Estimating Magmatic Temperatures and Source Lithologies for Off-Axis Alkaline Magmas

Ref: Abstract No: 312270

Snaefellsnes, Western Iceland

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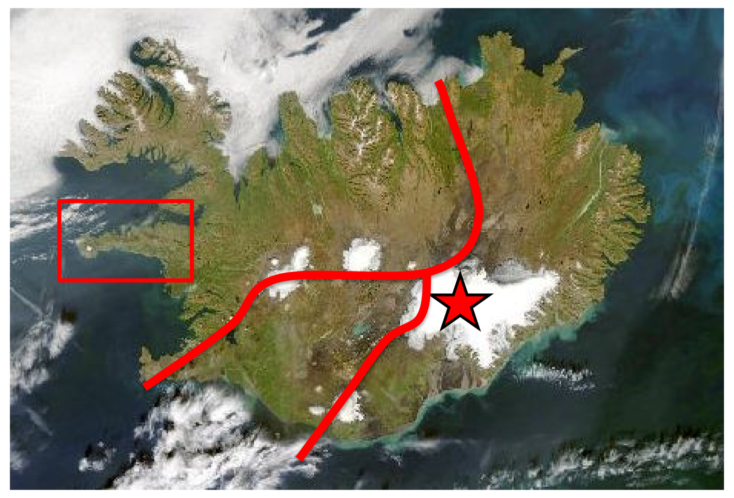
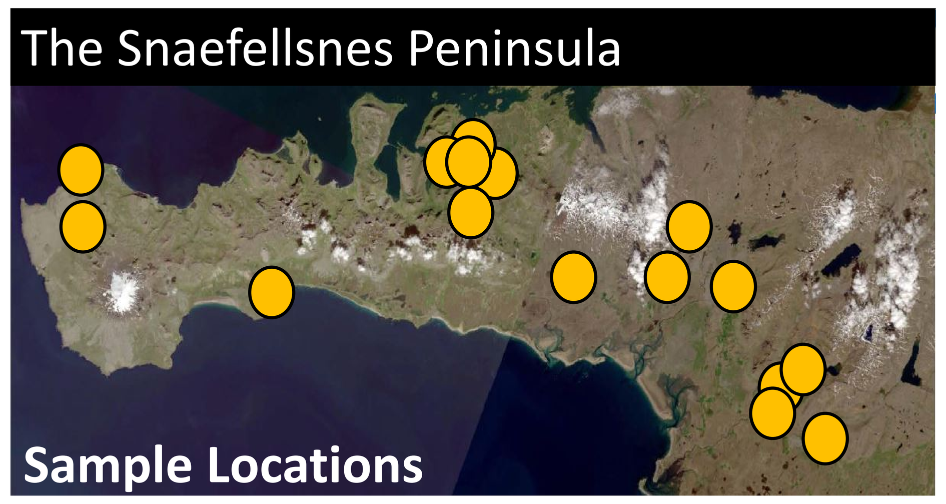
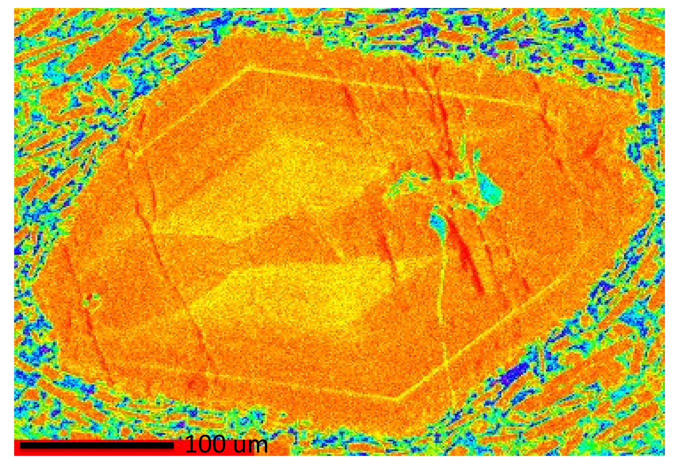
Introduction

Iceland is a hot-spot influenced, subaerial segment of the Mid-Atlantic Ridge. The active rift volcanics are tholeiitc magmas generated by decompression melting enhanced by the added temperature flux and/or more fusible lithologies inferred to be due to a mantle plume. The Snaefellsnes Peninsula (SNP) is an off-axis area that has recent (< 1 Ma) alkaline volcanism unconformably overlying older Neogene flood basalts. The SNP alkaline basalts are enriched in radiogenic isotopes ($^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$) and incompatible trace elements (higher La/Sm and Nb/Zr) relative to the rift tholeiites, indicating smaller degrees of melting of a more enriched mantle. It is unclear what role mantle temperature and source lithology (e.g., enriched peridotite vs pyroxenite) have in generating this off-axis volcanism in an area of limited crustal extension. In order to address these questions, high precision analyses of olivine macrocrysts and spinel inclusions were carried out on representative lavas from throughout the Snaefellsnes Peninsula.

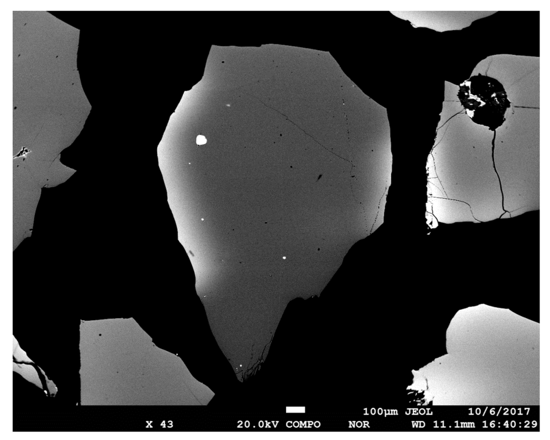




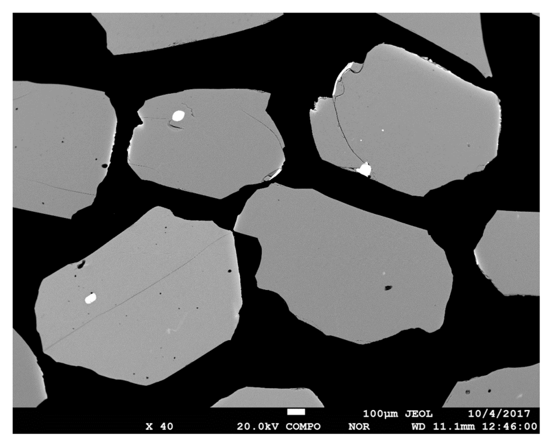
Satellite image of Iceland – The Snaefellsnes Peninsula outlined in red (Left). The inferred hot spot location is below the largest ice cap (red star). Approximate location of the active rift axes shown by red lines. Enlarged satellite map of Snaefellsnes Peninsula (right) showing the 15 lava flows that were sampled for high precision olivine and Olivine-Spinel geothermometry.



Phosphorus zoning in an olivine – showing that there is heterogeneity at a trace element level. Al concentrations in olivine are also variable, which has implications for calculating crystallization temperatures.

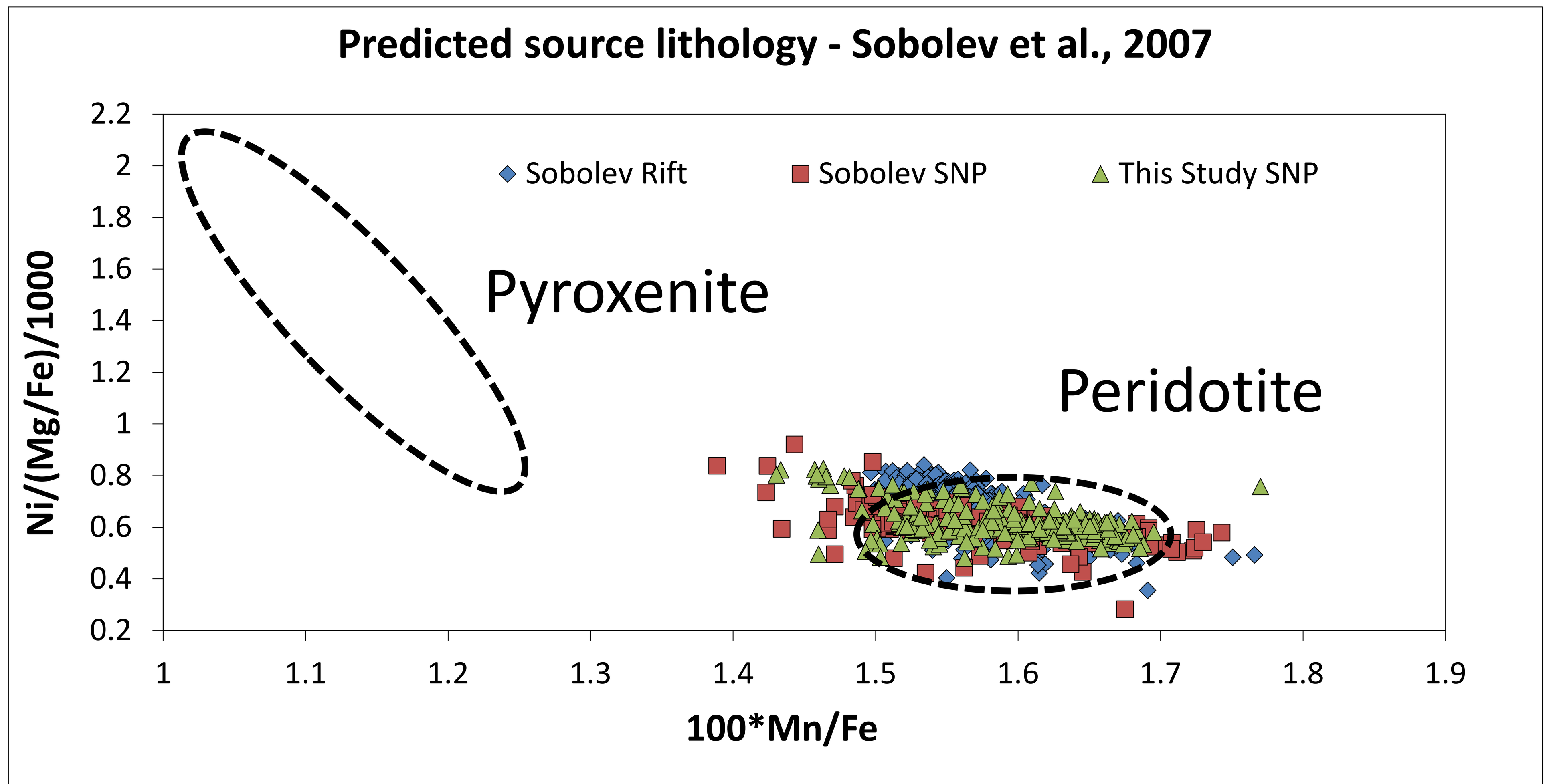


Back scatter images of olivine macrocrysts with spinel inclusions (bright white). Contrast and brightness adjusted to highlight more Fe-rich rims and any potential Mg-Fe zoning to be avoided during analysis.



High Precision Olivine Analyses

EPMA analyses of olivine macrocrysts, focusing on high Fo olivines (Mg/Mg+Fe atomic ratio). Following the model developed by Sobolev et al., (2007), the trace element composition of the olivines are plotted and a source dominant source lithology is determined (see graph below). Number of olivine macrocrysts analyzed – Sobolev rift n = 1151 (19 lava flows), Sobolev SNP n = 218 (3 lava flows), This study (Snaefellsnes Peninsula) SNP n = 259 (15 lava flows).

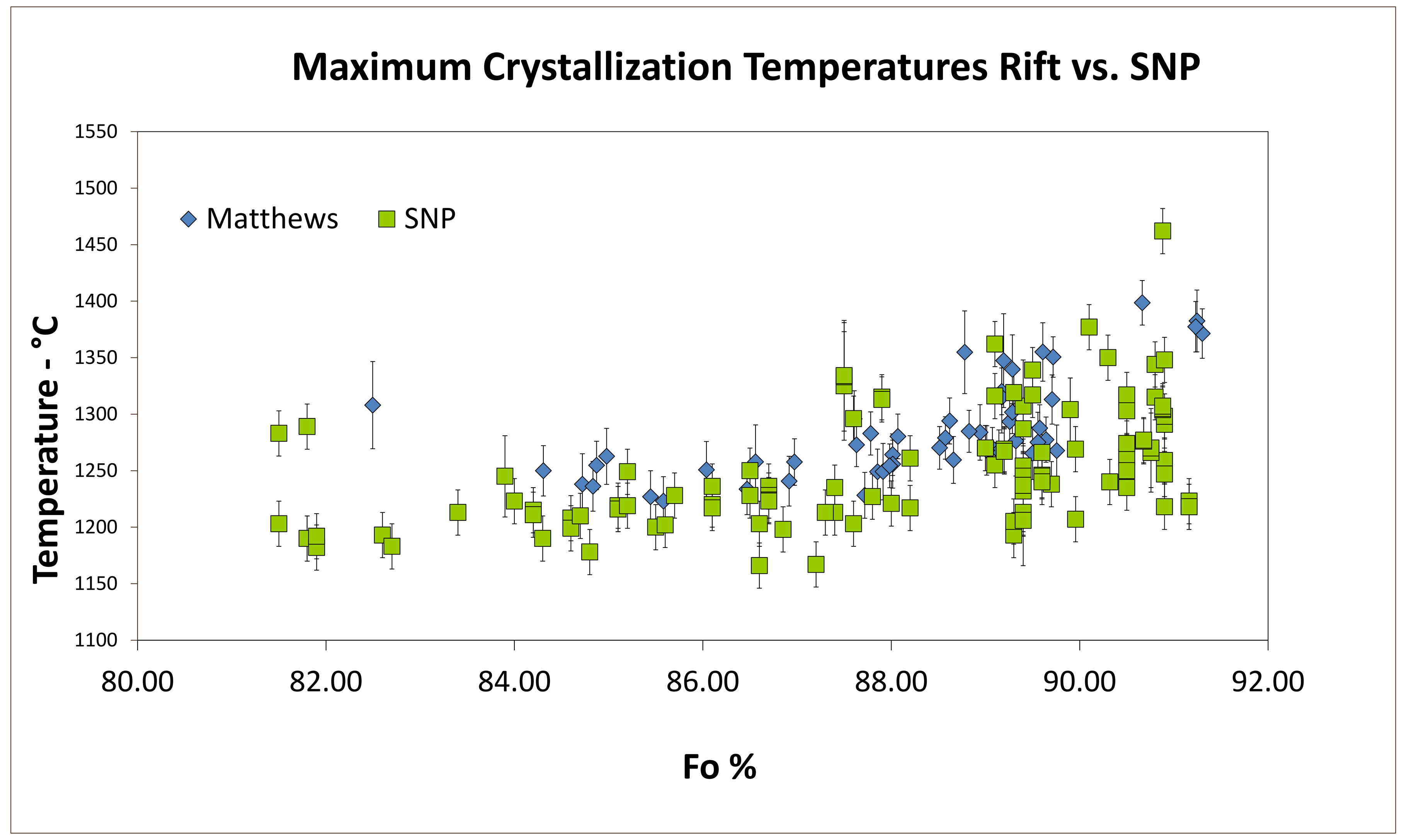


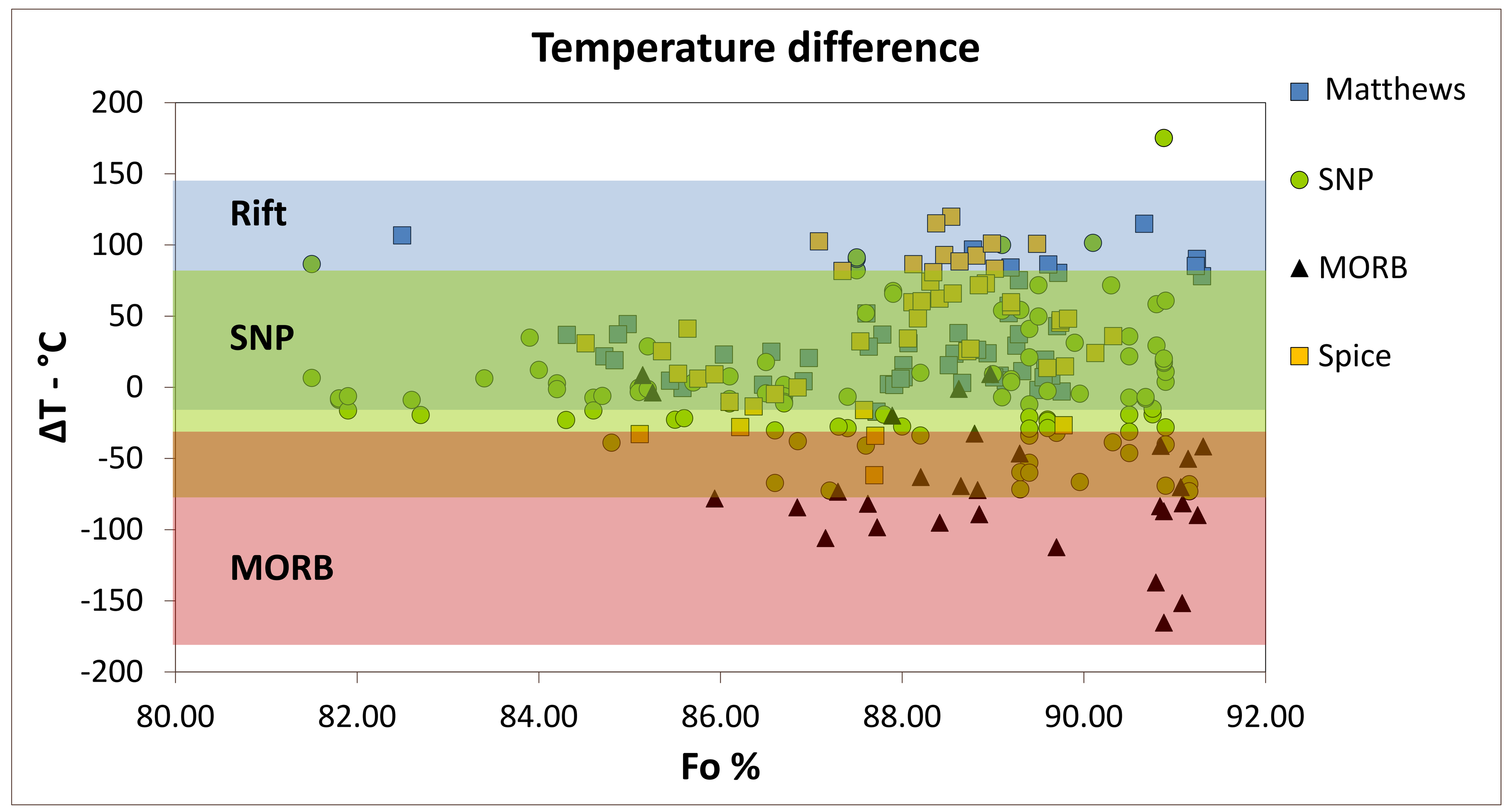
Field Work

Snaefellsjokull

Al-in-olivine Thermometry

The Al-in-olivine thermometer was developed by Wan et al., (2008) and calculates a crystallization temperature for the olivine and spinel based on the partitioning of Al between the host olivine and spinel inclusion. Multiple olivine-spinel pairs from 15 sample lavas from across Snaefellsnes were analyzed by EPMA. The results were put through a Monte Carlo error propagation calculation (Matthews et al., 2016). The resulting mean temperature and associated error is plotted below with temperatures for Iceland rift tholeiites from Matthews et al., (2016). The lower graph (Temperature difference) is composed using rift, SNP (Snaefellsnes Peninsula), and MORB temperature estimates obtained from various sources using the same Al-in-olivine thermometer. The temperature difference was calculated by finding the difference between the reported temperatures and a best fit line through the SNP data, showing overlapping but distinct groupings compared to MORB.





Conclusions

1) The mantle source lithology for the volcanism on Snaefellsnes is peridotite (same as the rift).

2) Despite a greater distance from the hotspot, magmatic temperatures for Snaefellsnes are elevated compared to MORB

Implications

- The enriched character of off-axis volcanism is due to preferential melting of a more fertile peridotite lithology compared to the rift tholeiites, and there is no evidence for melting of distinct lithologies such as pyroxenite or eclogite.
- Temperature is not the main control on compositional differences between the rift and SNP, but hotter mantle is being melted, even on the periphery of the Iceland plume.

References
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