INSIGHT INTO THE ORIGIN OF SILICIC ROCKS IN NORTHWESTERN ICELAND: EVIDENCE FOR FRACTIONAL CRYSTALLIZATION

SHEENA STYGER
University of the Pacific
Sponsor: Lydia K. Fox

INTRODUCTION

In Iceland, both extension and hot spot processes occur in one location, providing a unique place to study the genesis of igneous rocks. The general composition of Iceland is 80-85% basalt, 10% intermediate to silicic, and 5% volcanic sediment (Saemundsson, 1979). The basalts can be attributed to rifting processes, leading to fissure eruptions. Silicic rock origin in Iceland is linked to a combination of fractional crystallization, crustal remelting, and magma mixing (Gunnarsson et al., 1998). These processes generally occur in a magma chamber, fed from the mantle, beneath a central volcano (Saemundsson, 1979). Northwestern Iceland has evidence for both processes, though it is primarily composed of Tertiary basalts with a few areas of intermediate to silicic rocks.

The purpose of this study is to examine the relationships between the basic and intermediate rocks of northwestern Iceland. This study focuses on the area surrounding Tröllafell, a known location of intermediate rocks (Fig. 1). Special attention is given to determination of the origin of the intermediate rocks.

Methods

This study began with a survey of aerial photographs followed by field mapping. The field area was mapped in detail to locate contacts, describe units, and collect samples. 27 samples were brought back to the University of the Pacific and made into thin sections to analyze petrographically. To determine major and trace element chemistry 12 samples were analyzed using XRF and four samples were analyzed using ICP-MS at Washington State University's GeoAnalytical Laboratory. IGPET 2001 was then used to process the data and create geochemical diagrams. Mineralogy was further investigated by analyzing 11 whole rock samples using XRD at the University of the Pacific.

Field Relationships

The field area studied includes approximately 15 km^2 just south of the Leirufjördur valley, including Hestur, Nónhögg, and Tröllafell. This area has two distinct units; the first unit is a medium grey, porphyritic, porous basalt with plagioclase, pyroxene, and olivine phenocrysts

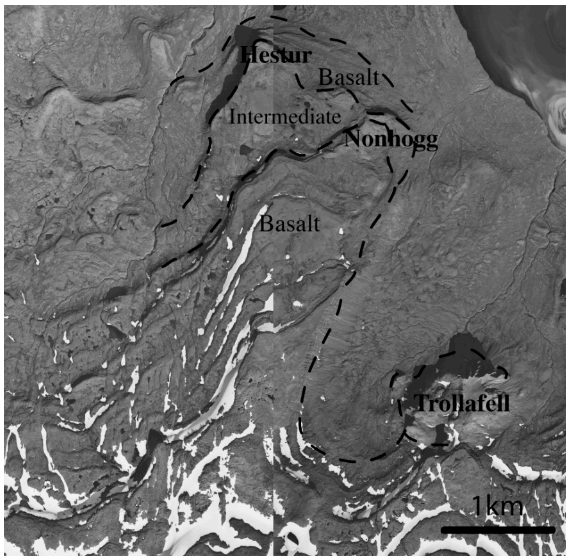

Figure 1. General field map over aerial photo displaying basalt and intermediate units.

(Fig. 1). This unit varies from no vesicles to layers of scoria.

The second unit, which I will refer to as the intermediate unit, is dark grey, has a finer groundmass, lower abundance of plagioclase and pyroxene phenocrysts, and no olivine phenocrysts. Flow banding is very apparent in outcrop of this unit and it weathers to a pink color. In some locations, the upper portion of the intermediate unit exhibited evidence of having been through vapor phase alteration. As many as 10 m of the light purple altered rock was found directly above the cliff-forming portion of the intermediate unit.

Stratigraphy

While the dominant rock exposure within the field area is basalt, sandwiched between the flows of basalt are flows of the intermediate unit. Starting at the shoreline north of Nónhögg (Fig. 1) the surface remains covered with soils until approximately 60 m in elevation. From 60 m to 235 m in elevation, basalt flows are seen in addition to areas of talus. The lower contact of the intermediate unit follows the 235 m elevation contour line from the corner of Nónhögg west (Fig. 1). The upper contact of the intermediate unit is located near 285 m in elevation. At elevations higher than 285 m, basalt is found. These stratigraphic relationships hold true for the majority of the field area.

The field relationships exhibited at Tröllafell do not match the basalt and intermediate layers of Nónhögg and Hestur. Tröllafell intermediate rock exposure begins at 300 m in elevation on the northwestern side and extends to the top of the mass at 558 m in elevation. On the southwest side of Tröllafell, relatively horizontally layered basalts onlap the intermediate unit (Fig. 2). Although the rocks of Tröllafell match the main intermediate unit in petrographic aspects, the chemistry provides evidence that the two regions are not related.

DATA

Petrography

The groundmass crystals of the basalt are fine grained and randomly oriented. Plagioclase phenocrysts, which range in size from 0.5-1.0 mm, generally have $An_{60} – An_{70}$. Samples also include phenocrysts of clinopyroxene and olivine. Two samples from the basalt unit have a subophitic texture with sparse euhedral olivine crystals.

The groundmass of the intermediate unit is very fine grained. Phenocrysts in this unit include plagioclase and pyroxene. Tabular groundmass plagioclase crystals near phenocrysts are aligned parallel to the faces of the phenocrysts. The crystals further from phenocrysts are all aligned in one direction. Plagioclase phenocrysts, which tend to be less than 0.5 mm in length, have $An_{40} – An_{60}$. All samples taken from the intermediate unit display a glomerophyric texture.

Mineralogy

XRD analysis provided additional information on mineralogy. The basalt unit contains plagioclase, clinopyroxene, orthopyroxene, olivine, and magnetite. The intermediate unit contains plagioclase, clinopyroxene,

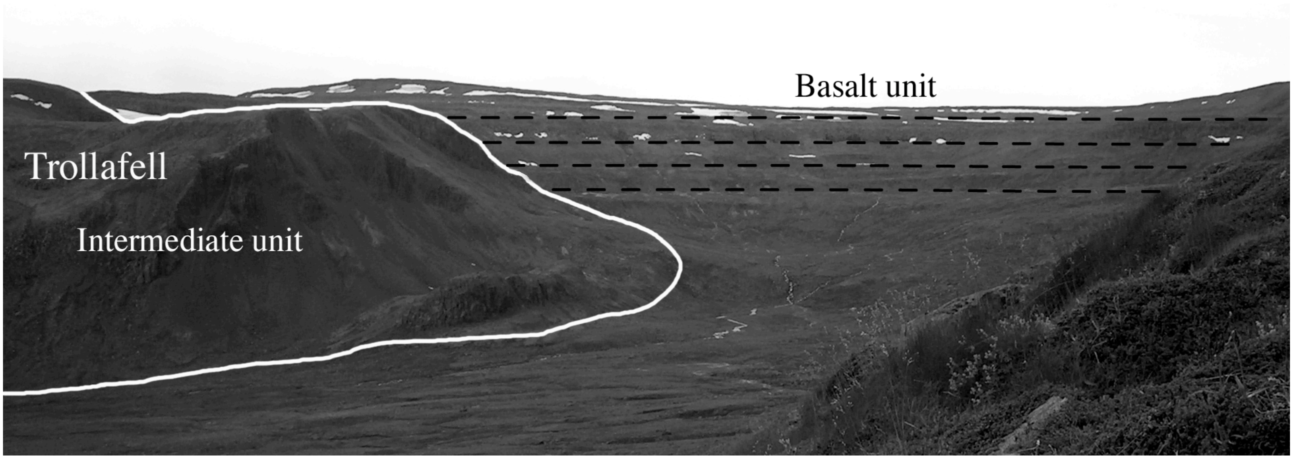

Figure 2. View of Tröllafell facing southeast with onlapping basalts flows.

orthopyroxene, magnetite, and low cristobalite.

Geochemistry

Geochemical results show that the basalt unit ranges from 47 to 49 wt.% SiO_2. The intermediate unit has a much larger range from 60 to 67 wt.% SiO_2 (Fig. 3). Harker and Fenner diagrams display linear patterns for samples collected (Figs. 4 and 5). This observation led to Pearce element diagram construction in order to further understand the suite of rocks collected. All Pearce diagrams display linear trends. The data plotted on the Si/K versus (2Ca+3Na)/K forms a very straight line with a slope near one. This observation supports fractional crystallization as an explanation for the variation in samples collected, as a slope near one indicates the possibility of plagioclase fractionation.

The samples tend to fall into linear paths, with the exception of one outlier. The outlier is from the intermediate unit and was collected from Tröllafell, while the other samples were taken from intermediate unit between the two regions of the basalt unit. The intermediate unit, excluding the outlier from Tröllafell, will now be referred to as the main intermediate unit.

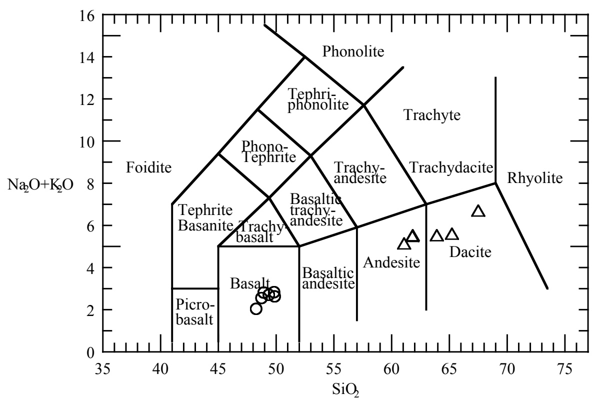

Figure 3. Total alkalis versus silica classification (after LeBas et al., 1986). Circles represent the basalt unit and triangles represent the intermediate unit.

Within the main intermediate unit, silica content increases with stratigraphic height of samples. Using Harker diagrams to establish oxide trends, with increasing silica content, the main intermediate unit samples exhibit a decrease in FeO, MgO, MnO, TiO_2, CaO, and P_2O_5, and an increase in Na_2O and K_2O. These trends imply progressive fractional crystallization with increasing stratigraphic height.

Analysis

Geochemical evidence and field relationships strongly imply fractional crystallization as the dominant process in producing the main intermediate unit. The linear trends of the major and trace elements for the main intermediate rocks generally point towards the most evolved basalts. This provides evidence for the basalts to be from a parental magma source that was then fractionally crystallized to produce a variety of daughter lavas, representing the main intermediate unit samples.

To model fractional crystallization the most primitive sample collected was used as the parent in a mass balance of major element oxides. The samples collected for this study in addition to the samples collected in an adjacent field area (cf. Randall, this volume) fall relatively close to the predicted results with approximately 93% fractional crystallization of the initial magma. This implies that crustal remelting and magma mixing did not play a significant role in the formation of the main intermediate unit rocks.

The sample taken from Tröllafell displays distinctly different values for all elements measured and does not correlate with the linear trends of the main intermediate unit. This evidence implies that it is not a result of fractional crystallization of the same source, but rather has a source distinctly different from the source that produced the basalts and the main intermediate unit.

CONCLUSION

Data collected provides evidence for two origins of magma within the field area. The lower basalt unit, main intermediate unit, and upper basalt unit can all be related by fractional crystallization to the most primitive basalt sampled. It is possible that fractional crystallization of a magma chamber produced intermediate composition lavas located directly above basalt. Following emplacement of the main intermediate unit, a replenishment of the magma chamber returned the chamber to a more mafic composition. Following this replenishment, the vent may have effused basaltic lava on top of the intermediate lava to form the upper basalt layers.

It is also possible that the region studied is a result of multiple vents that have evolved through fractional crystallization to form silicic lavas. A more detailed study is needed in order to determine which of these theories is more plausible.

The chemical differences between Tröllafell and the other intermediate rocks cannot be explained by fractional crystallization. The source for Tröllafell is different than the other rocks in the area. It is possible that crustal remelting, magma mixing, or a combination of processes affected the magma chamber feeding the vent for Tröllafell. Further investigation of the field area, in addition to the surrounding area is needed to determine the origin of the Tröllafell dacite.

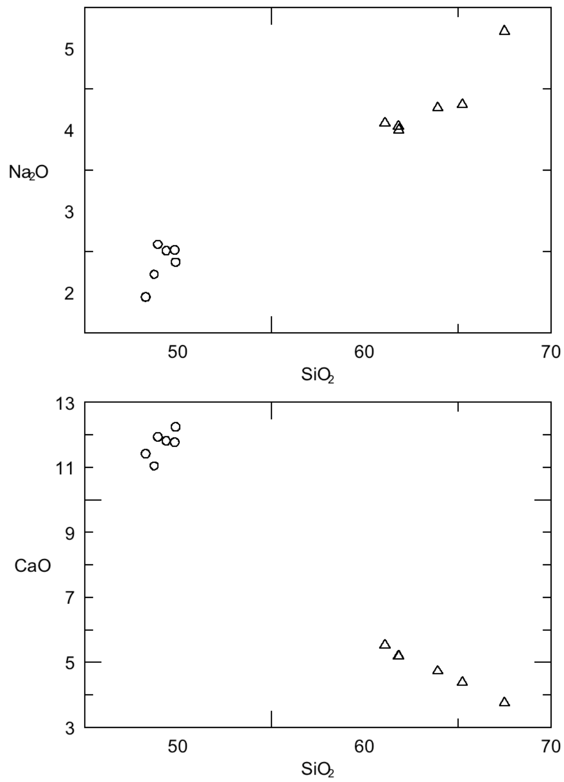

Figure 4. Harker diagrams of samples collected; intermediate unit samples represented by triangles, basalt unit samples represented by circles.

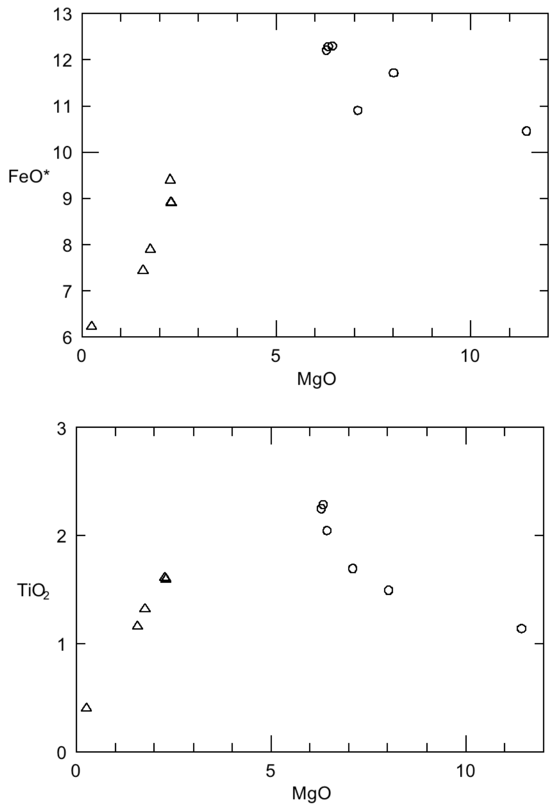

Figure 5. Fenner diagrams of samples collected; intermediate unit samples represented by triangles, basalt unit samples represented by circles.

ACKNOWLEDGMENTS

I would like to thank Brennan Jordan, Keegan Schmidt, and Lydia Fox for providing guidance and support to complete this project. For their excellent field assistance, I also thank Emily Baldwin and Lara Kapelanczyk.

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