Melt Inclusions in Primitive Basalts

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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?
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• 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 mixtures 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)
Mid Ocean Ridge basalt glasses
(Cottrell et al. 2002)
Variability in trace element composition is \textbf{driven by the same processes} in inclusions and in lavas.
Another Example… (Kent et al. 2002)

Yemen Basalt Whole Rocks
Melt Inclusions from three samples

Uncontaminated MORB & CFB
Aside:
Contamination occurs early
Comparison of melt inclusions with host lava

PM Normalized

PM & NbHost Normalized

With Grain 3

Average MI

Whole rock

Other Incl.

Whole rock

High-Sr

282
One very anomalous crystal...
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.
Enriched Lavas

\[ \chi^2 = 4.3 \]

Matrix Glasses
\[ s = 0.006 \]

Melt Inclusions
\[ s = 0.058 \]

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

Matrix Glasses
\[ s = 0.006 \]

Melt Inclusions
\[ s = 0.058 \]
Enriched Lavas

Matrix Glasses
\[ s = 0.006 \]

Melt Inclusions
\[ s = 0.058 \]

\[ s_{\text{lava}} = \frac{s_{\text{inclusions}}}{\sqrt{n}} \]
\[ n \approx 90 \]

[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...
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.
Required volume: 0.014-0.14 km$^3$
(Total flow ~15 km$^3$)
Melt Inclusions in Primitive Olivine Phenocrysts: the Role of Localized Reaction Processes in the Origin of Anomalous Compositions

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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 carefully about anomalous or otherwise unrepresentative melt inclusions.