INTRODUCTION

Interaction between a mantle plume and the mid-Atlantic ridge has led to Iceland’s unusually thick lithosphere, up to 45 km thick. Due to the absolute westward motion of the European and North American Plates over the stationary mantle plume, the mid-Atlantic ridge has periodically “jumped” eastward approximately 100 to 200 km every 6 to 8 million years, abandoning the old ridge, to re-center itself on the mantle plume and consequently the area of maximum volcanism (Helgason, 1984). A suite of basaltic, intermediate and rhyolitic flows in Langadalsfjall represent volcanism ranging from approximately seven to eight million years old on a ridge segment which was abandoned soon thereafter as the ridge jumped to its present location, approximately 100 km to the SE.

A section of 760 m of volcanics in the Langadalsfjall region on the Skagi peninsula in northwestern Iceland was described, sampled and mapped over an area approximately 8 km² (figure 1). 50 samples from basaltic flows, rhyolites, and a coarsely plagioclase porphyritic unit of intermediate composition, were collected. 15 representative samples were analyzed petrographically, XRF data on major, minor and trace elements were also obtained for 11 samples, and three Ar-Ar dates were obtained for three representative samples, in order to better understand mid-ocean ridge and mantle plume interaction, magma mixing and other magmatic processes in northwestern Iceland.

Field Relations

Langadalsfjall is a northwest-trending flat-topped ridge that rises approximately 760 m above the northern side of the glaciated Blanda River valley. Post-glacial Quaternary landslides have exposed the volcanic sequence. The lowest exposures consist of 34 relatively homogenous basalt flows ranging from 5 to 30 meters in thickness, overlain by a 40-60 m thick plagioclase phryic unit. This unit is overlain by a tuffaceous layer (too thin to be mapped) and another series of
approximately 20 basalts of comparable thickness to those lower in the section. Numerous normal faults with 5-20 meters of offset cut the plagioclase phyric unit, and one large fault approximately 1.5 km long with a trend of N15E and a dip to the SW cuts from the base of the plagioclase phyric unit through its overlying basalts.

These strata are complicated by an additional rhyolitic unit, which crops out at the same stratigraphic level as the plagioclase phyric unit, but across the major fault, and appears to gradually grade into the plagioclase phyric unit. It too is overlain by basalts that are assumed to be stratigraphic equivalents of the basalts that overlie the plagioclase phyric unit on the west side of the fault. Obsidian with medium-grained plagioclase phenocrysts is plentiful within the rhyolitic unit. Due to this stratigraphic similarity and Ar-Ar geochronologic dates of 7.80 +/- 0.09 Ma for the plagioclase phyric unit and 7.82 +/- 0.04 Ma for the rhyolite the plagioclase phyric unit and the rhyolitic unit are considered to be related and expressing local heterogeneity.

**Petrography**

The rocks in the map area can be grouped into three main units: tholeiitic basalts, a plagioclase phyric unit of intermediate composition, and rhyolites (see Figure 2: also present in Figure 2 are three additional groups from related studies discussed later).

The basalts have aphanitic groundmasses with varying amounts of plagioclase and vesicles visible in hand sample. In thin section, the dominant textures range from ophitic to intergranular to intersertal to hyalopilitic, and identifiable mineralogy consists of plagioclase>>clinopyroxene>>Fe-Ti oxides. Basaltic glass is also present. Plagioclase occurs predominantly as microlites in the groundmass (demonstrating either trachytic or felty texture), and as phenocrysts. The dominant clinopyroxene is augite, which is present in the groundmass as well as phenocrysts up to 0.5mm in diameter, although pigeonite is also present as a minor phase in some samples. The basaltic glass ranges from 2% to 10%, is present in every basaltic sample, and is typically altered to brownish palagonite.

The plagioclase phyric unit has up to 35% phenocrysts in a dark gray groundmass that is highly flow banded. In thin section flow banding is also visible in the groundmass that is made up of plagioclase laths, augite, olivine, Fe-Ti oxides and glass. Plagioclase crystals up to 7mm in length have well-developed albite and pericline twinning and show disequilibrium textures such as embayed margins, rounded edges and resorption.

The rhyolites are a highly variable group. One appears to be a well-consolidated tuff, two are highly devitrified and flow-banded rhyolites, one is a glassy obsidian sample with plagioclase phenocrysts up to 3mm in length, and one an extremely fine-grained dark flow-banded rock. All are highly altered and the mineralogy is very difficult to identify in thin section with the exception of plagioclase phenocrysts.

**Geochemistry**

All basalts are evolved compared to primitive basalt, all are quartz-normative, and plot on a tholeiitic AFM trend. Mg# varies from 35.0 to 51.7, which is well below the average value of 70 for primitive basalts, and falls on the evolved end of average MORB values. The compatible element values for Ni (28 to 98 ppm) and Cr (10 to 185 ppm) also suggest an evolved basaltic composition. These basalts also have a combined alkali content of 3.15,
which is slightly higher than that of average MORB, 2.72 (Winter, 2001, p. 248).

The rhyolites range from 75.51 to 74.53 wt% SiO$_2$ and the composition of the plagioclase phryic unit falls between the basalts and the rhyolites. It contains 58.61 wt% SiO$_2$ and 1.86 wt% MgO, putting it much closer to the basalts in SiO$_2$ content and closer to the rhyolites in MgO content (Figure 3). The trace element compositions as well are intermediate between the rhyolites and the basalts, but generally much closer to the basalts.

**Discussion/Conclusions**

The basalts are MORB-like tholeiites, but all incompatible elements plot higher than typical E-MORBs, suggesting that they are fairly evolved with respect to the typical N-MORB, presumably due to fractional crystallization in magma chambers. The nature of the rhyolites and the plagioclase phryic unit are more complex. The rhyolitic lavas could possibly be the result of extensive crystal fractionation of a basaltic parent magma, or of crustal melting. Similarly the plagioclase phryic unit could be an intermediate differentiate after a basaltic magma, or the product of magma mixing between basalt and rhyolite. These issues can be addressed by looking at three variation diagrams, Zr versus MgO, TiO$_2$ versus MgO, and Al$_2$O$_3$ versus MgO (Figure 3).

Data from closely related field areas (see Ackerly, and Walker this volume) have also been included in the analysis. These samples include glassy frame of dacitic composition picked from a pyroclastic tuff overlying the plagioclase phryic unit (Walker), a second equivalent sample of the plagioclase phryic unit (Walker) found less than 10 km away from those collected by this author, and three samples of a plagioclase ultraphyric basalt (commonly referred to as PUB, Hansen and Gronvold, 1999) of similar composition to those basalts already mentioned but with a much higher percentage of plagioclase phenocrysts and consequently a higher Al$_2$O$_3$ content.

![Figure 3. Variation diagrams of Zr vs. MgO, Al$_2$O$_3$ vs. MgO, and Zr vs. MgO. Circles = basalts, triangles = plagioclase phryic unit, diamonds = dacite, x’s = rhyolite, stars = plagioclase ultraphyric basalts (see Ackerly this volume). Diagrams demonstrate the role of crystal fractionation and magma mixing in the creation of the volcanics discussed.](image-url)
parent magma is a more likely model. The rhyolites in this study have a lower Zr composition than the dacites. If basaltic crustal melting were the mechanism for the generation of these magmas, the opposite would be expected. This is because if a rhyolite were formed from a typical Icelandic basalt, this would represent a low degree of partial melting and would thus concentrate the incompatible element Zr. A lava of dacitic composition formed from crustal melting would require a higher degree of partial melting than would the rhyolite, and thus should have a lower Zr content than the rhyolites. As clearly visible in the Zr versus MgO variation diagram, the dacites in the Langadalsfjall area have a higher Zr content than the rhyolites.

There are several indicators that the plagioclase phyric unit is a result of magma mixing. The most obvious reason is the presence of textural banding in hand sample, representing the comingling of two magmas of different composition (Figure 4). Another textural indicator of magma mixing is visible in thin section as resorbtion textures on large plagioclase and augite grains. Geochemically, the plagioclase phyric unit falls in an intermediate location between the PUB samples and the dacites, which all follow a linear path on the variation diagrams represented in figure 3. The dacitic samples can be determined as the silicic end-member in this mixing event in the variation diagram Zr versus MgO. Here the plagioclase phyric unit falls on a line between the dacites and both of the basaltic units, thus excluding the rhyolites from the mixing event. The mafic end member can then be decided by the variation diagram Al₂O₃ versus MgO, where the plagioclase phyric unit falls on a line between the Al rich PUB, and the rhyolites and dacites, thus excluding the basalts from the mixing. The high aluminum content of the PUB magmas in Figure 3 is probably a result of plagioclase accumulation. Upon mixing of the PUB magma with the dacitic magma plagioclase phenocrysts were incorporated into the plagioclase phyric unit. The plagioclase phyric unit can therefore best be explained by end-member mixing between magma of dacitic composition and the PUB magma.

REFERENCES CITED


