PETROGENESIS OF EARLY SKAGI-SNAEFELLSNES RIFT BASALTS AT GRUNNAVIK, ICELAND

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INTRODUCTION

The majority of field research in Iceland has been centered on the current Mid-Atlantic Ridge. However, there are two locations of previous rift activity on Iceland, the Skagi-Snaefellsnes Rift that was active 15-7 Ma, and the NW Iceland Rift that was active 24-15 Ma (Hardarson et al., 1997). At 14 Ma, the Skagi-Snaefellsnes Rift is thought to have been nearly centered over the Iceland mantle plume, but by 7-8 Ma, the rift had migrated northwest, away from the plume. This led to the relocation of the rift to its current location along the neovolcanic zones (Fig. 1).

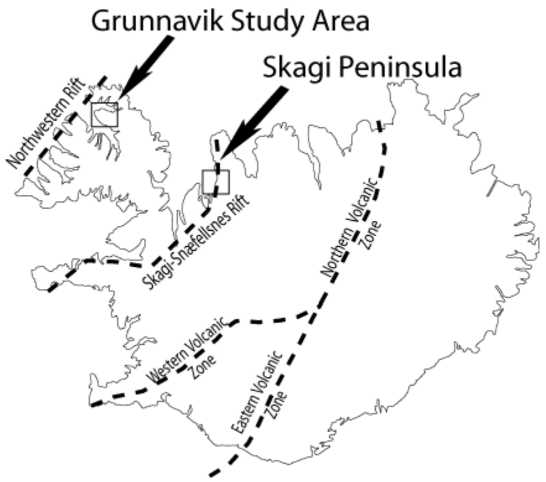

Figure 1. Map of rift systems on Iceland. Study areas of 2003 and 2004 projects are highlighted (after Hardarson et al., 1997).

The Skagi-Snaefellsnes Rift was the focus of a Keck project in Iceland during July and August 2004. The field research for these projects took place in the Westfjords of northwestern Iceland, near the abandoned town of Grunnavik, as well as along the Skagi Peninsula, near the study area of the 2003 Keck project. In the Westfjords, three student projects were conducted, including this study, Randall (this volume), and Styger (this volume). This study focuses on basaltic volcanism, examining the volcanic stratigraphy of three mountain cliffs, and their geochemistry and petrography. These data provide information about the petrogenesis of the basalts from early rift activity.

A comparison of the older rocks of the Westfjords to the younger rocks of the 2003 and 2004 Keck projects on the Skagi Peninsula allows a comparison of plume centered versus off-centered rift activity. This information provides a better understanding of how the mantle source is affected by proximity of the rift to the plume.

METHODS

The area was mapped on 1:20,000 and 1:10,000 scale topographic maps. Of the 39 samples collected, 36 were studied petrographically, 12 were analyzed for major and trace elements using XRF, four of which were also analyzed for trace elements with ICP-MS at Washington State University. Samples were selected from the tops and bottoms of each mountain section, as well as to cover the lithologic variability of the three sections. One sample was dated by the $^{40}Ar/^{39}Ar$ method at Oregon State University.

RESULTS

Field Description/Stratigraphy

Grunnavik, Iceland is located in the Westfjords of Iceland along the coast of the Jokulfirdir and Isafjardardjup fjords overlooking the bay of Grunnavik. The mountains of this study are Mariuhorn, Geirsfjall, and Bjarnanupur. These mountains range in height from approximately 300 to 700 m. Stratigraphic sections were measured for each mountain. The sections are composed of relatively uniform basalt flows. Bjarnanupur has 27 flows, Mariuhorn has 37 flows, and Geirsfjall has 27 flows. There is a mafic and a felsic tuff near the top of Geirsfjall.

The stratigraphic relationship between the lava flows from each mountain is complicated by the approximate 4-5^{o} regional dip to the southeast. Based on elevation and regional dip, Bjarnanupur is the stratigraphically lowermost section; the top of Mariuhorn should correlate to the top of Bjarnanupur and the bottom of Geirsfjall. Correlation of individual flows was not possible due to a lack of significant marker beds. Analysis of percent plagioclase and olivine phenocrysts provided no clear correlation relationships.

The lowermost sample, collected at sea level from Bjarnanupur Mountain, represents the oldest lava flow of this suite. It yielded a $^{40}Ar/^{39}Ar$ whole-rock plateau age of 14.20 ± 0.33 Ma (2-sigma error).

Petrography

The main mineralogical components of these basalts include plagioclase, augite, olivine, and Fe-Ti oxides. The rocks show approximately 0-25% modal abundance of plagioclase and olivine phenocrysts and are locally glomeroporphyritic. Phenocrysts range in size from 0.1-1 mm. Plagioclase is typically subhedral, zoned, and tabular to equant in form. Olivine, when present, forms round crystals that are variably altered to iddingsite.

The groundmass of these basalts displays intergranular and pilotaxitic textures and is composed of acicular plagioclase and anhedral clinopyroxene.

This sample suite includes one felsic welded tuff from Nupdalur and two dikes, one next to the welded tuff and one near the bottom of Mariuhorn. These three samples show considerable variation in composition. The two dikes are completely aphanitic with trachytic textures. The welded tuff preserves approximately 70% modal abundance of glass in the groundmass.

Geochemistry

All rocks of this study are sub-alkaline basalts based on the total alkali silica diagram (Fig. 2) and have normative olivine. The concentration of SiO_2 in these lavas ranges from 48.2-49.7 wt. %. Composition does not vary systematically with stratigraphic order.

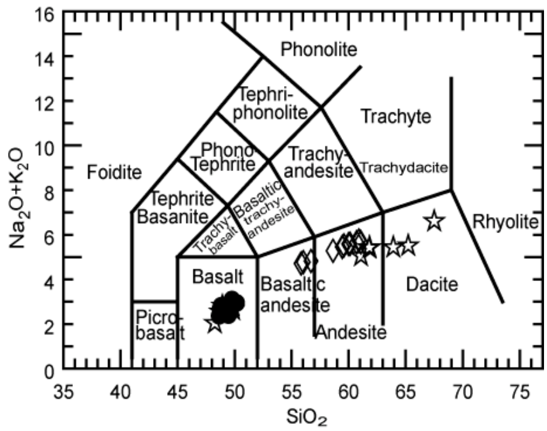

Figure 2. Plot of Westfjords data on TAS diagram (after Le Bas et al., 1986). Circles, this study; diamonds, Randall (this volume); stars, Styger (this volume).

Fenner diagrams of the Westfjords basalts display generally linear trends including a decrease of Ni, then Al_2O_3, and then CaO/Al_2O_3 with decreasing MgO (Fig. 3).

The basalts are enriched in incompatible elements relative to N-MORB and are similar to E-MORB (Fig. 4), but have lower LILE. The evolved rocks from the Westfjords are more enriched in incompatible elements (cf. Randall, this volume; Styger, this volume).

INTERPRETATION

Based on petrography and major and trace element geochemistry, the basalts of the Westfjords, Iceland show evidence for fractional crystallization of magma with an enriched mantle source. The rocks of this study are representative of the early Skagi-Snaefellsnes Rift activity. Basalts collected on the Skagi Peninsula, which formed at the end of rift activity, show similar geochemical concentrations, an indication of continued plume interaction with the rift.

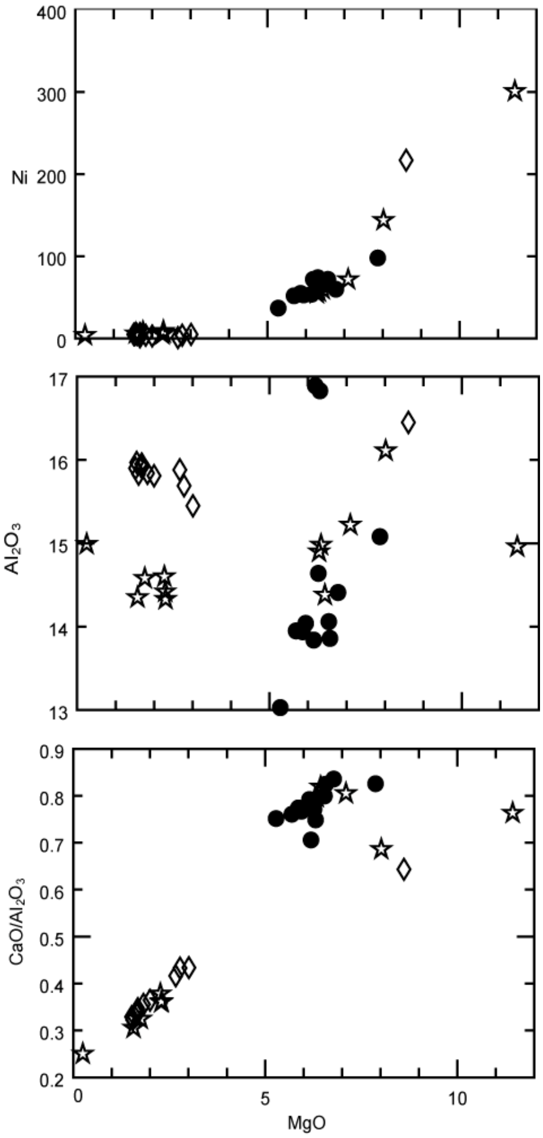

Figure 3. Fenner diagram of MgO compared to Ni (top), Al_2O_3 (middle), and CaO/Al_2O_3. Circles, this study; diamonds, Randall (this volume); stars, Styger (this volume).

Westfjords Petrogenesis

The basalts that compose the three mountains near Grunnavik are typical tholeiite basalts. The chemical variation displayed by the Westfjords basalts can be explained by fractional crystallization. Fenner diagrams showing decreasing Ni, Al_2O_3, and CaO/Al_2O_3 with dropping MgO (Fig. 3) are evidence of fractional crystallization of olivine, plagioclase feldspar, and clinopyroxene. However, there is no correlation of this fractionation within the stratigraphy. This suggests numerous magma chambers feeding

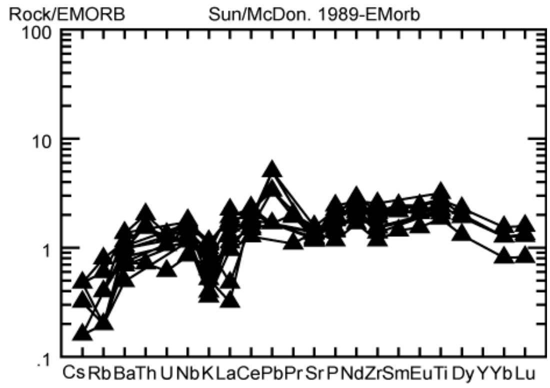

Figure 4. Spider diagram of whole-rock trace element concentrations normalized to E-MORB (this study) (after Sun and McDonough, 1989).

the volcano over time. Two samples from this study that fall off the CaO/Al_2O_3 vs. MgO trend likely contain cumulate plagioclase. Analysis of the other Westfjords data shows evidence of continued fractionation of these minerals, Fe-Ti oxides and minor amounts of apatite (cf. Randall, this volume; Styger, this volume).

The patterns of the spider diagram of the basalts for this study include high concentrations of Pb and small negative Sr anomaly. The decrease in Sr likely reflects the fractionation of plagioclase. The high levels of Pb have been observed in other data sets, including those from the 2003 Keck project on the Skagi Peninsula.

Rift Evolution

The basalts of this study were compared to those from the Skagi Peninsula. It has been proposed (Hardarson et al., 1997; Jordan et al.,

2004) that the Skagi area was the location of the last volcanic activity before the relocation of the rift to its current position. The data presented in the results from this project suggest a strong plume signature for the duration of rifting.

Nb-Zr-Y relationships can distinguish N-MORB signatures. The trends of N-MORB and Icelandic basalts plot as distinct trends on logarithmic plots of Nb/Y vs. Zr/Y diagrams (Fitton et al., 1997; Hardarson et al., 1997). The basalts from both the Westfjords and the Skagi Peninsula plot solely in the Icelandic basalt field (Fig. 5), and lack a clear N-MORB component.

There is a large amount of overlap between the trace element concentrations for the

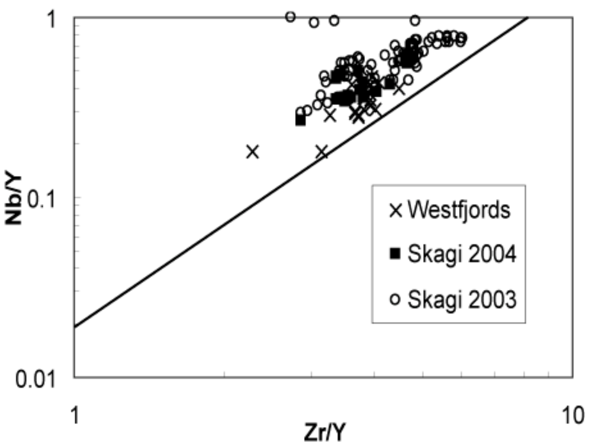

Figure 5. Plot of Zr/Y vs. Nb/Y for Westfjords and Skagi basalts (after Fitton, et al., 1997). Line divides field of Icelandic basalts (top) from N-MORB (bottom). X's, Westfjords basalts; circles, Skagi 2003 basalts; squares, Skagi 2004 basalts.

Westfjords and Skagi datasets, but the Westfjords basalts display a more restricted range on E-MORB normalized spider diagrams and are slightly less enriched than the Skagi basalts. For example, the Zr/Nb ranges from 6-11 in the Skagi basalts and 9-13 in the Westfjords basalts. This could be due to some combination of slightly higher and less variable degrees of partial melting or melting of a plume source depleted by melt extraction, both of which might be expected for a plume centered rift, and/or the relatively small size of the Westfjords dataset. However, the high degree of variation *and* high values of Zr/Nb seen in both the NW Iceland rift and the neovolcanic zone, attributed to melting of a mantle depleted by melt extraction (Hardarson et al., 1997), are not observed in either the Skagi or Westfjords data.

According to Hardarson et al. (1997) there is evidence that basalts erupted late in the history of the NW Iceland Rift were derived from the mixing of plume and N-MORB mantle sources. This is interpreted to reflect a decrease in plume input due to the increased distance between the rift and the plume during the waning stages of the rift. Data from the Skagi Peninsula and Westfjords all fall within the Iceland array on the log plots of Nb/Y vs. Zr/Y and show no evidence of a trend towards N-MORB. This information suggests a significant dilemma when the Skagi-Snaefellsnes Rift is compared to the data from the NW Iceland Rift. An alternative to account for the differences in chemistry between the basalts from the waning stages of the Skagi-Snaefellsnes Rift and the NW Iceland Rift could be due to the intensity of plume activity (Schilling et al., 1982), either weaker during the NW Iceland Rift, or stronger during the Skagi-Snaefellsnes Rift.

The information presented by this data set is significant for the understanding of how the Mid-Atlantic Ridge evolves on the island of Iceland.

ACKNOWLEDGMENTS

Support from the Keck Consortium and the NSF made this project possible. I would like to thank the project leaders Brennan Jordan, Keegan Schmidt, and Paul Olin, as well as the students of the project and all of their assistance in the field and with my research. Thank you also to my advisor and sponsor, Jim Rougvie.

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