VOLCANIC STRATIGRAPHY AND PETROLOGY OF THE NORTHERN SNAEFELLSNES RIFT, SOUTHERN LAXÁRDALSFJÖLL, ICELAND

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INTRODUCTION

Iceland is exposed above sea level due to thick crust produced by the interaction between a stationary mantle plume and the Mid-Atlantic Ridge. The ridge drifts westward with respect to the plume and then periodically jumps to the east, abandoning the old ridge to re-center over the plume. The most recent jump occurred at ~7 Ma when the ridge abandoned the Snaefellsnes rift and jumped 100-200 km eastward to its present location (Hardarson et al., 1997).

The volcanic rocks of the southern Laxardalsfjoll range in the northern Snaefellsnes rift are predominantly Tertiary tholeiitic basalt flows. Major and trace element data for these basalts, when compared to typical primary N-MORB, indicate they are evolved. This reflects fractional crystallization in a shallow magma chamber, and enrichment in incompatible trace elements due to interaction with the Icelandic plume. Near the middle of the sequence are felsic volcanics that include a rhyolite, a coarsely porphyritic andesite, and several tuffs (Fig. 1, 2). Samples were analyzed petrographically and geochemically to evaluate the generation and evolution of these volcanics allowing for a better understanding of magmatic processes involving the interaction between a mid-ocean ridge nearing abandonment and a mantle plume.

Field Area

Laxardalsfjoll (Fig. 1) is a NW-SE trending ridge at the southern end of the Skagi Peninsula in northern Iceland. This field area was chosen due to the presence of intermediate and silicic units (Fig. 3), which are unusual in Iceland. The lower 200 m of exposure are basalt flows ranging from 3-12 m thick (Fig. 1, 2). These relatively homogenous lavas are overlain by a ~60 m andesite that contains plagioclase phenocrysts up to several centimeters in diameter and has been named

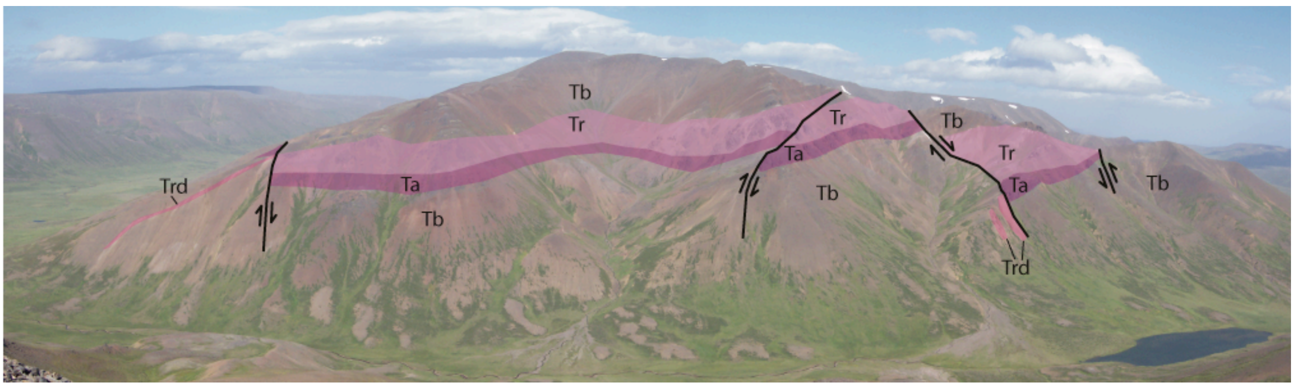

Figure 1. Panoramic view of the study area looking NW. Tb indicates Tertiary basalt, pink Tr is rhyolite, purple Ta is Strjugsskard andesite, and pink Trd is rhyolite dikes. Faults indicated by black lines. All faults are normal faults (some distorted by perspective). (Photos by Keegan Schmidt)

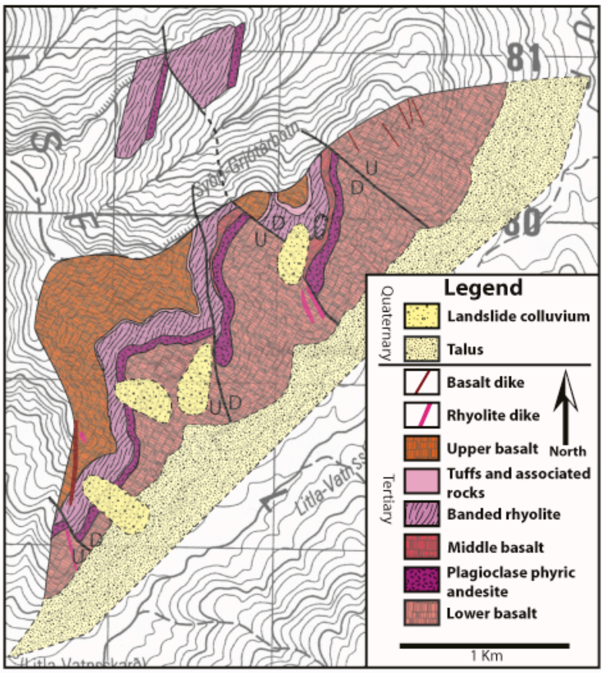

Figure 2. Geologic map of southern Laxaralsfjoll, NE Iceland.

the Strjugsskard andesite (cf. Adzima, this volume). This unit is discontinuously overlain by tuffs, a tuffaceous breccia, and a few thin basaltic andesite lavas. Up section is a 30-80 m thick flow-banded rhyolite. Above the rhyolite is a discontinuous band of tuffs, some containing large plagioclase crystal fragments. The upper 200 m of the ridge is another thick section of basalt lavas.

Several major NW-SE trending normal faults are found in the field area (Fig. 2), as are numerous small basaltic dikes, most of which were too small to map. A few large rhyolite dikes also crop out above and below the flow-banded rhyolite unit. The rhyolite thickens near the center of the field area and relationships become more complex. One particularly complex faulted and tilted block contains thick tuffs, andesite, dacite, and rhyolite that may be at or near a center for the silicic eruptions.

Petrography

In hand specimen the basalts exhibit an aphanitic groundmass with only a few phenocrysts and vesicles. Thin sections reveal textures that are typically intergranular to intersertal. The groundmass is composed of predominately felty, but occasionally trachytic, plagioclase laths, clinopyroxene microlites, iron-titanium oxides, and glass (typically altered to brown palagonite). Phenocrysts are sparse: mostly 1-2 mm plagioclase and augite.

The plagioclase phyric andesitic unit (Strjugsskard andesite) contains up to 35% euhedral plagioclase phenocrysts ranging up to several centimeters in diameter. The groundmass is generally dark gray to purple near the bottom of the flow, becoming more red toward the top. Flow banding (interpreted as commingling) is locally prominent, and manifested in thin section by variation in crystal size and glass concentration. The groundmass contains small plagioclase laths with augite, iron-titanium oxides, some olivine, and glass. Plagioclase phenocrysts exhibit some oscillatory zoning, and several disequilibrium textures including sieve, resorption, rounded edges, and embayed margins.

Rhyolites in the field are usually dark grey to purple and highly flow banded, although some isolated outcrops contain porphyritic obsidian. Rhyolite dikes are generally light colored and very fine-grained. Alteration and the small grain size make mineral identification very difficult in thin section. A few small plagioclase laths are visible, occasionally with inclusions of clinopyroxene and zircon.

Geochemistry

Many Harker-type diagrams exhibit smooth trends suggesting that all the lavas are genetically related. Samples span a wide range

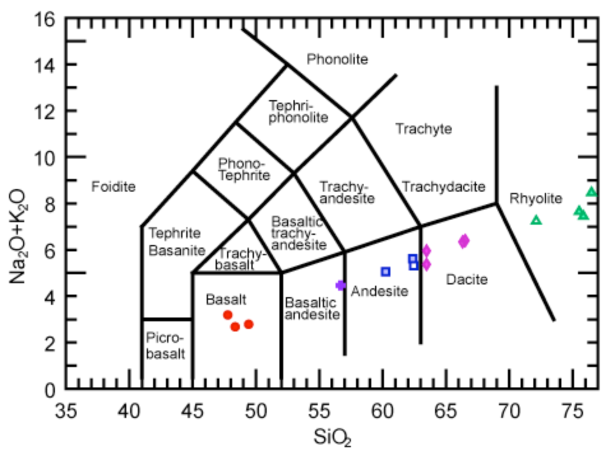

Figure 3. Total Alkali vs. Silica Diagram. ● = basalts, ✚ = basaltic andesite, ■ = Andesite (hollow = Strjugsskard andesite), ♦ = dacite, △ = rhyolite.

of composition, from basalts to rhyolite (Fig. 3). Most of the basalts and basaltic andesites conform to a tholeiitic AFM trend. Most incompatible element concentrations in the basalts are high, even higher than in typical E-MORBS. The basalts also show an average Mg# of 39 which is much lower than near 70 for primitive basalts. Most major element variation diagrams show trends for the basalts that are generally compatible with a model of crystal fractionation in a shallow magma chamber. The concentrations of MgO, FeO, and CaO decrease with increasing SiO_2 content, compatible with crystal fractionation of olivine, plagioclase, and clinopyroxene. When plotted against MgO, the concentrations of FeO, TiO_2, and P_2O_5 initially increase and then decrease, indicating the fractionation of Fe-Ti oxides and apatite followed the peak. Rhyolites and dacites plot on a trend of decreasing Zr with increasing SiO_2, which, combined with thin-section observations, indicates late zircon fractionation.

Several variation diagrams, such as those in Figure 4, show additional trends that cannot be completely explained by crystal fractionation and require other processes.

DISCUSSION AND CONCLUSION

Although most of the basalts and basaltic andesites seem to follow a trend of fractional crystallization (labeled in Fig. 4b, 4c), the rhyolites, dacites, and Strjugsskard andesite require a more complex explanation involving both fractional crystallization and magma mixing.

Silicic Fractional Crystallization

Volcanics in Iceland are distinctly bimodal. Basalt predominates, but there are also some volcanic centers with a substantial rhyolite component. Intermediate rocks are rare. Rhyolites have generally been attributed to crustal melting (Tronnes, 2002). Meganck (2004), argued against partial melting for Skagi rhyolites and dacites based primarily on Zr concentrations. As seen in Figure 4d, the concentration of Zr is lower in the more evolved rhyolites than in the dacites. In partial

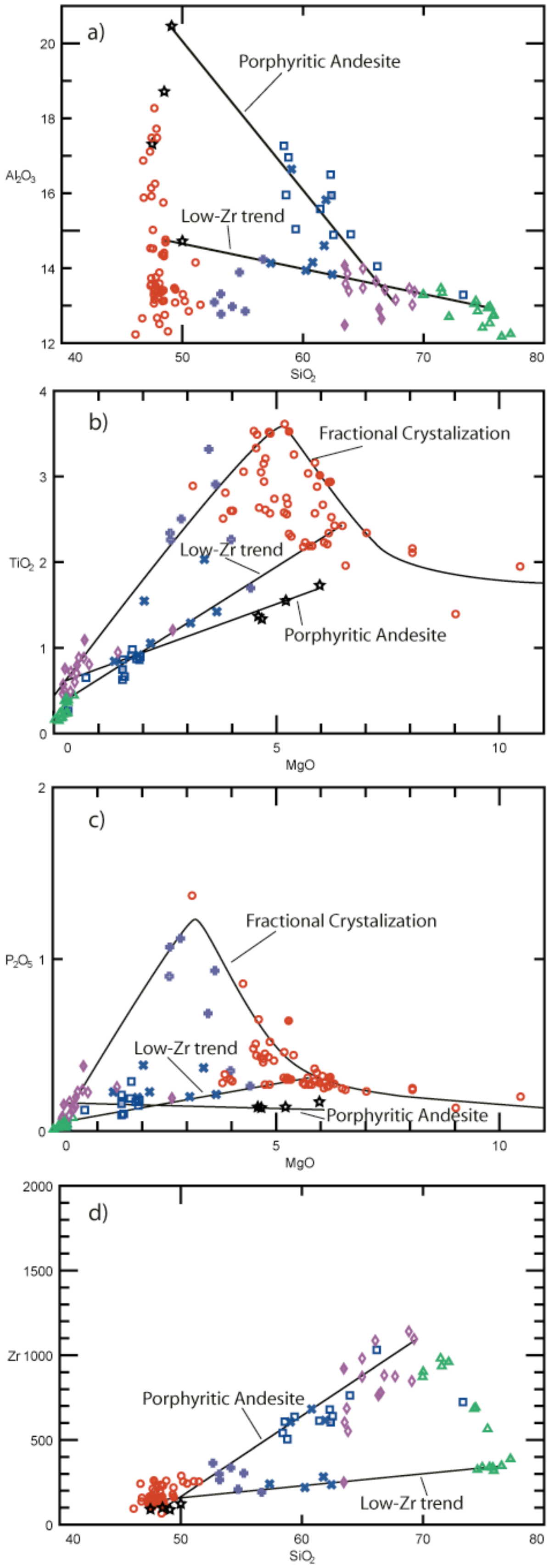

Figure 4. Variation diagrams showing various trends (solid shapes indicate my data). ● = basalts, ✚ = basaltic andesite, ✖ = andesite, ■ = Strjugss-kard andesite, ☆= PUB, ◆ = dacite, ▲= rhyolite. These trends support crystal fractionation and magma mixing. (Plots show all data from the Skagi area from both the 2003 and 2004 Keck projects)

melting Zr (an incompatible element) should be concentrated in initial melts (rhyolite) and become diluted as melting progresses toward producing dacite. Meganck (2004) thus attributed the lower Zr concentration in the rhyolites to fractional crystallization. The simplest model suggested by the Harker-type diagrams relates most basalts, basaltic andesites, and dacites by crystal fractionation. The rhyolites are then a further fractionation with a lower Zr concentration because zircon became a fractionating phase at the point of dacite development. An alternative explanation is that the dacites are the result of partial melting that then fractionated zircon as the rhyolite is produced.

Magma Mixing

Two mixing trends must be added to the fractional crystallization trends in Figure 4 if all of the data are to be adequately explained. The first is necessary to explain the production of the Strjugsskard andesite, and the second involves basaltic andesites and andesites with low Zr contents.

Distinct flow banding in hand sample is evidence for magma mixing in the Strjugsskard andesite, seen in thin section as extensive resorption textures on phenocrysts of plagioclase and augite. Minor and trace element data often show this unit plotting off fractionation trends defined by the basalts and basaltic andesites (Fig. 4b, 4c). If the Strjugsskard andesite were the result of mixing between two magmas that are represented in this suite of rocks, it would be expected to plot on a straight line between the two mixed end-members.

In the Al_2O_3 versus SiO_2 diagram (Fig. 4a) the Strjugsskard andesite plots on a line connecting the dacites and rhyolites with a plagioclase ultra-phyric basalt unit (PUB). This basalt is of a similar character to the other basalts, but with a much higher concentration of plagioclase phenocrysts. The PUB does not appear in the Laxardalsfjoll area, but does in nearby Vatnsdalsfjall.

Figure 4d may permit us to distinguish between rhyolite and dacite as the silicic end member. A plot of Zr versus SiO_2 shows the andesite plotting between the dacites on the right, and the basalts on the left. Microprobe analysis of the plagioclase phenocrysts in the Strjugsskard andesite by Charlene Adzima (cf., this volume) yields a composition of An_{85-87}. This is much more calcic than would be expected in an intermediate rock and almost certainly comes from a basaltic magma. This composition overlaps with microprobe analysis from the PUB plagioclases. The Strjugsskard andesite has therefore been interpreted as the result of magma mixing between the PUBs and the dacites (Meganck, 2004).

The second mixing trend, low-Zr basalatic andesites and andesites, appears to involve the high silica rhyolites and tholeiitic basalts. On many plots, several samples of intermediate composition plot in a very straight line connecting these two end-members (all plots in Figure 4, indicated by the labeled Low-Zr trend). These intermediate rocks are found just above or below the Strjugsskard andesite and the rhyolite, many from the middle basalt unit in Figure 2. They usually occur as thin, relatively discontinuous flows. Samples in the low-Zr trend fall well below the fractionation curve and fall on a straight line connecting relatively evolved tholeiitic basalt and some of the most silicic rhyolites (Fig. 4b-d).

Model

Meganck (2004) proposed a zoned rhyolitic and dacitic magma chamber with a concentration of rhyolite near the top due to density differences. To generate the Strjugsskard andesite a PUB dike may have propagated into this magma chamber initiating a rapid mixed eruption that tapped the lower part of the magma chamber and thus involved the PUB and the dacite. The introduction of this PUB dike may also have triggered eruption of the rhyolite. For the low-Zr trend I propose that some of the numerous tholeiitic basalt dikes in the area may have propagated into the upper portion of the magma chamber, mixing with the more silica rich rhyolites. These smaller scale eruptions produced localized flows of an intermediate composition and show evidence for magma mixing.

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