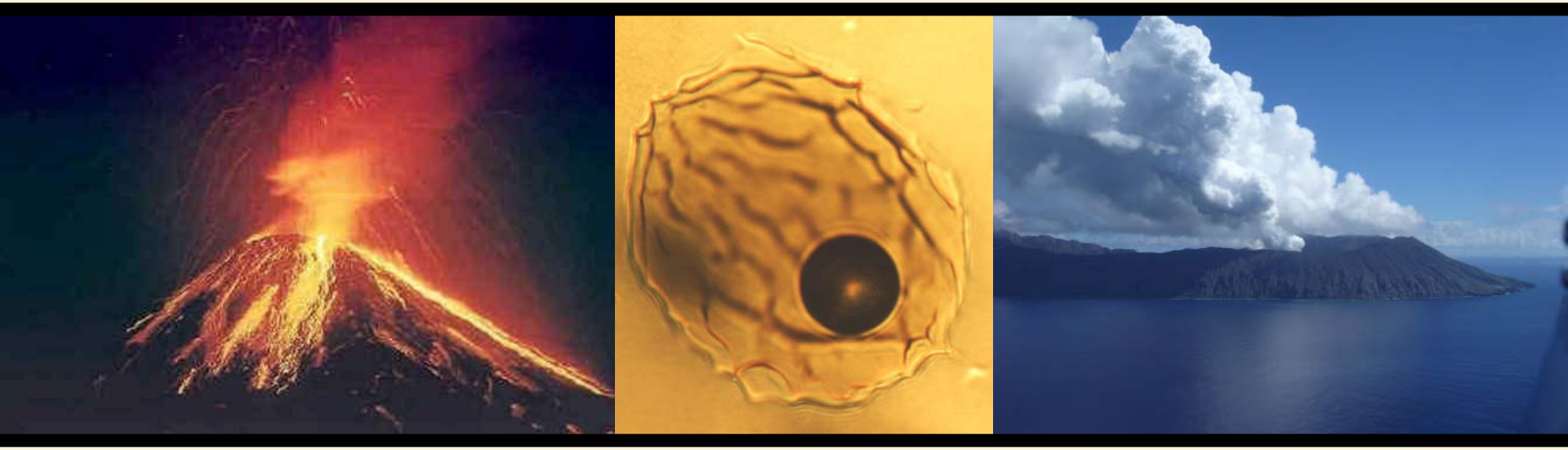
Melt Inclusions in Primitive Basalts

Adam Kent, Oregon State University



MARGINS

NSF

VIPER

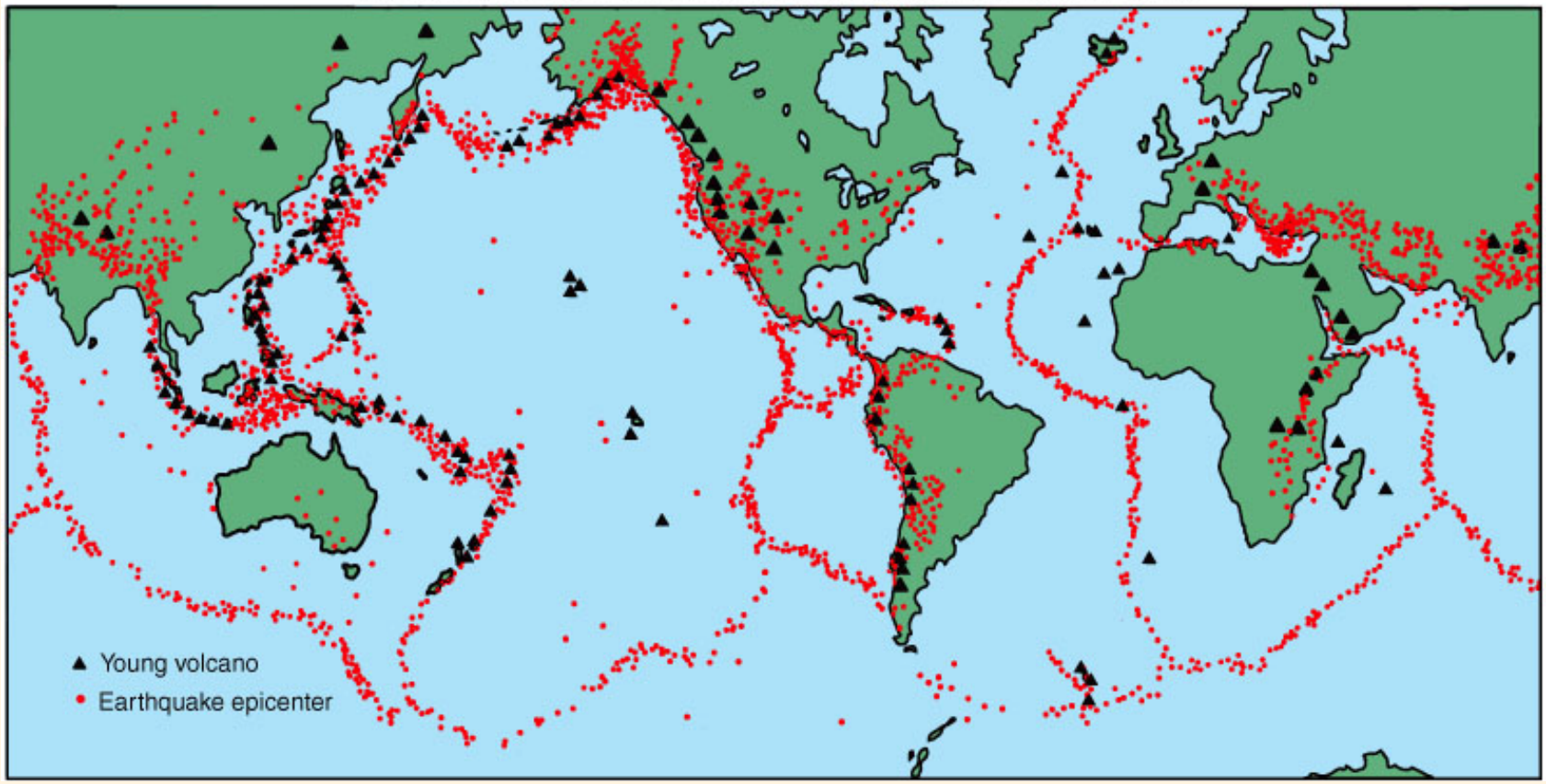
OSU Oregon State University

Key Questions

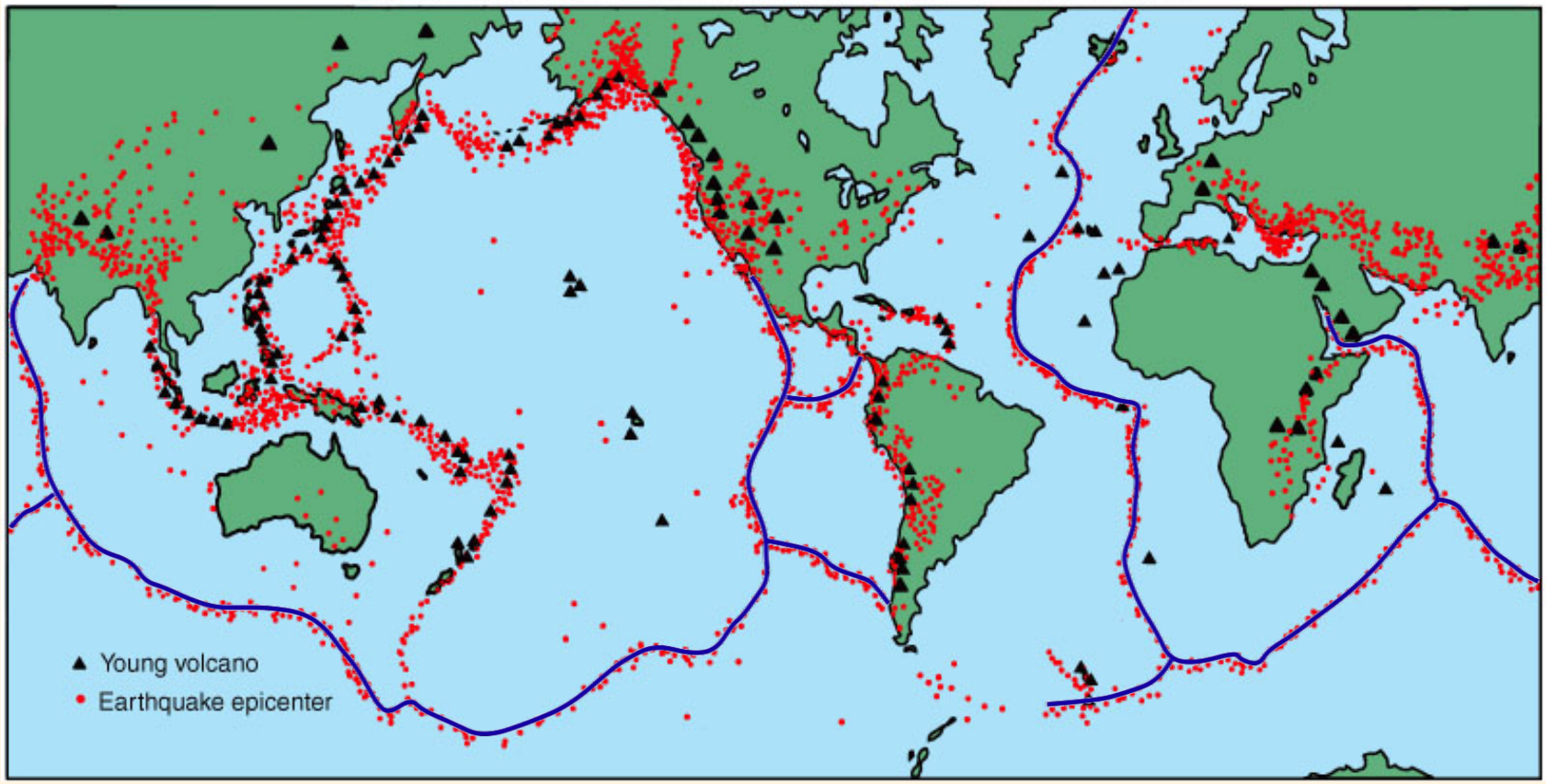
- What information do melt inclusions in primitive basalts provide?
- Where do variations in melt inclusions derive from?
- How do primitive magmas get processed by magma transport and eruption?

The message from melt inclusions: Variability

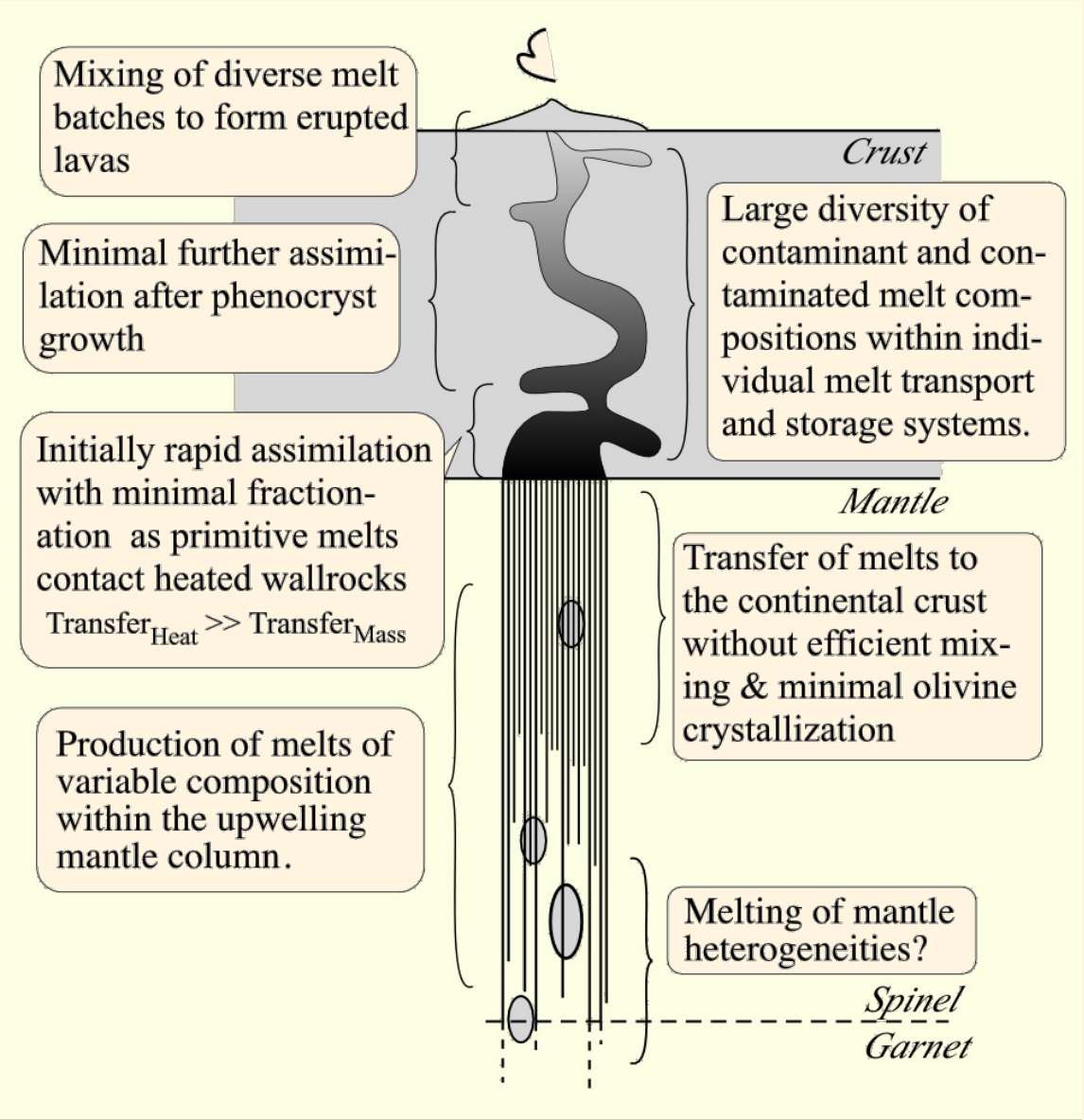
- In many basaltic systems it is clear that the primary control on melt inclusion compositions is the variability of melts present within the system
  - These are sampled by erupted lavas as well, but are homogenized
  - Implies large scale mixing of smaller melt “batches” is extremely widespread
- Melt inclusions and host lavas related by mixing



Why study (any) magmatism?

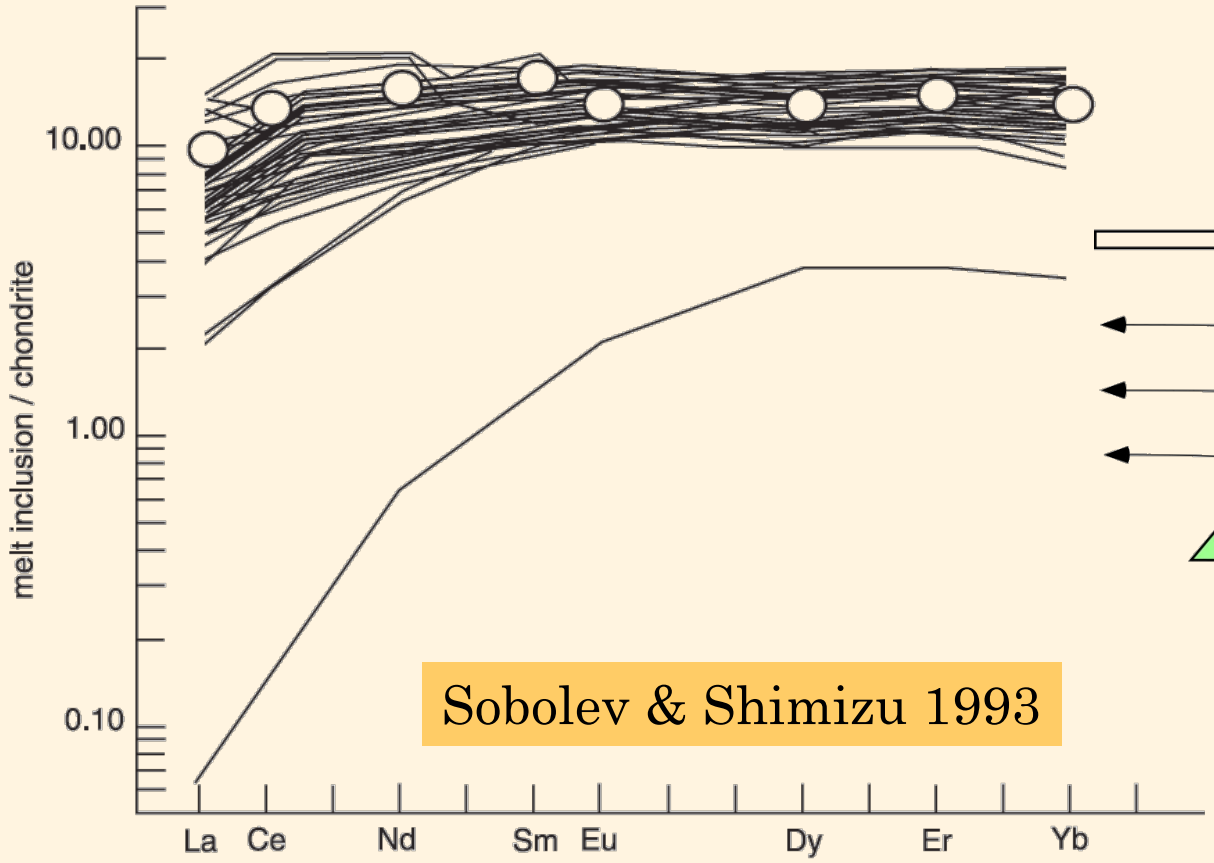


Why study (any) magmatism?

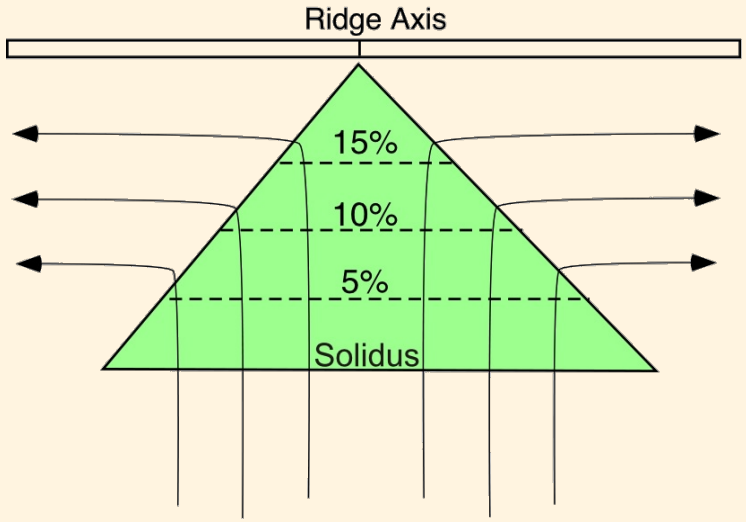


- Basaltic melt generation and transport systems are variable at scales smaller than individual eruptive units (factors of 10's)
- Phenocrysts show this, and some lavas too
- Melt inclusions sample this variation

Melt inclusions from MORB Mid Atlantic Ridge, 9° N

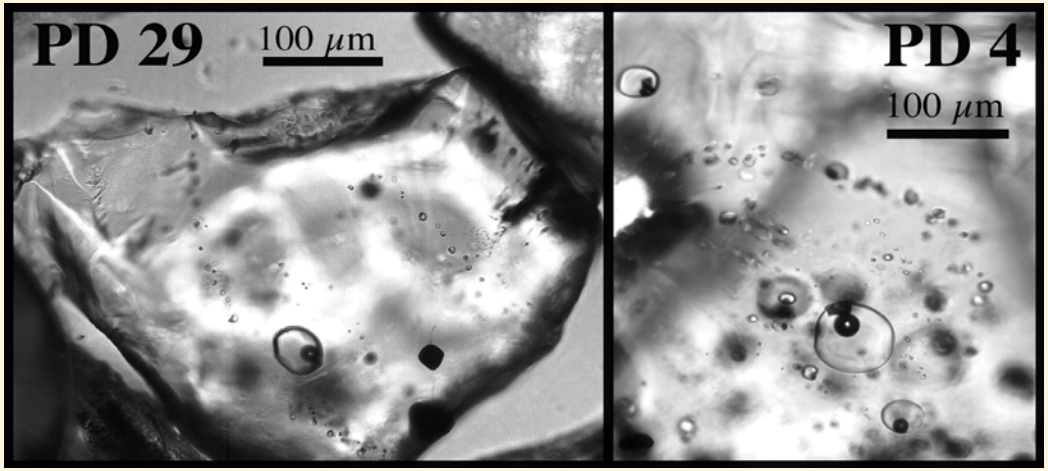


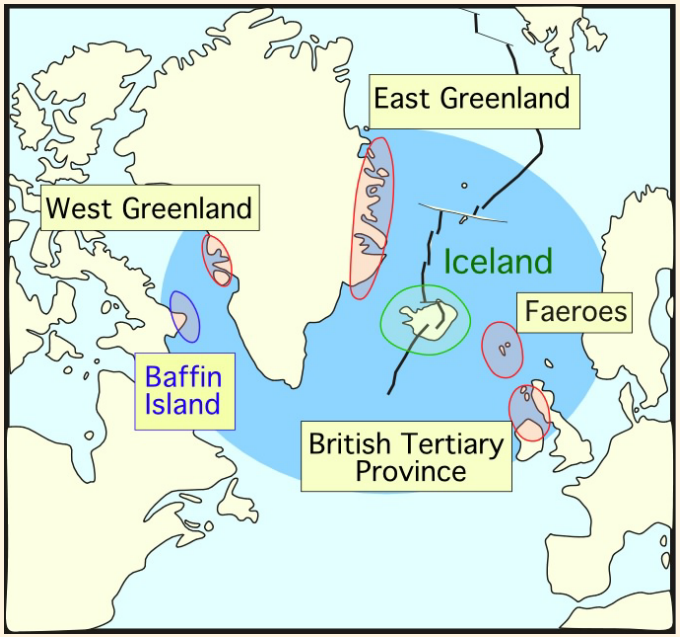
Sobolev & Shimizu 1993

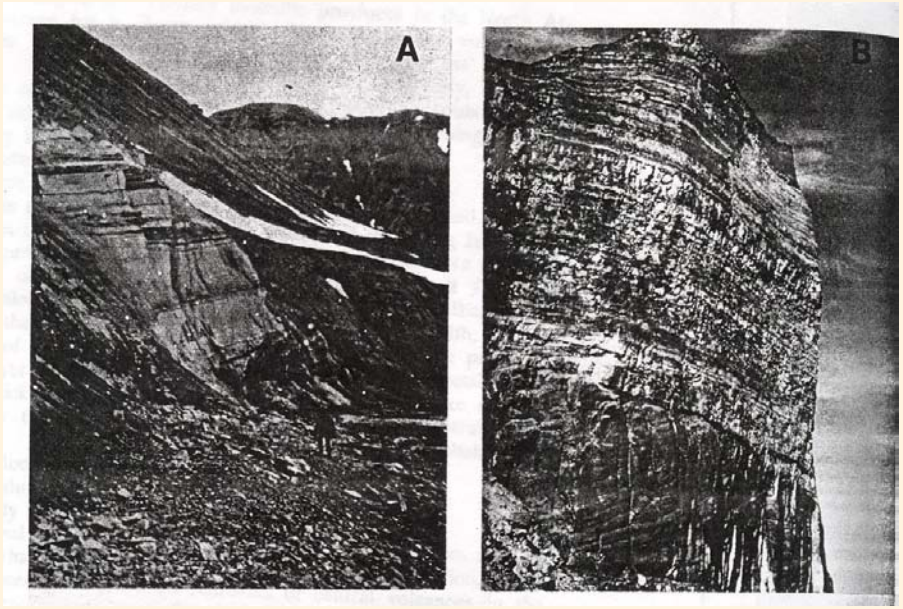


How does processing in a magma transport system effect lava and melt inclusion compositions?

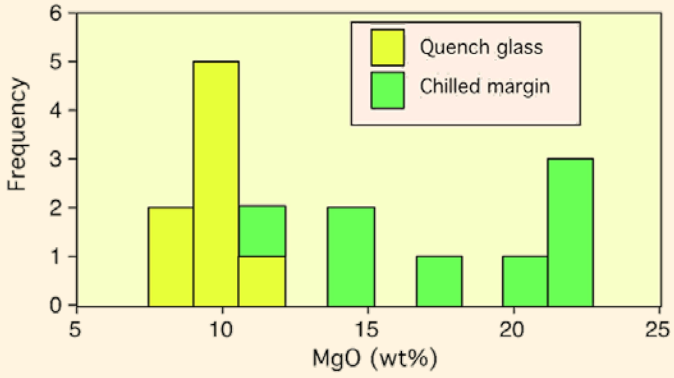
Baffin Island Tertiary lavas

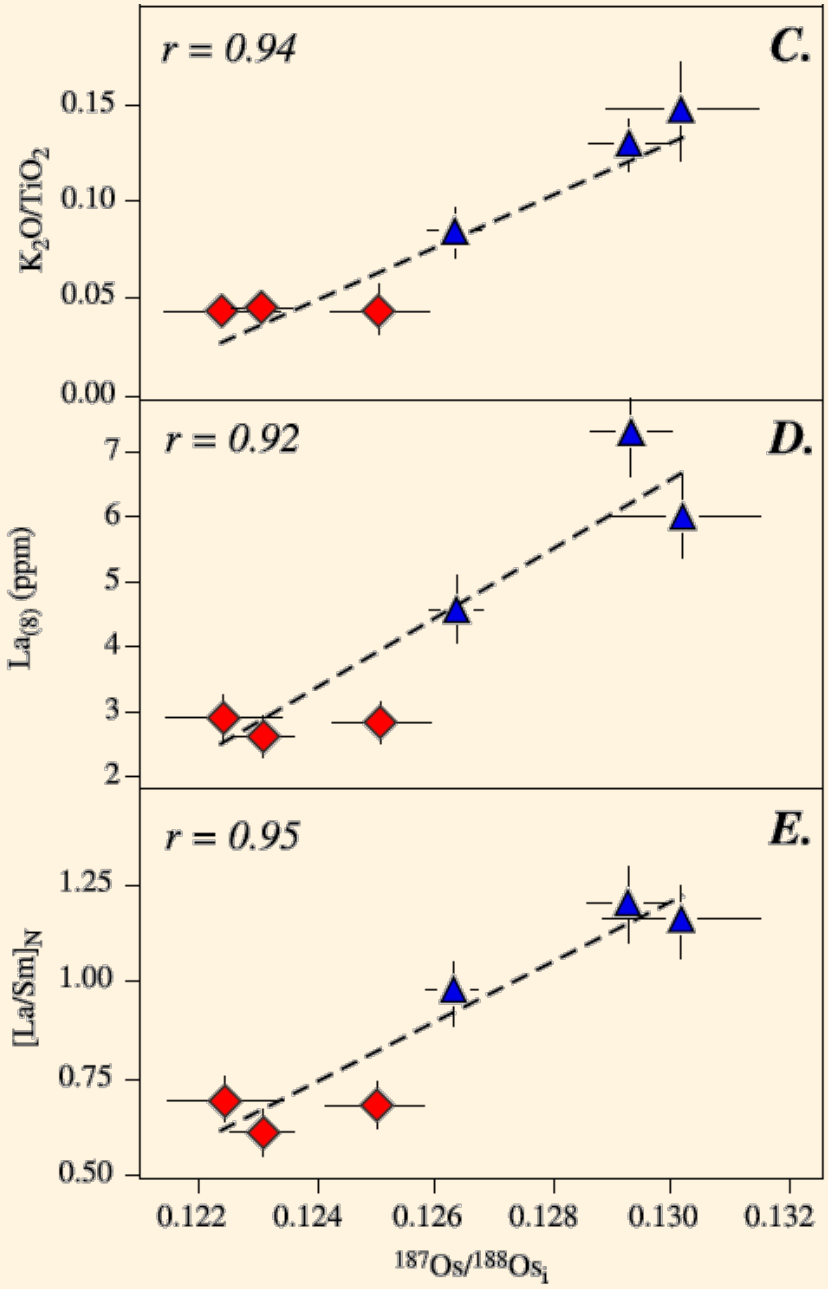






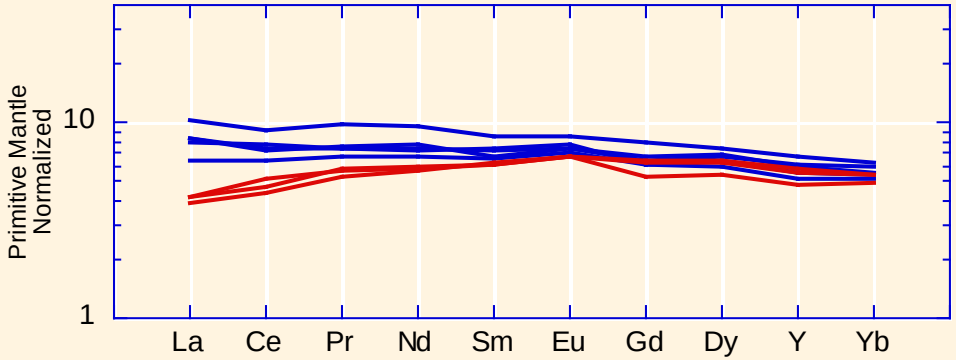
Clarke 1970

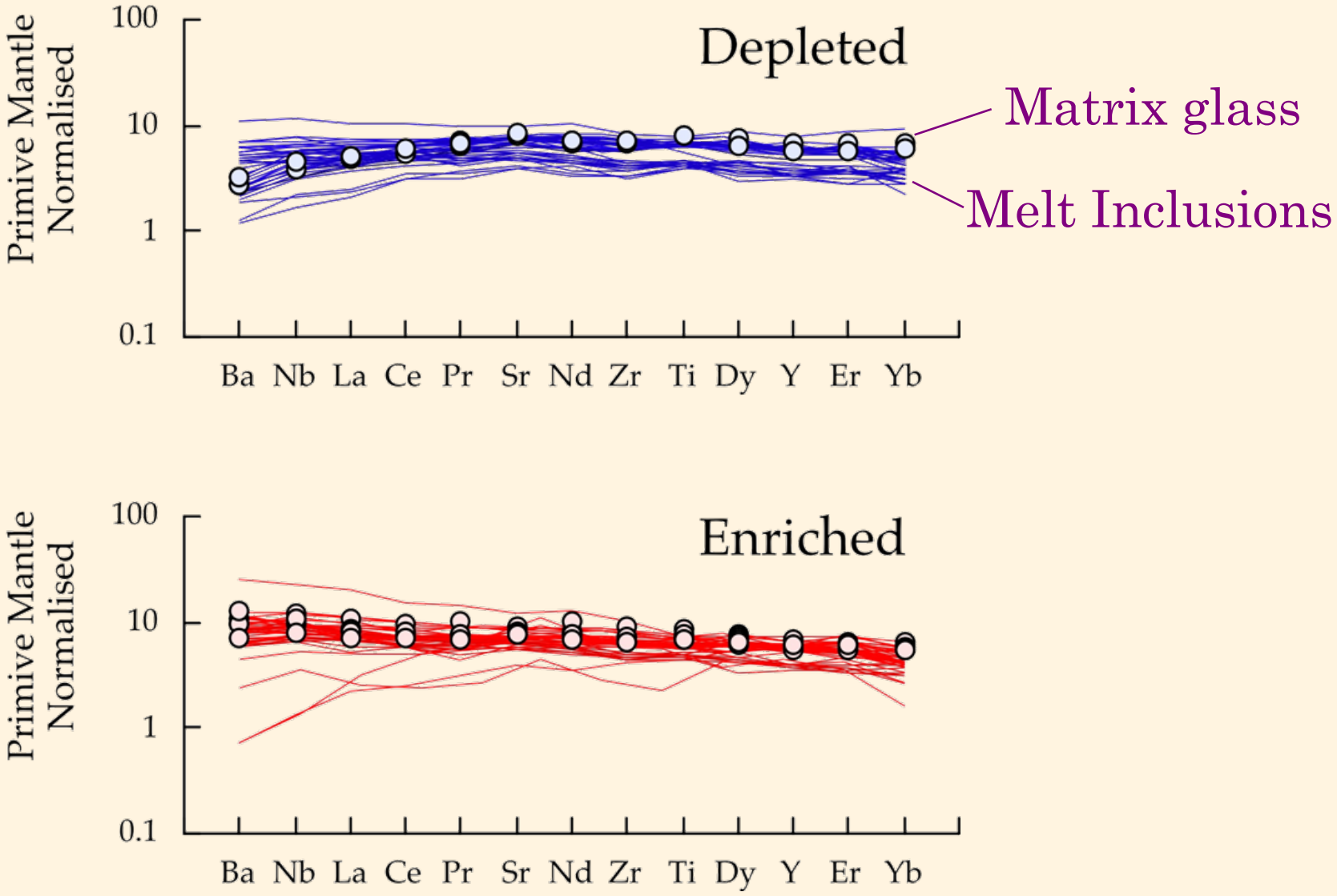


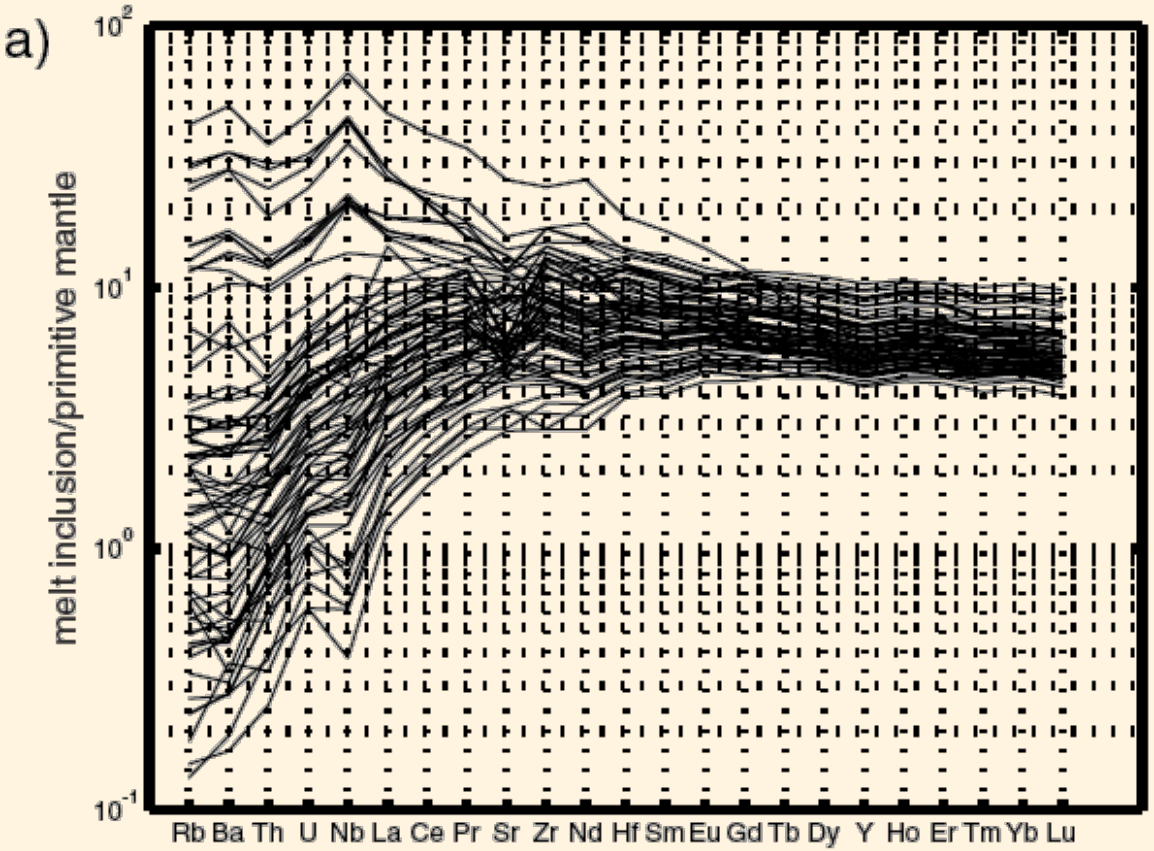


- **Two lava types are present**
  - Represent <u>mixtures</u> of two mantle sources
  - Enriched (E-type)
  - Depleted (N-type)

- Produced by mixing of depleted mantle and recycled lithosphere
- No crustal contamination (c.f. Yaxley et al., 2004
  Kent et al. 2004)

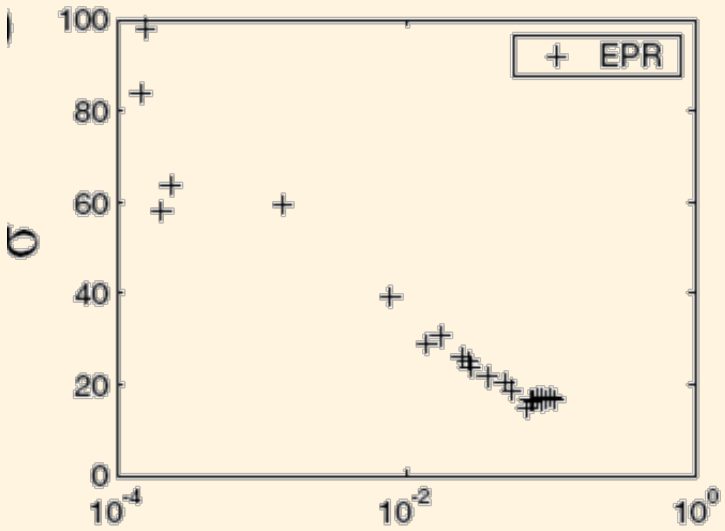


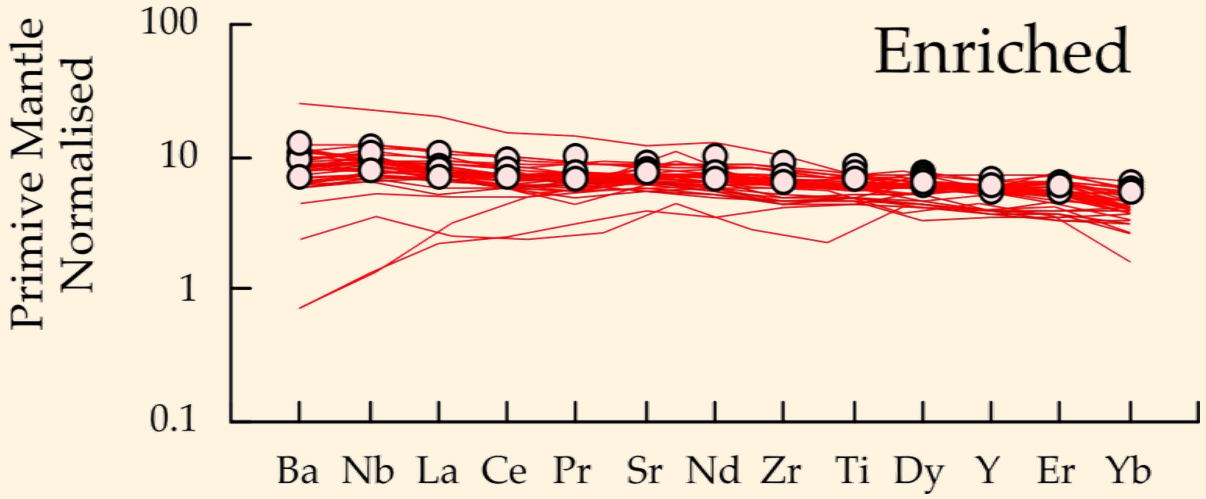

Depleted
Primive Mantle Normalised
100
10
1
0.1
Ba Nb La Ce Pr Sr Nd Zr Ti Dy Y Er Yb
Matrix glass
Melt Inclusions
Enriched
Primive Mantle Normalised
100
10
1
0.1
Ba Nb La Ce Pr Sr Nd Zr Ti Dy Y Er Yb

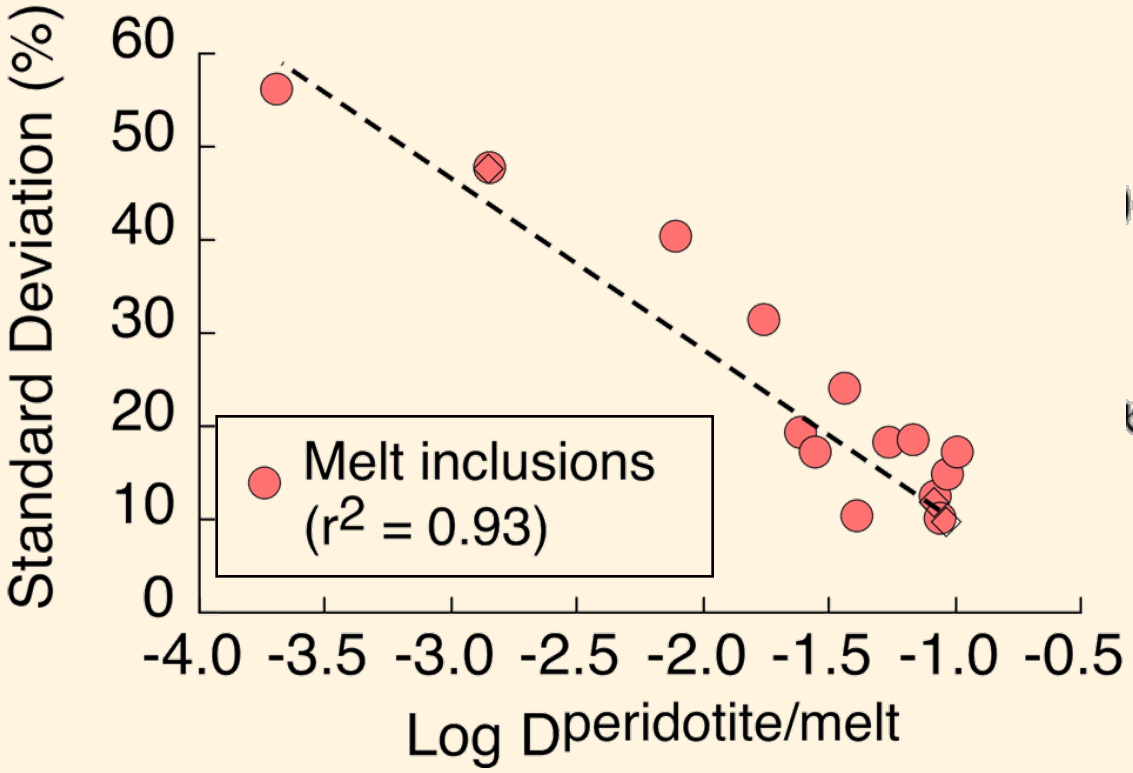


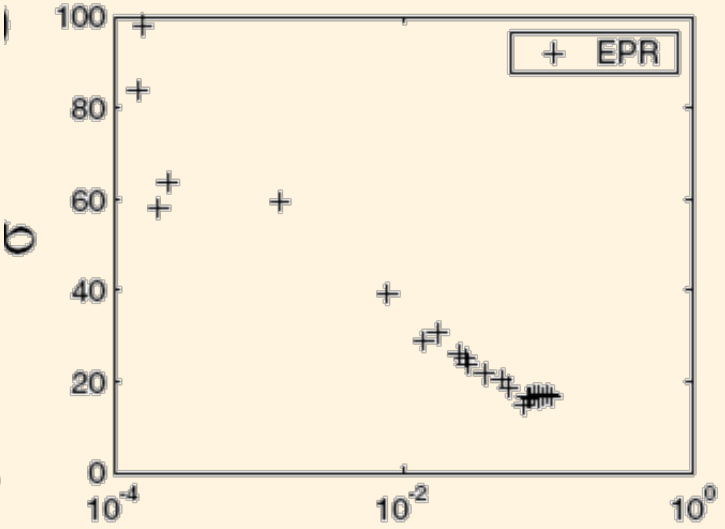
Mid Ocean Ridge basalt glasses

(Cottrell et al. 2002)

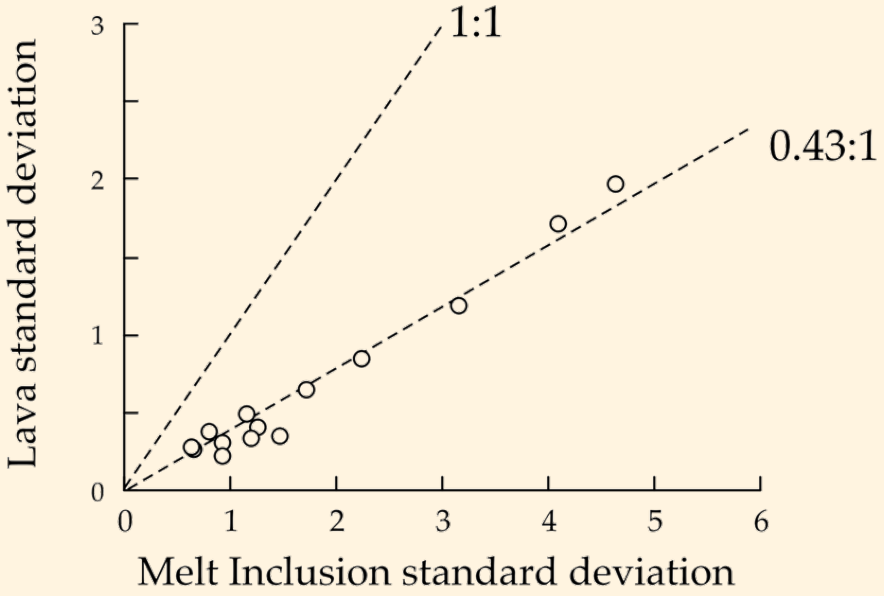


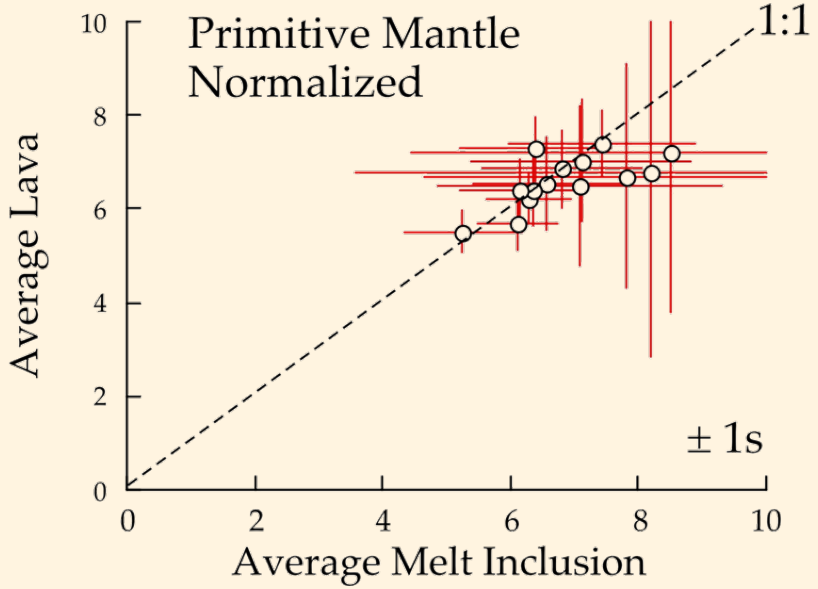

Enriched
Primive Mantle Normalised
100
10
1
0.1
Ba Nb La Ce Pr Sr Nd Zr Ti Dy Y Er Yb


Standard Deviation (%)
60
50
40
30
20
10
0
-4.0 -3.5 -3.0 -2.5 -2.0 -1.5 -1.0 -0.5
Log Dperidotite/melt
Melt inclusions
(r2 = 0.93)


EPR
100
80
60
40
20
0
10-4
10-2
100

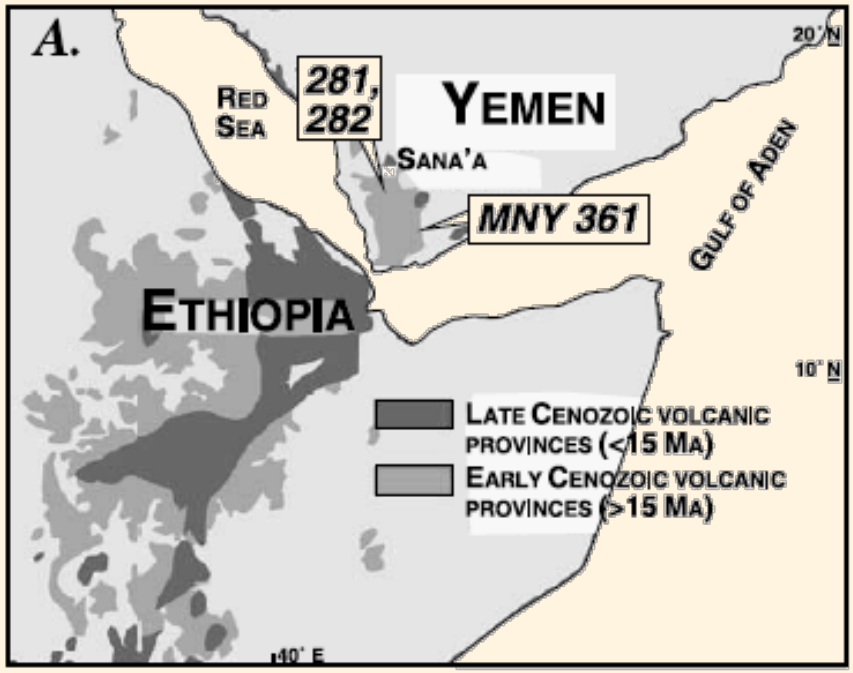
Comparison between melt inclusions and host lavas

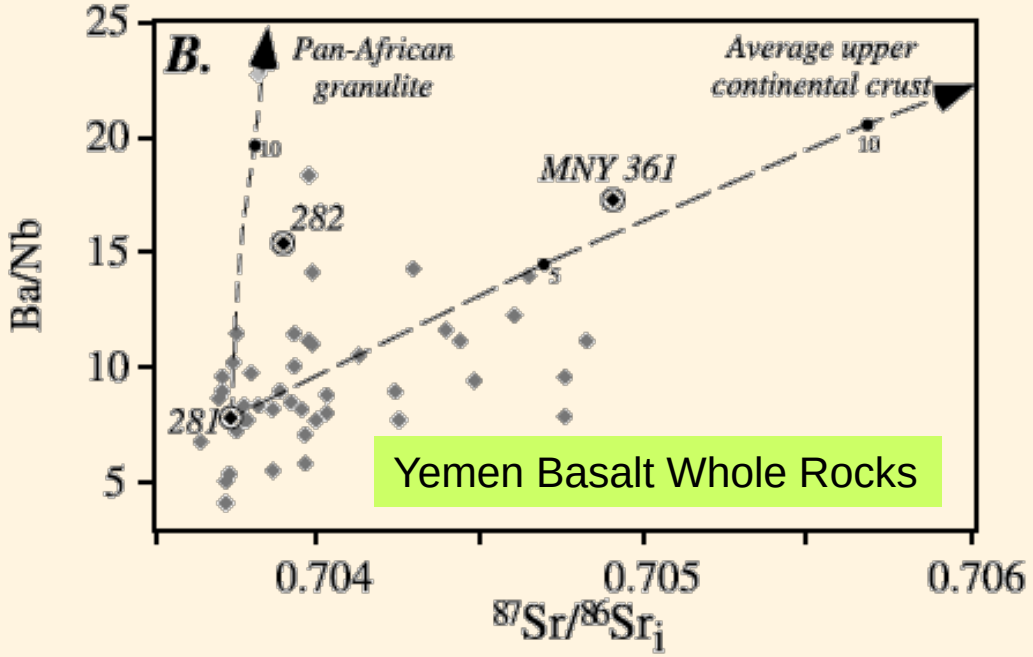




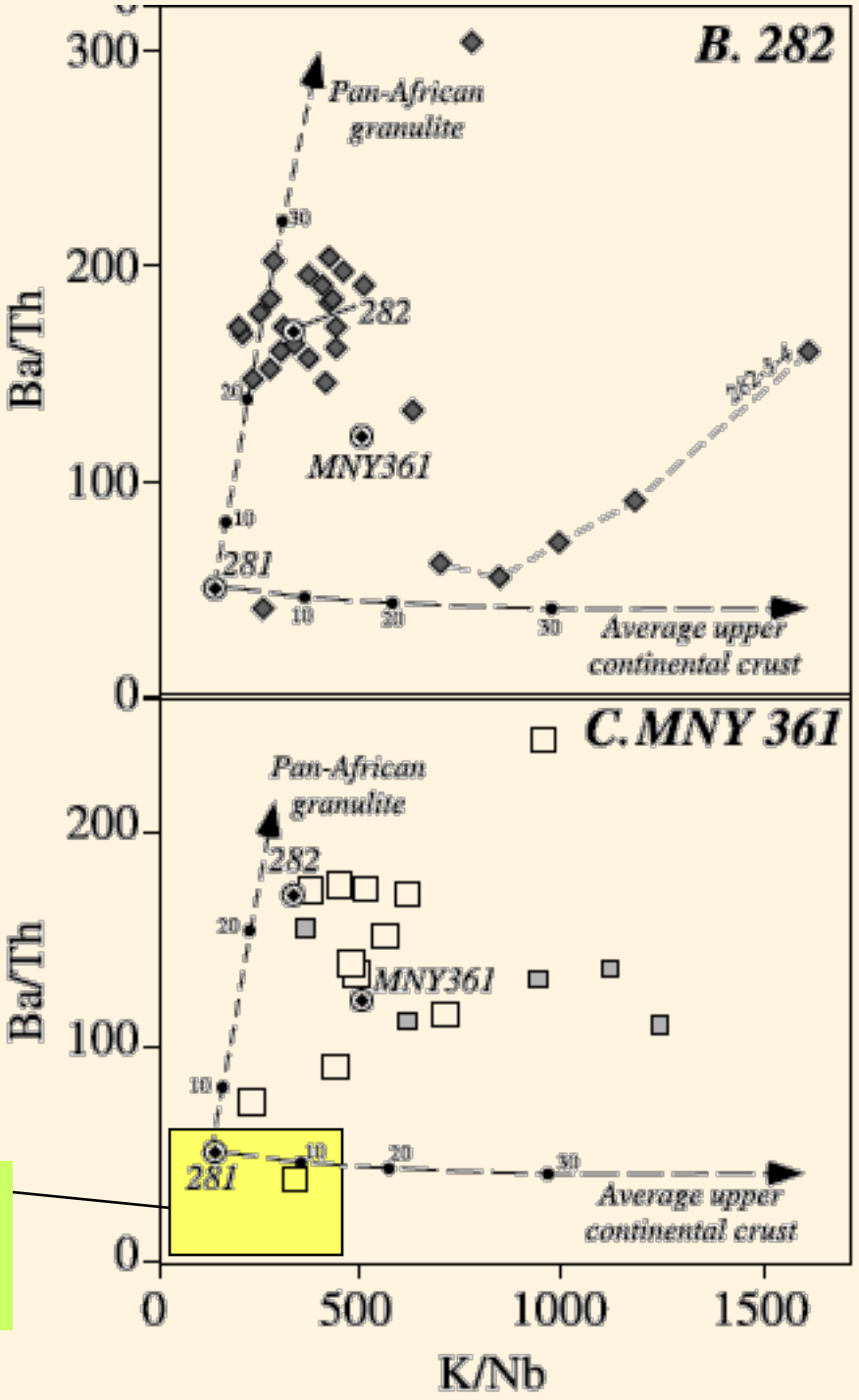
Variability in trace element composition is **driven by the <u>same processes</u>** in inclusions and in lavas

Another Example…
(Kent et al. 2002)



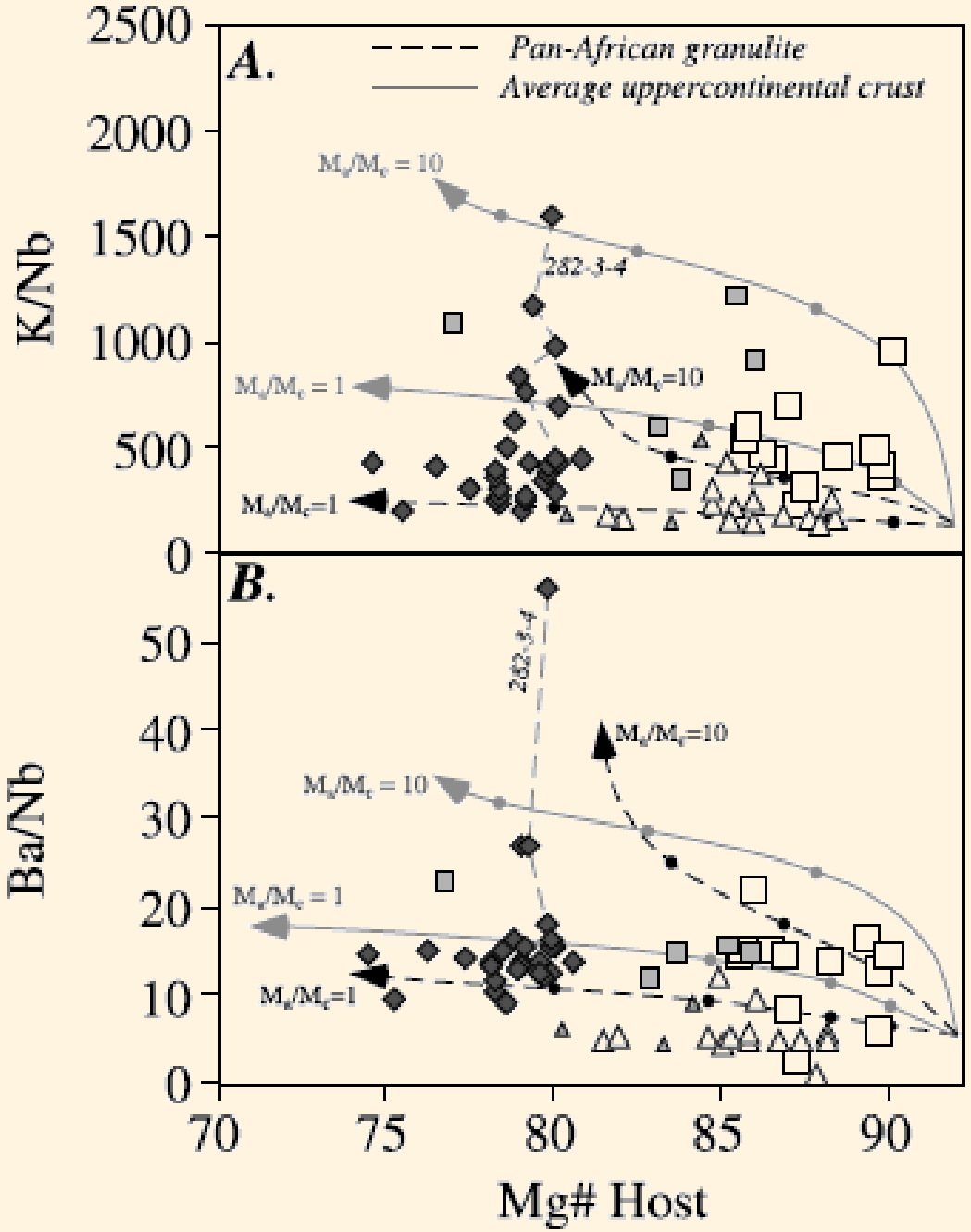


Melt Inclusions
from three samples

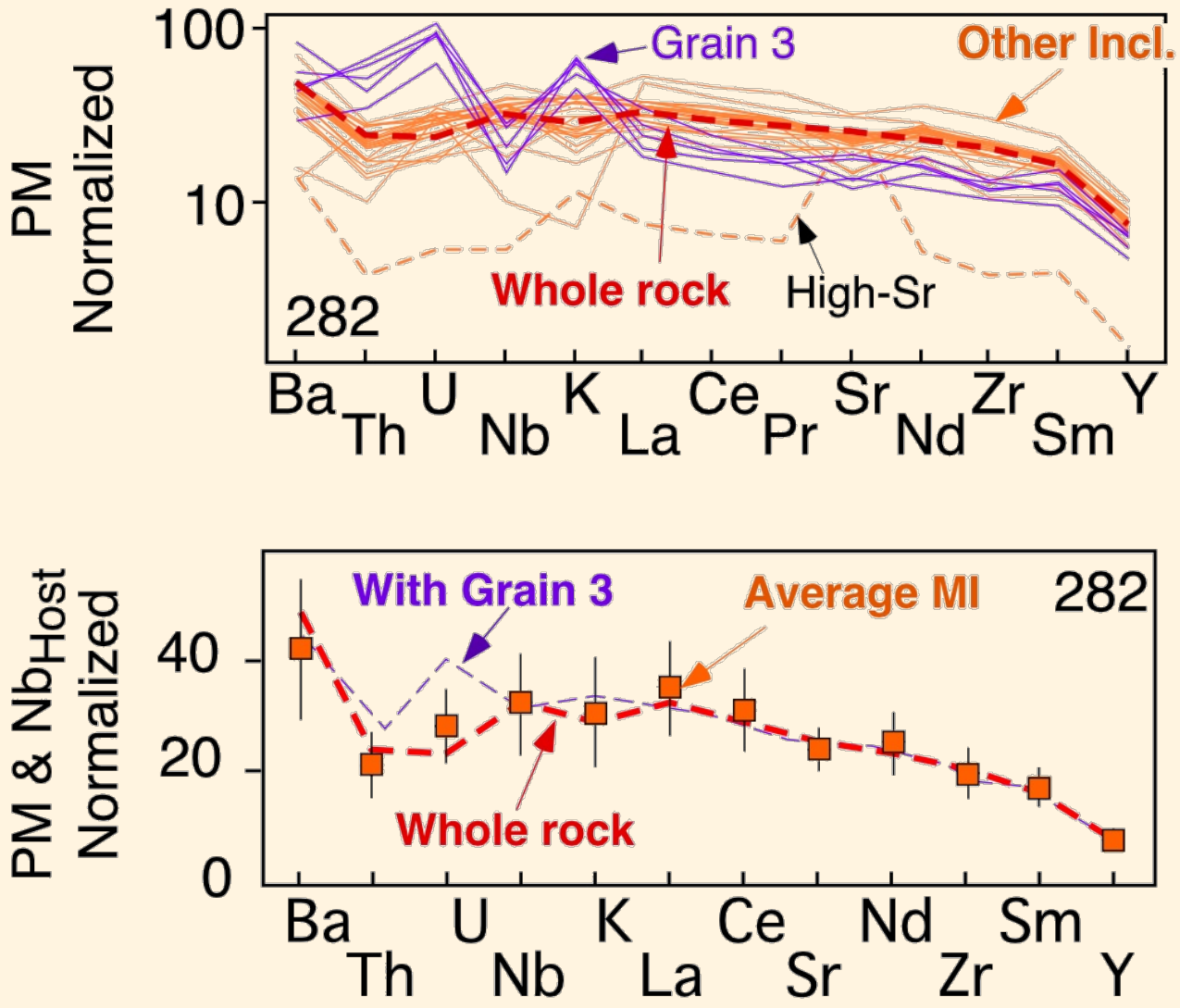


Uncontaminated
MORB & CFB

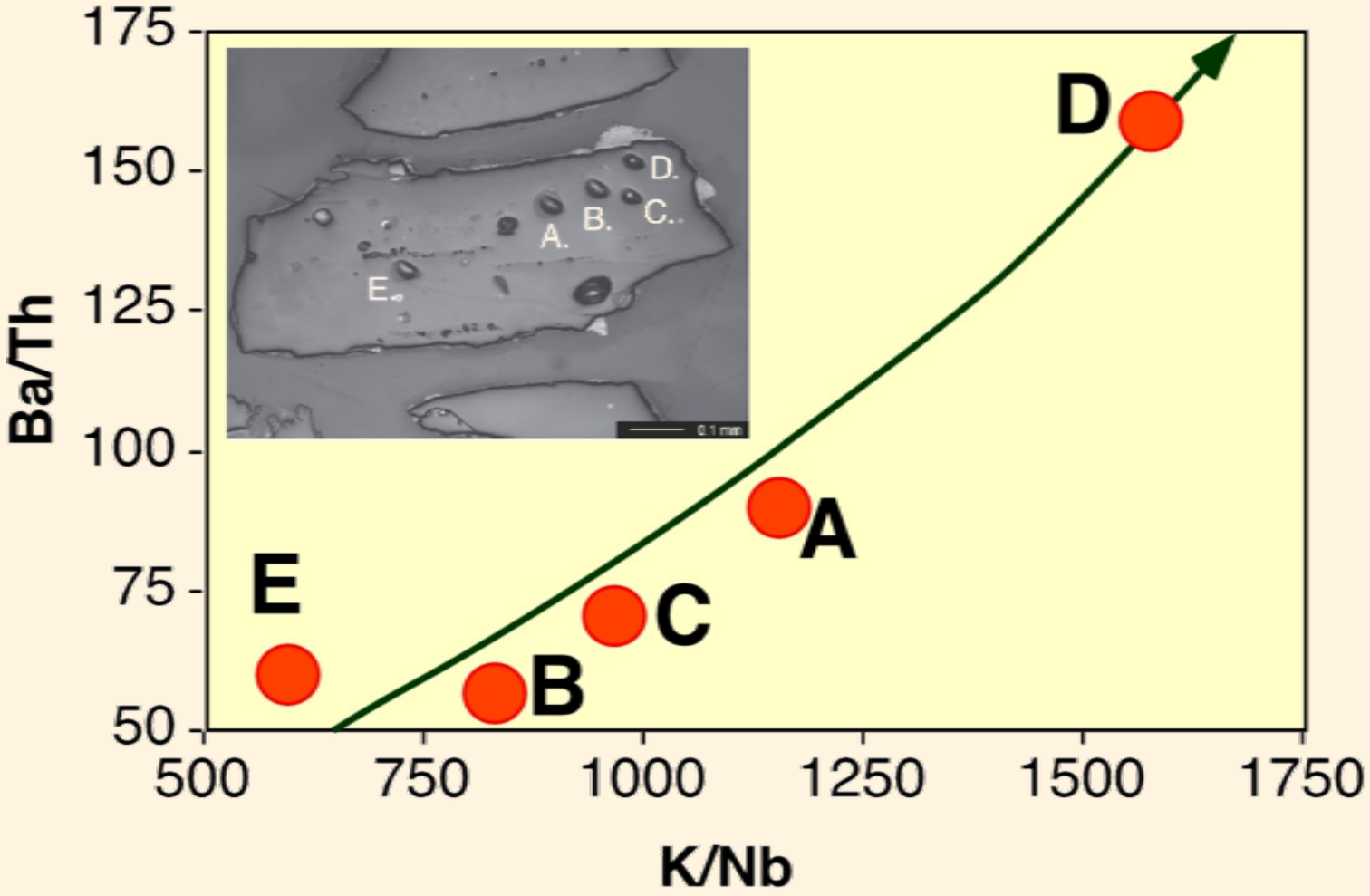
Aside:
Contamination occurs early

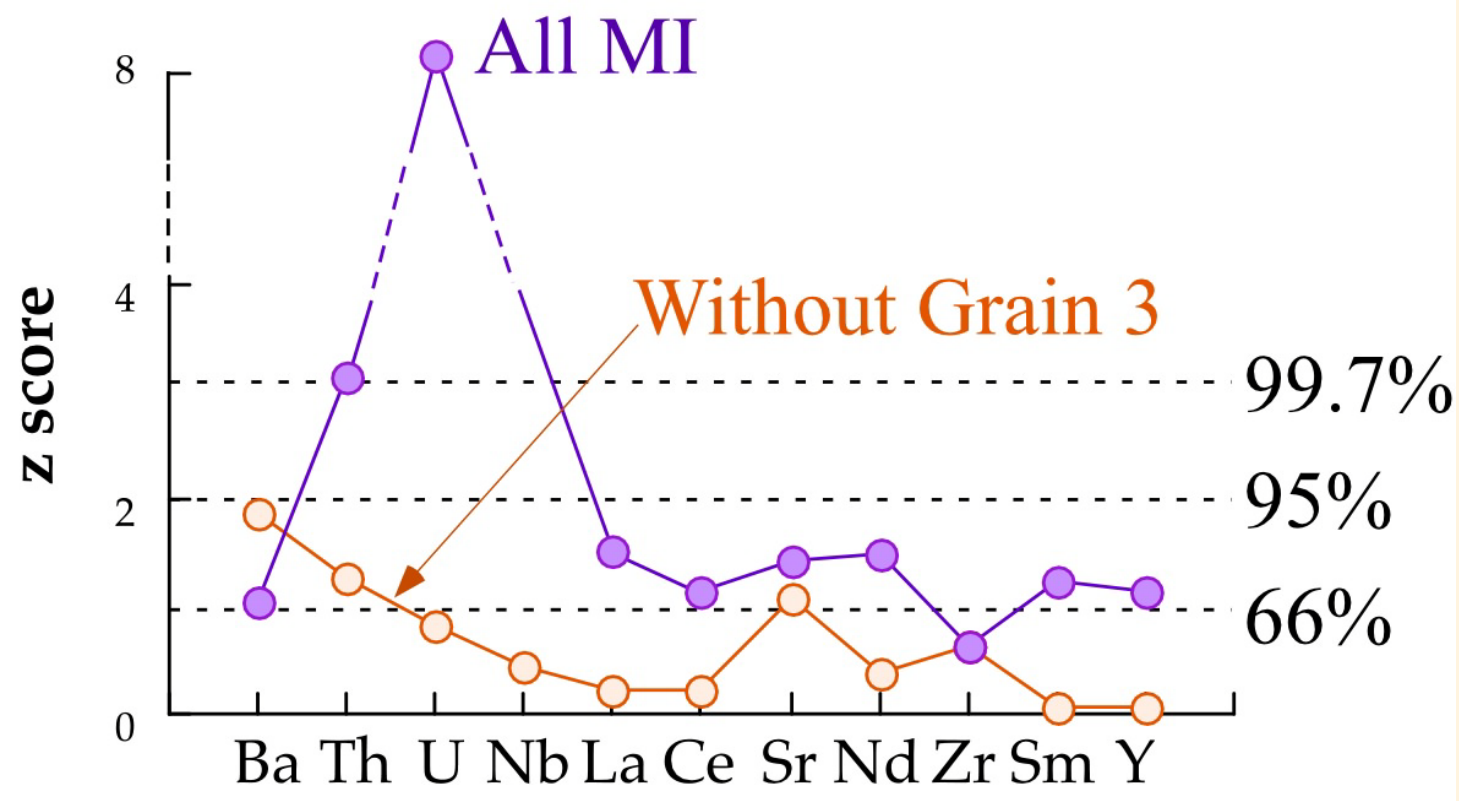


Comparison of melt inclusions with host lava



One very anomalous crystal…

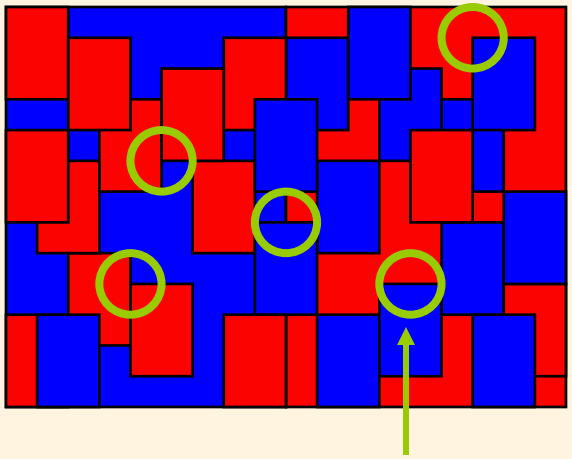


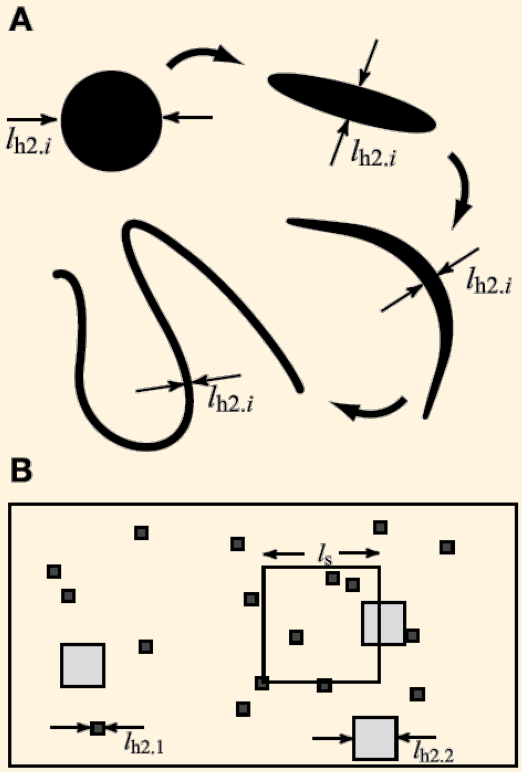

All MI
Without Grain 3
z score
8
4
2
0
99.7%
95%
66%
Ba Th U Nb La Ce Sr Nd Zr Sm Y

Conclusion:

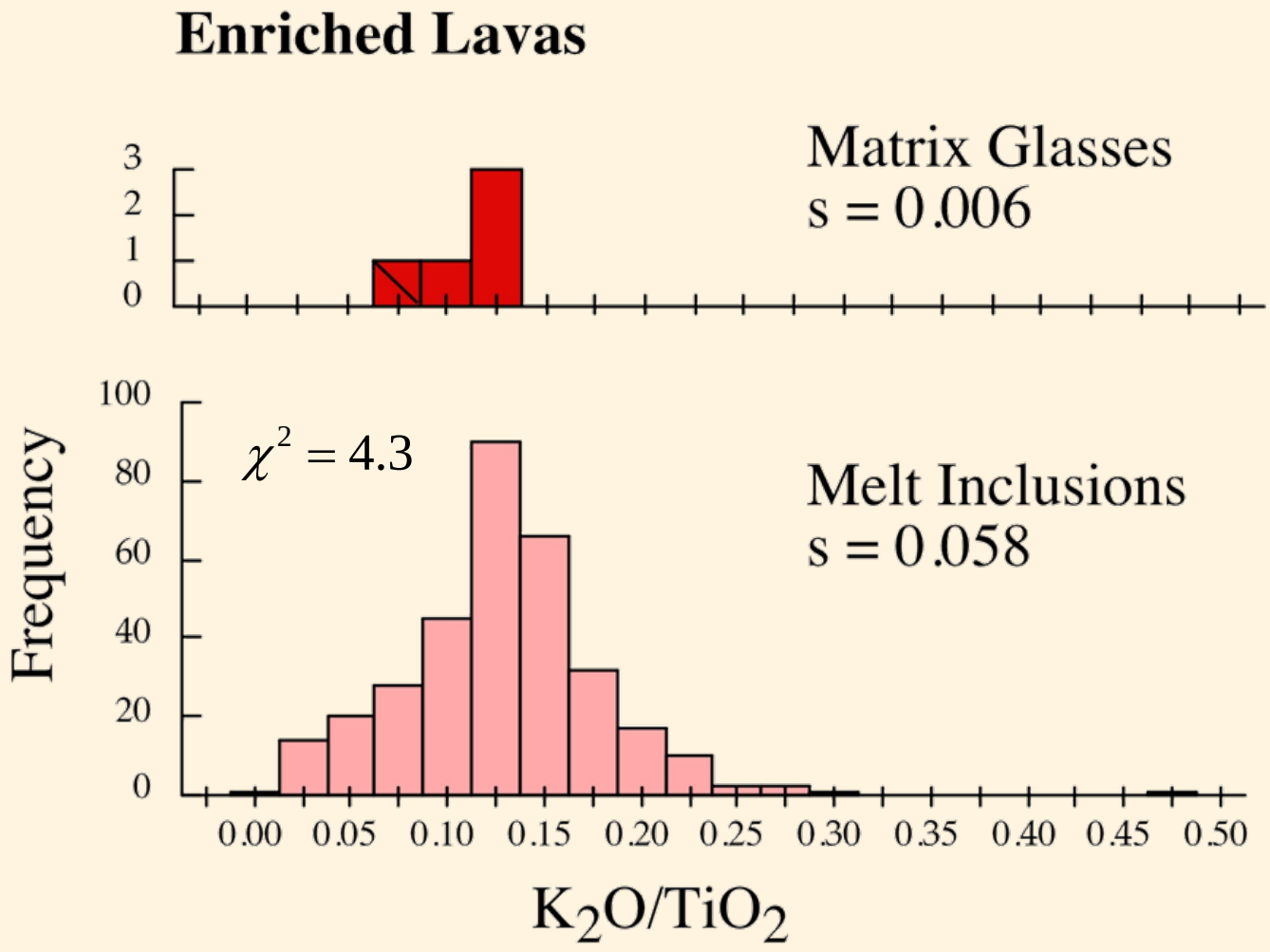
In many cases melt inclusion composition are very variable compared to their host rocks, but the AVERAGE composition is comparable to the host lava composition.

Magma

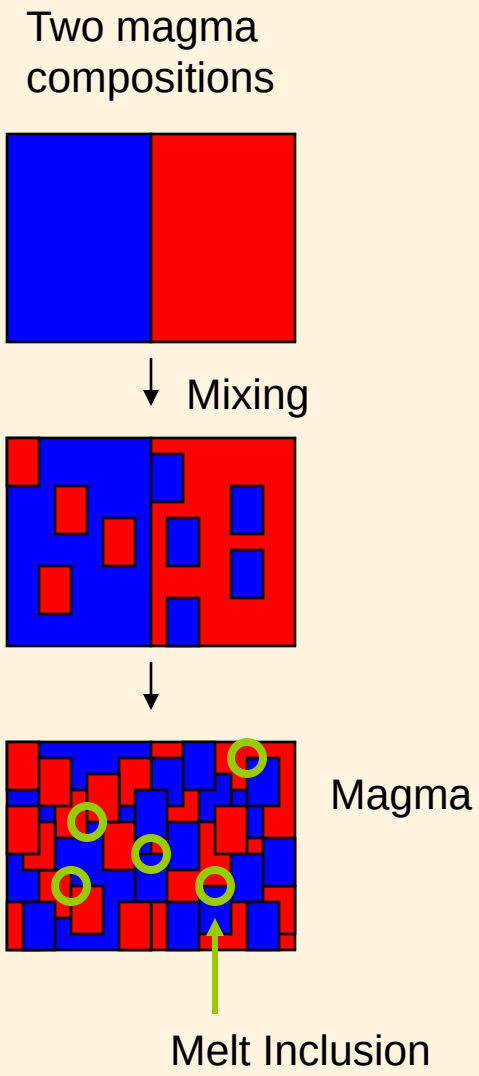




Kellogg et al. 2002



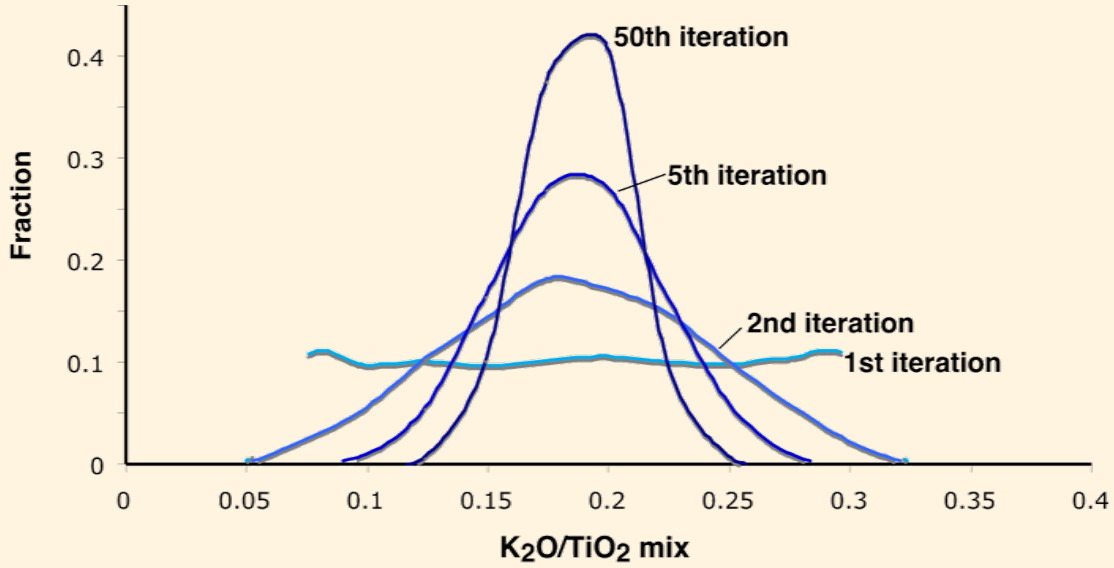
Baffin Island melt inclusions



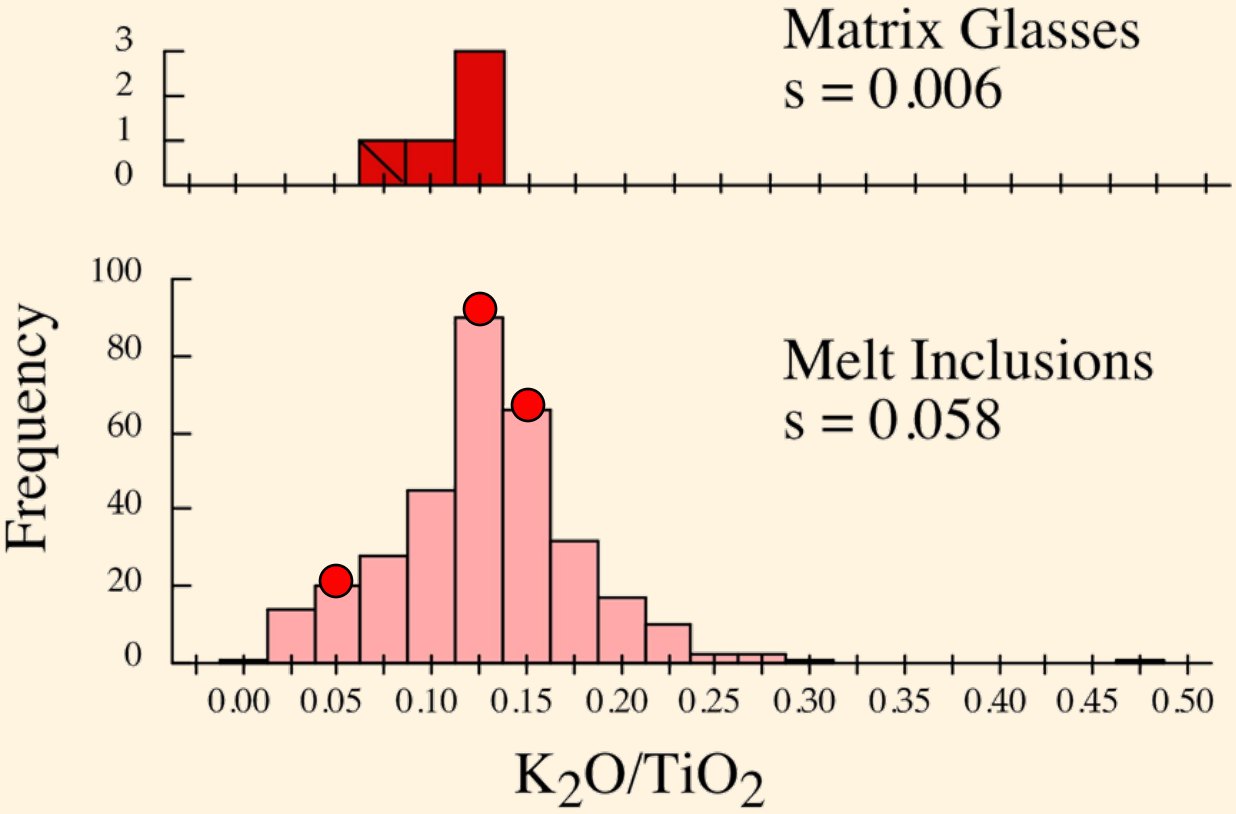
Randomized mixing experiment

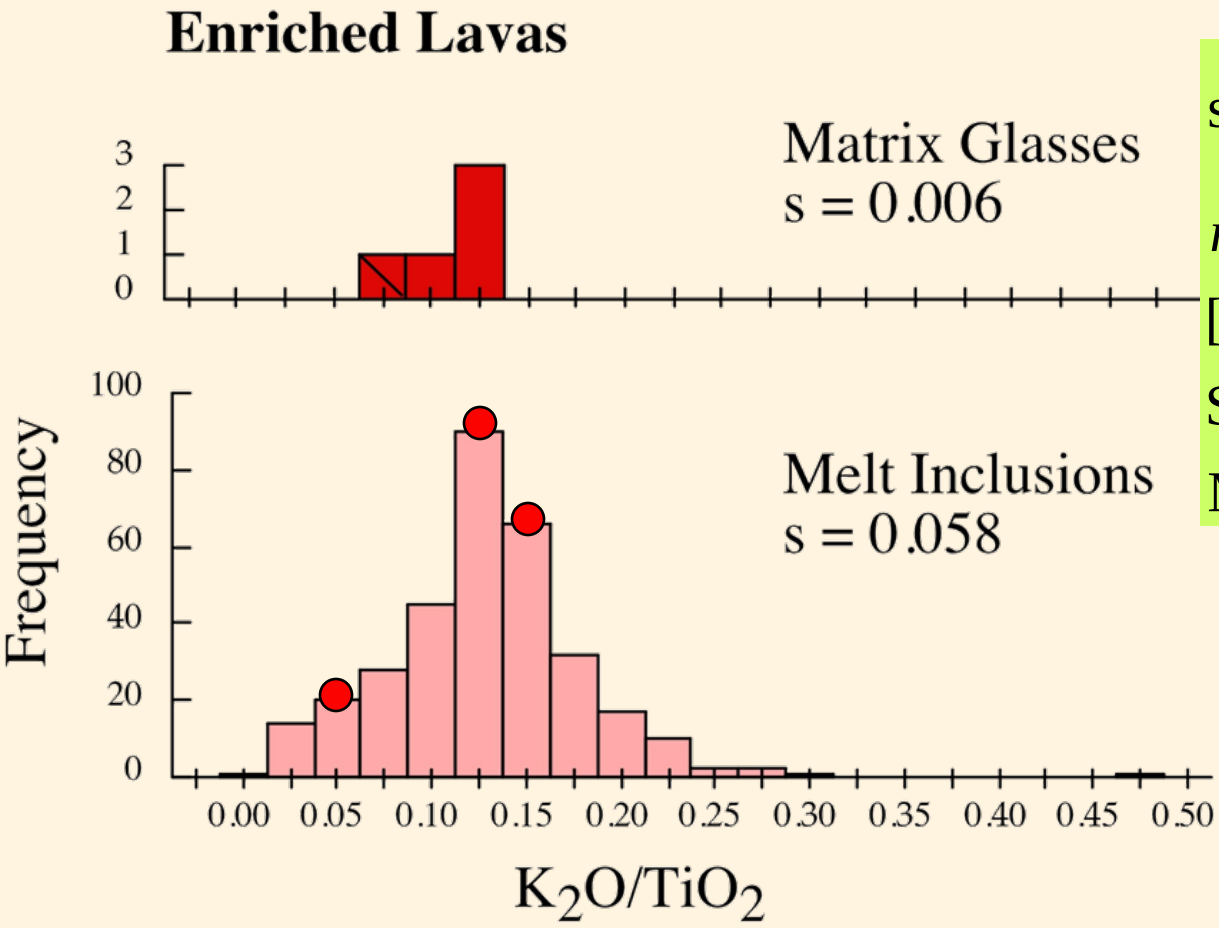
Calculated compositions of 10^4 random mixtures of two endmember melts

Calculated distribution used for starting composition



Enriched Lavas





$$s_{lava} = \frac{s_{inclusions}}{\sqrt{n}}$$

$n \approx 90$

[Theistareykir : n $\approx 30-100$

Slater et al. (2001)

MacLennan et al. 2003]

Implications

Melt inclusions sample magma systems at smaller scales (spatial and temporal?) than lavas

But

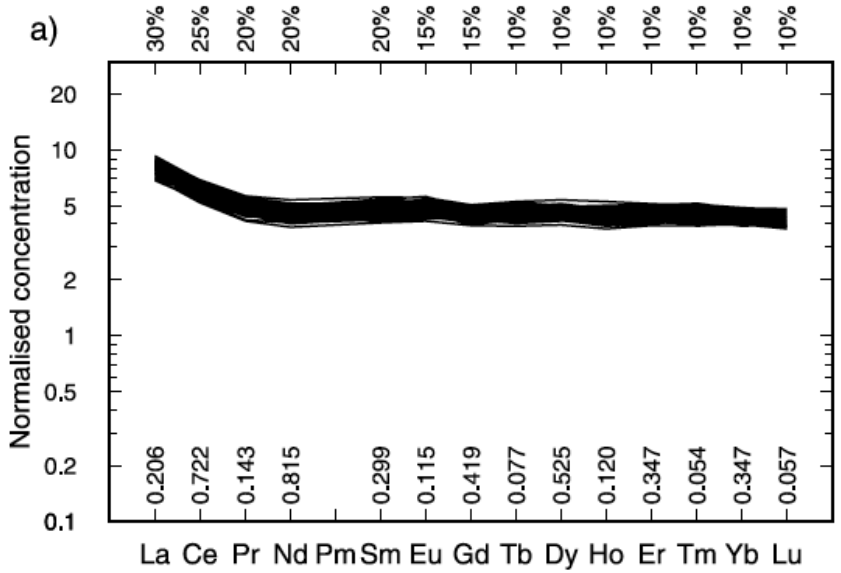
They both sample the same material and are have variations that reflect the same processes

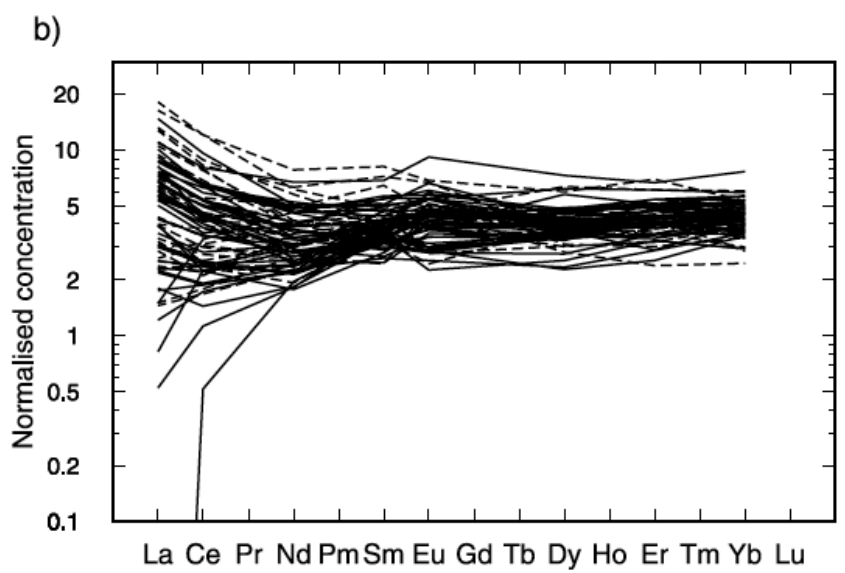
We can argue about what these are…

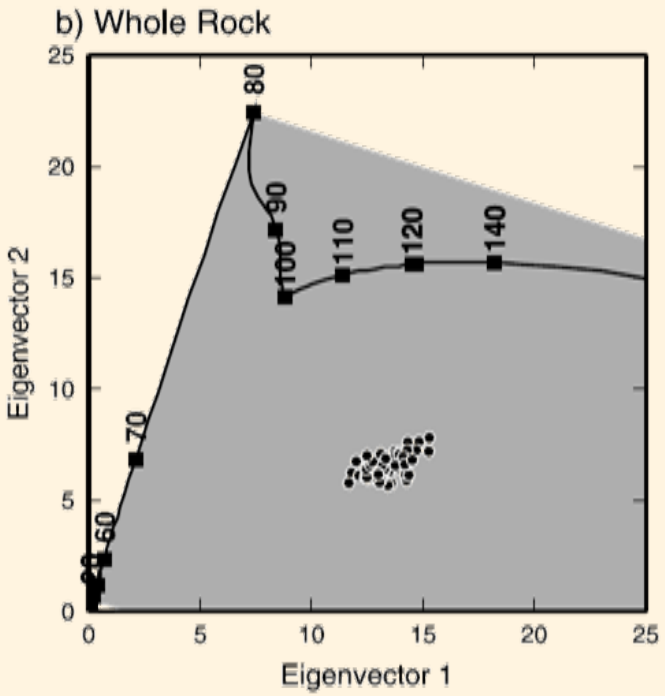
QuickTime™ and a
decompressor
are needed to see this picture.

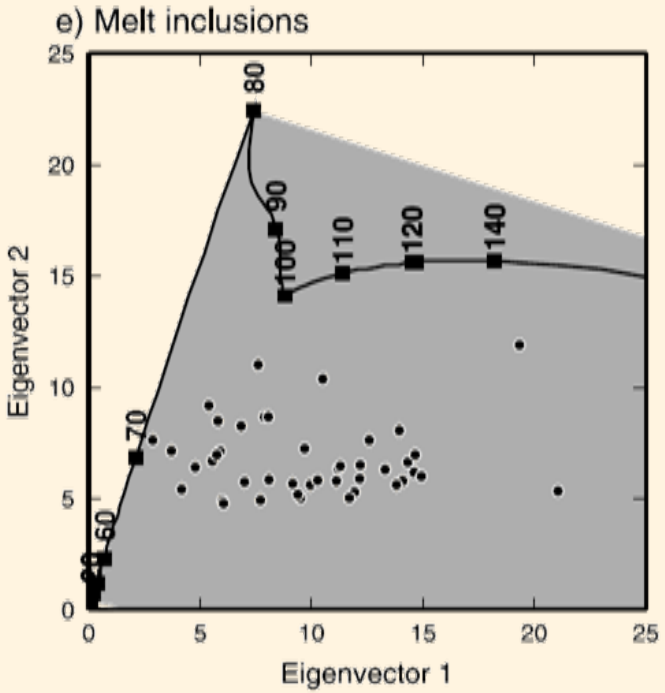
Maclennan (2003) sampled a single flow from Theistareykir, Iceland and looked at chemical variation between whole rock and melt inclusion samples

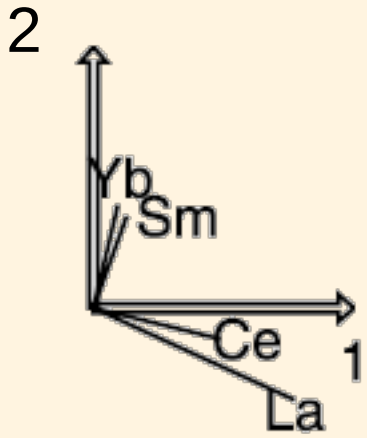
Differences between lava and melt inclusion samples consistent with difference in sampling volume of ~30 times.

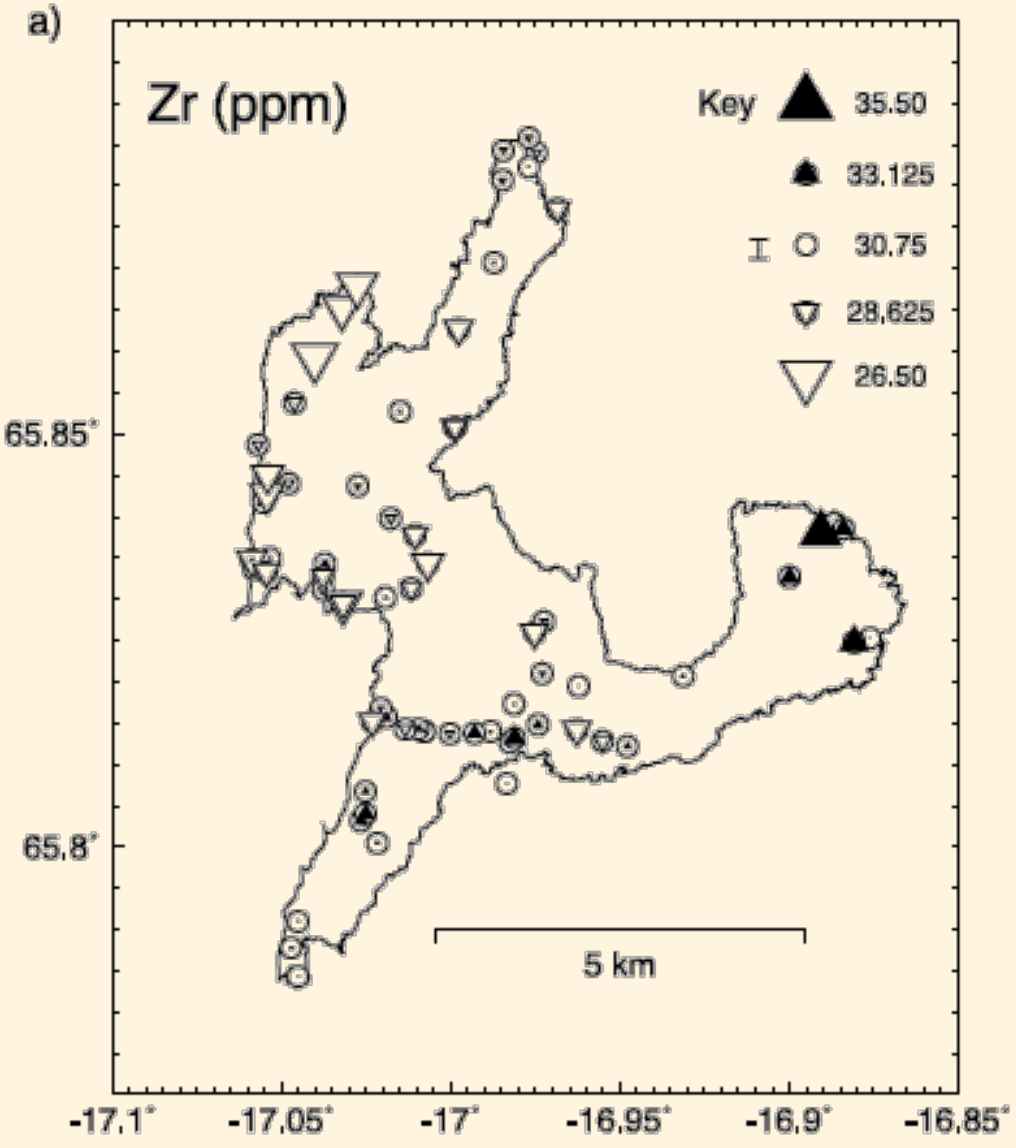


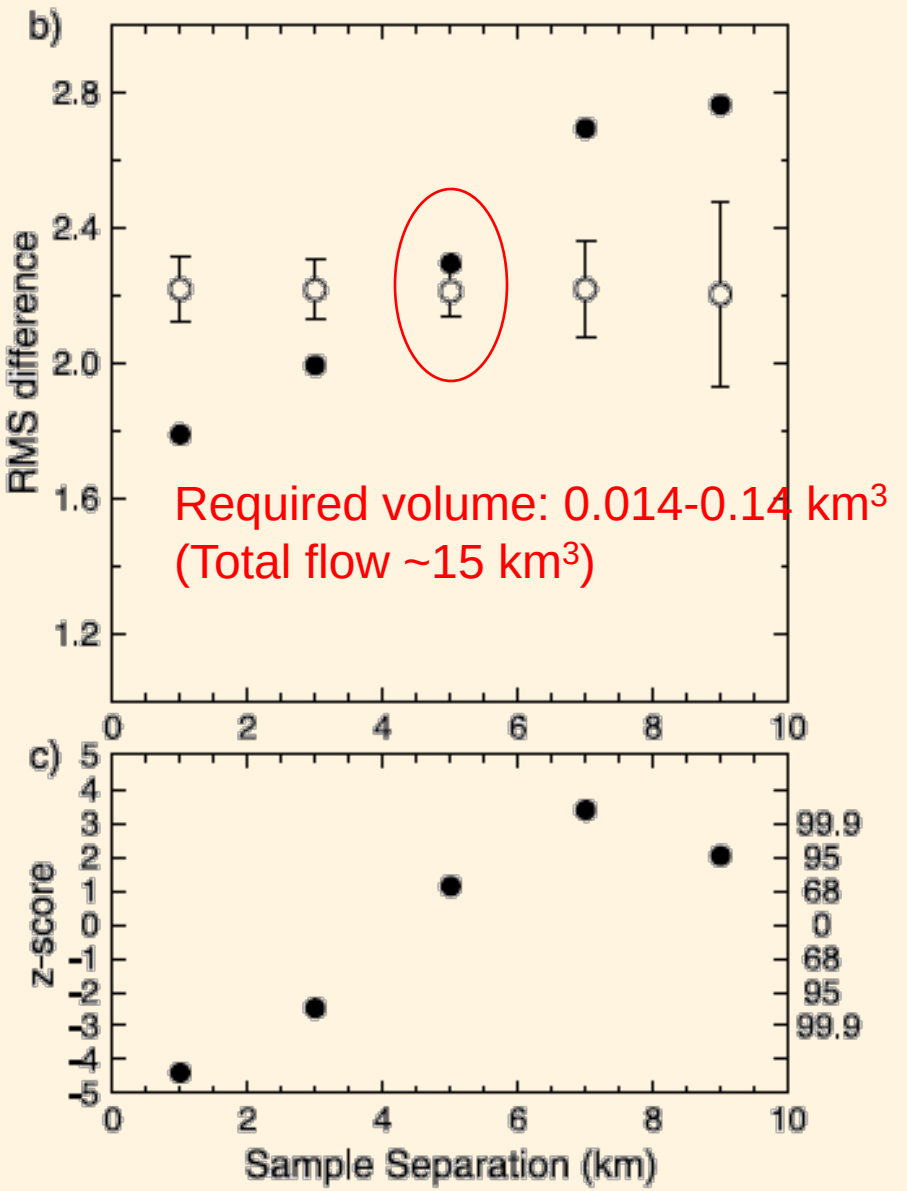



b) Whole Rock
Eigenvector 2
Eigenvector 1
0
5
10
15
20
25
60
70
80
90
100
110
120
140


e) Melt inclusions
Eigenvector 2
Eigenvector 1
0
5
10
15
20
25
60
70
80
90
100
110
120
140


2
Yb
Sm
Ce
La
1


a)
Zr (ppm)
Key
35.50
33.125
30.75
28.625
26.50
65.85°
65.8°
5 km
-17.1°
-17.05°
-17°
-16.95°
-16.9°
-16.85°

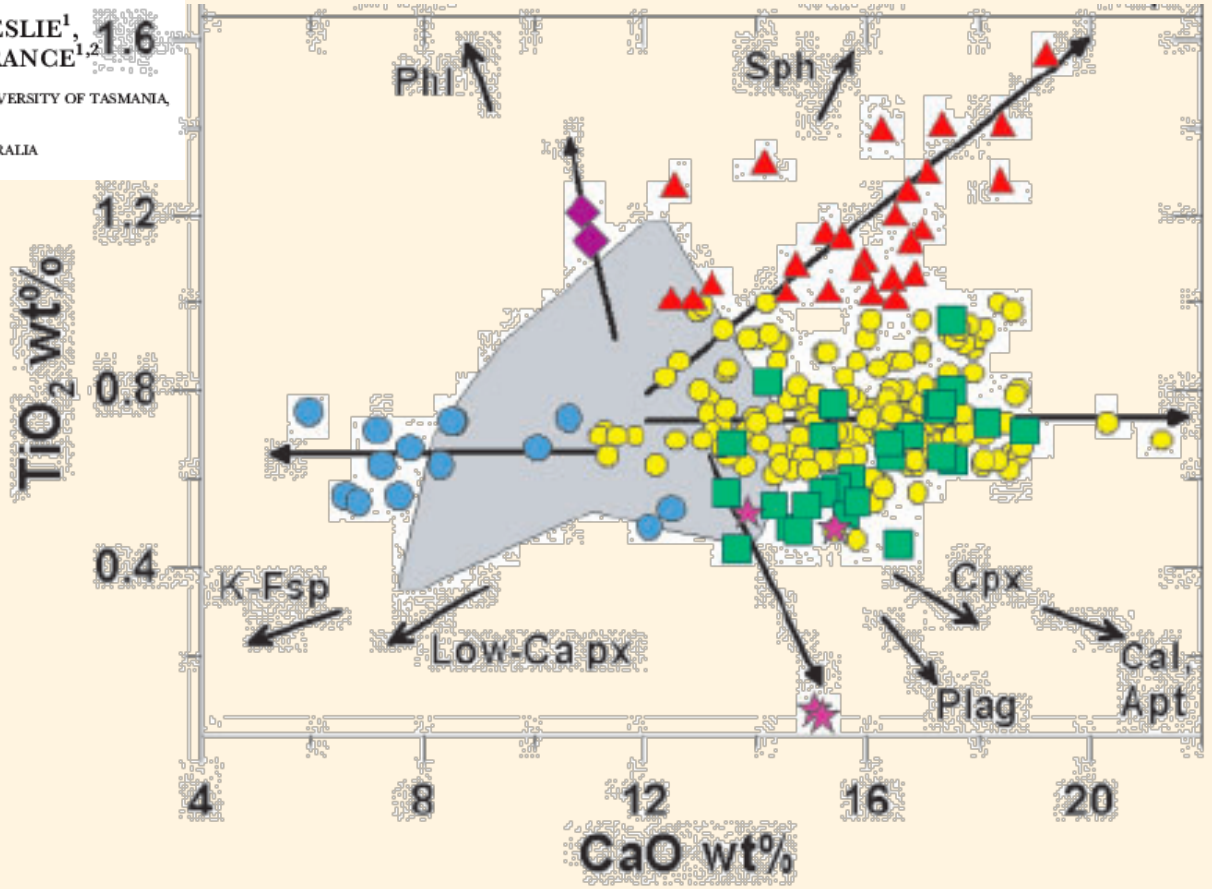

b)
RMS difference
2.8
2.4
2.0
1.6
1.2
0
2
4
6
8
10
Required volume: 0.014-0.14 km³
(Total flow ~15 km³)
c)
z-score
5
4
3
2
1
0
-1
-2
-3
-4
-5
99.9
95
68
0
68
95
99.9
Sample Separation (km)

Melt Inclusions in Primitive Olivine Phenocrysts: the Role of Localized Reactio Processes in the Origin of Anomalous Compositions

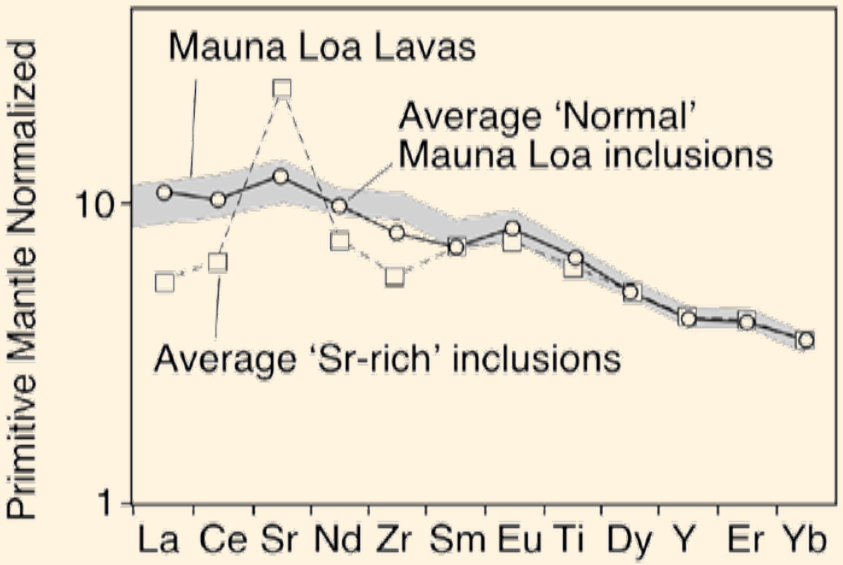
LEONID V. DANYUSHEVSKY[1]*, ROMAN A. J. LESLIE[1], ANTHONY J. CRAWFORD[1] AND PATRICIA DURANCE[1,2]

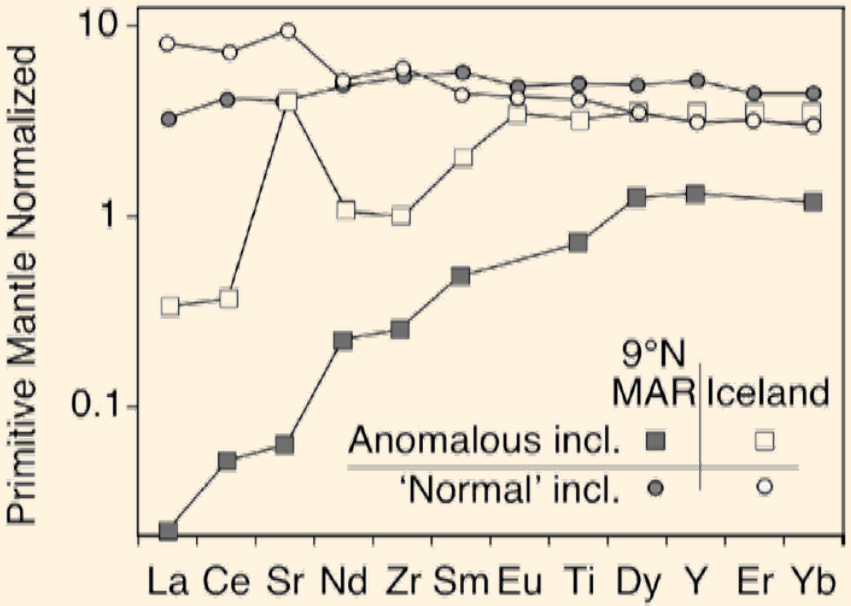
[1]SCHOOL OF EARTH SCIENCES AND CENTRE FOR ORE DEPOSIT RESEARCH, UNIVERSITY OF TASMANIA, PRIVATE BAG 79, HOBART, TAS. 7001, AUSTRALIA

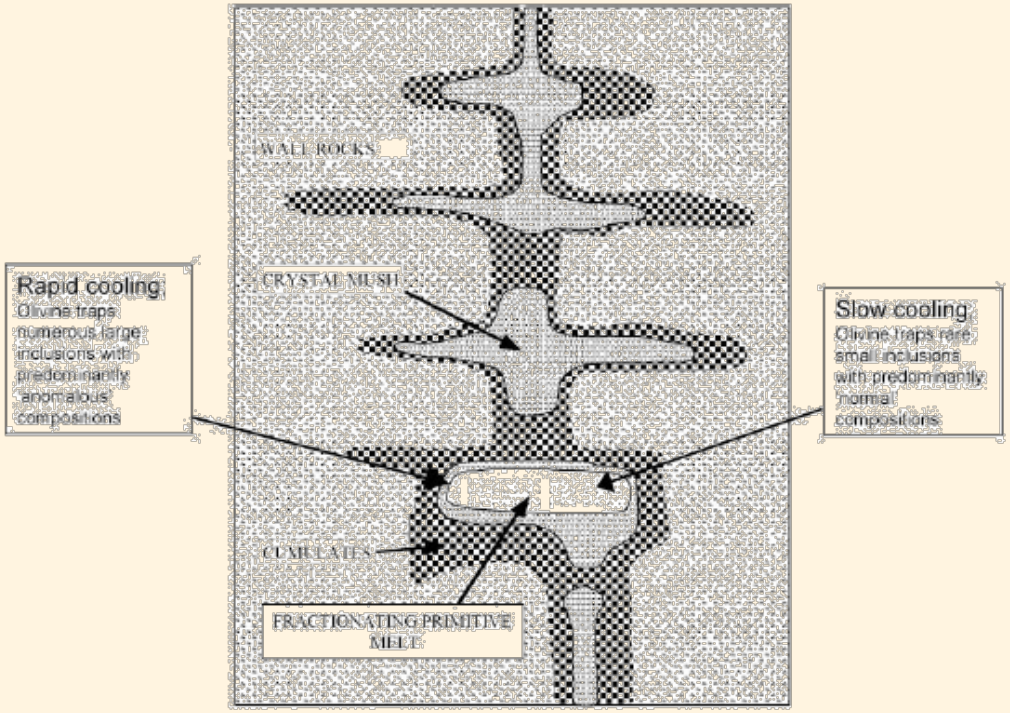
[2]SCHOOL OF GEOSCIENCES, PO BOX 28E, MONASH UNIVERSITY, VIC. 3800, AUSTRALIA



Melt Inclusions showing anomalous compositions, possibly related to localized dissolution trends







Carl Sagan "*Incredible conclusions require incredible evidence*"

Points to remember

- Melt inclusions are often highly variable with respect to the host and associated lavas
- It is VERY important to establish the relationship between melt inclusions and the rocks that host them
- The greater variability of melt inclusions may reflect the fact that they sample variable magmatic systems at smaller spatial scales
- Think carefull about anomalous or otherwise unrepresentative melt inclusions