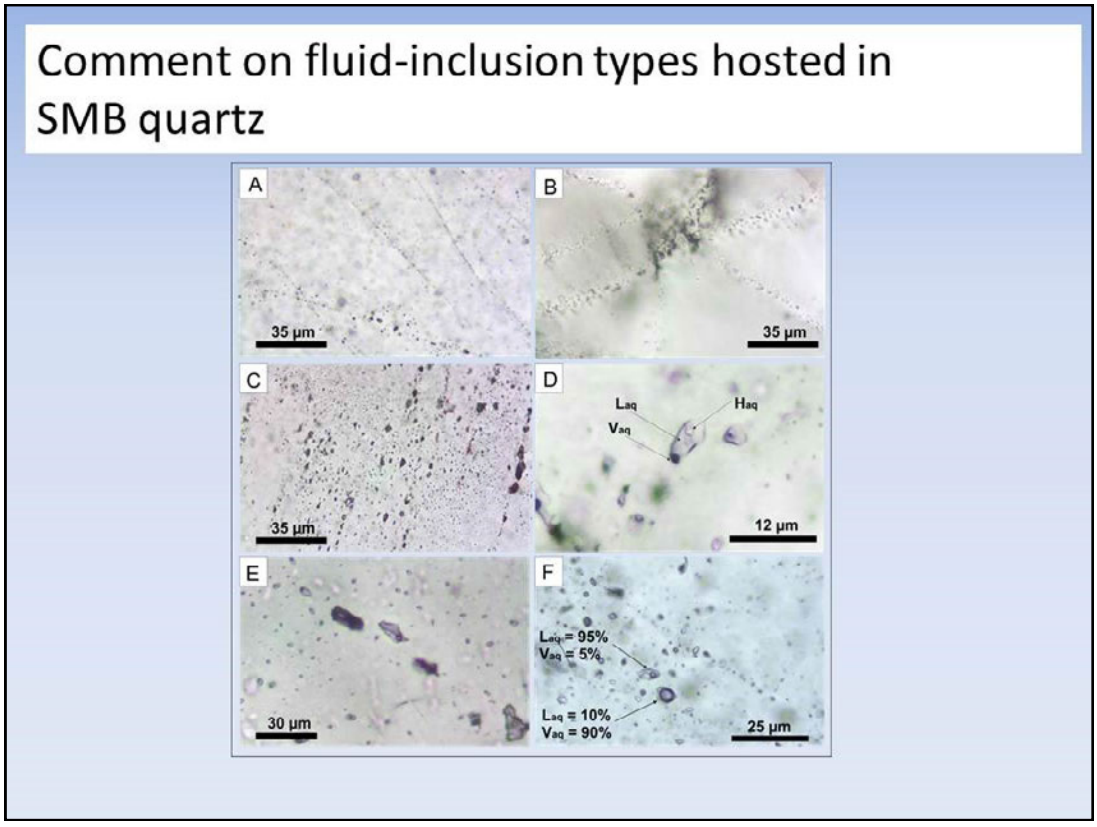

Different extrapolation techniques: a flexible exploration tool
Inverse Distance Weighting (IDW) versus Kriging
Fluorine
INVERSE DISTANCE WEIGHTING
KRIGING


Comment on fluid-inclusion types hosted in SMB quartz
A
35 µm
B
35 µm
C
35 µm
D
Laq
Haq
Vaq
12 µm
E
30 µm
F
Laq = 95%
Vaq = 5%
Laq = 10%
Vaq = 90%
25 µm