KECK GEOLOGY CONSORTIUM

21ST KECK RESEARCH SYMPOSIUM IN GEOLOGY SHORT CONTRIBUTIONS

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Franklin & Marshall College

Keck Geology Consortium
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Kevin Pogue (Whitman College) and Chris Oze (Bryn Mawr College)
Students: Ruth Indrick, Karl Lang, Season Martin, Anna Mazzariello, John Nowinski, Anna Weber

The Árnes central volcano, Northwestern Iceland
Brennan Jordan (University of South Dakota), Bob Wiebe (Franklin & Marshall College), Paul Olin (Washington State U.)
Students: Michael Bernstein, Elizabeth Drewes, Kamilla Fellah, Daniel Hadley, Caitlyn Perlman, Lynne Stewart

Origin of big garnets in amphibolites during high-grade metamorphism, Adirondacks, NY
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Students: Denny Alden, Erica Emerson, Kathryn Stack

Carbonate Depositional Systems of St. Croix, US Virgin Islands
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Sedimentary Environments and Paleoecology of Proterozoic and Cambrian "Avalonian" Strata in the United States
Mark McMenamin (Mount Holyoke College) and Jack Beuthin (U of Pittsburgh, Johnstown)
Students: Evan Anderson, Anna Lavarreda, Ken O'Donnell, Walter Persons, Jessica Williams

Development and Analysis of Millennial-Scale Tree Ring Records from Glacier Bay National Park and Preserve, Alaska (Glacier Bay)
Greg Wiles (The College of Wooster)
Students: Erica Erlanger, Alex Trutko, Adam Plourde

The Biogeochemistry and Environmental History of Bioluminescent Bays, Vieques, Puerto Rico
Tim Ku (Wesleyan University) Suzanne O'Connell (Wesleyan University), Anna Martini (Amherst College)
Students: Erin Algeo, Jennifer Bourdeau, Justin Clark, Margaret Selzer, Ulyanna Sorokopoud, Sarah Tracy

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Keck Geology Consortium: Projects 2007-2008
Short Contributions – Iceland

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SILICIC VOLCANISM AT REYKJARFJÖRÐUR, NORTHWESTERN ICELAND

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INTRODUCTION

The Mid-Atlantic ridge at Iceland drifts westward in relation to the Iceland hotspot. Instead of separating entirely, a new rift develops, centered over the hotspot, and the old rift is abandoned. The Árnes central volcano in the Westfjords of Iceland erupted at about 11 Ma in the Skagi-Snaefellsnes rift zone and represents a transitional period between the 15 Ma formation of the rift and its 7 Ma abandonment (Hardarson et al., 1997). This project focuses on the silicic lava flows north of Reykjarfjörður (smoky fjord) in the southern portion of the Árnes central volcano complex.

Geochemical and petrographic analyses were carried out on 25 representative samples in the Reykjarfjörður field area in order to understand how these intermediate and silicic lavas were produced. XRF data shows that the basaltic samples follow a tholeiitic trend and are more evolved than N-MORB, suggesting a more enriched deeper magma source. Trends in major and trace elements were used to determine whether the silicic and intermediate rocks were formed by partial melting of a basaltic crust (Gunnarsson et al., 1998) or extreme fractionation of a basaltic magma (Furman et al., 1992). This work, in combination with the other 2007 Iceland Keck projects, provides a better understanding of the hotspot-ridge interaction as it transitioned from abandonment to relocation.

FIELD RELATIONS

The field area northwest of Reykjarfjörður makes up part of the southern portion of the larger Árnes central volcano complex and consists of numerous rhyolite flows and an andesite flow between a lower and upper unit of flood basalts (Fig. 1). The field area is ~12 km^2 and is adjacent to another field area to the north (Fellah this volume) and another to the south (Drewes this volume). Several units were rec-

Figure 1. View of field area looking northwest across Reykjarfjörður. LB= lower basalt, R= rhyolite, A= andesite, and UB= upper basalt. (photo taken by Brennan Jordan)

ognized in the field and are briefly described below.

The lower basalt unit extends from the bottom marshland up to an elevation of ~300 m and is made up of thinly layered flood basalts and thicker basalt layers ranging from 3-40 m thick. These basalts are exposed on the entire southwest facing slope of the field area (Fig. 2). The silicic to intermediate unit above the lower basalts extends from ~300 m to 500 m in elevation and consists of 4-5 rhyolite flows ranging from ~20-80-m thick and a distinct ~20 m thick andesite flow. These flows are present on the southwest facing slope, on the top of the saddle, and extend back down into the northeast facing slope (Fig.2). The devitrified rhyolites have numerous textures on the outcrop scale including spherulites, lithophysae, flow banding, and vitric bases. Most rhyolite outcrops have a characteristic brecciated base with red weathered soil eroding from them. The upper basalt unit above the silicic to intermediate unit extends from ~500-700 m in elevation and consists of a highly porphyritic basalt (~15-20 m -thick) with thinly layered flood basalts above (Fig. 2). The Glifsa and Reykjarfjarðarfjall peaks in the field area are comprised of this unit.

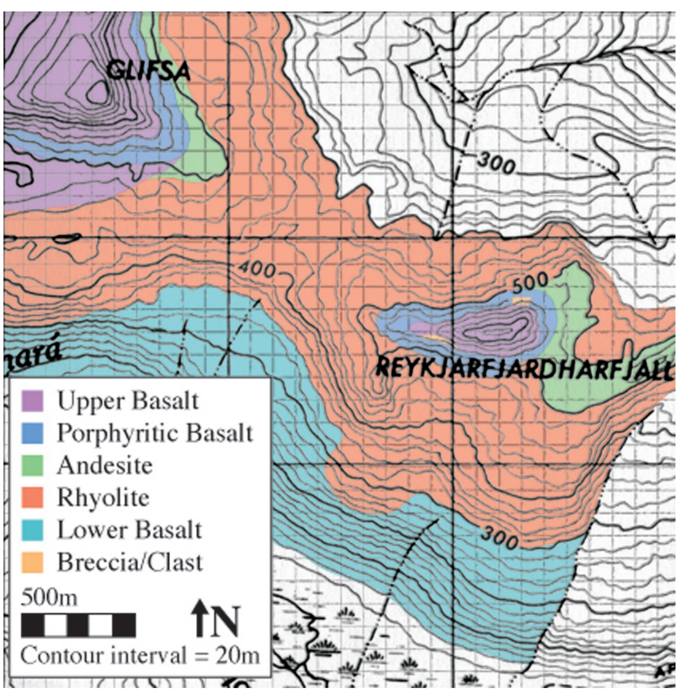

Figure 2. Geologic map of field area northwest of Reykjarfjörður in the southern portion of the Árnes central volcano complex.

The area has numerous basaltic dikes with trends ranging from N 0˚E to N 48˚E. There is also a wide columnar jointed basaltic dike on the north side of Reykjarfjarðarfjall and is seen again on the southwest face of the peak. There is a complex breccia cliff exposure accompanying the columnar-jointed dike on the north side and a small exposure on the southwest side. The breccia layer represents a water-magma interaction and could have formed by basaltic lava erupting into a temporary lake formed by the uneven topography of the lava flows erupted from the central volcano.

PETROGRAPHY

The lower basalts are medium-dark gray in hand sample and have plagioclase and clinopyroxene phenocrysts in a fine grained aphanitic groundmass. Phenocrysts are typically 1-2 mm, with some up the plagioclase phenocrysts up to 5-6 mm. Phenocryst content ranges from 3-4% in hand sample, and pyroxenes are typically smaller than the plagioclase. In thin section the lower basalts have an intergranular groundmass and glomeroporphyritic texture. The plagioclases are mostly euhedral to subhedral, have twinning, and are more abundant than the clinopyroxenes. The clinopyroxenes are typically subhedral. Numerous Fe-Ti oxides are also present.

The rhyolites are also medium-dark gray in hand sample and have plagioclase and clinopyroxene phenocrysts in a very fine grained groundmass. Phenocrysts are typically 1-2 mm with some up to 5 mm, and phenocryst content is 2-3%. Thin sections reveal cryptocrystalline groundmasses with mostly euhedral plagioclases, a few clinopyroxenes, and Fe-Ti oxides. Groundmass textures vary considerably throughout the samples. Examples include prominent flow banding with alternating gray and dark gray layers wrapping around phenocrysts, spherulitic textures, and swirl patterns of dark gray bands indicating shear as the lavas cooled. Plagioclases are more abundant than the pyroxenes and have both twinning and zoning. The distinct andesite flow is dark gray-black in hand sample, has around 1% phenocrysts, and is extremely dense. In thin section the groundmass is either cryptocrystalline or slightly felty, and has very small amounts of plagioclase and clinopyroxene phenocrysts.

The upper basalt unit is similar to the lower basalt unit in hand sample, but thin sections show altered olivines in addition to plagioclase and clinopyroxene. Clinopyroxenes were also more abundant. The upper basalts are slightly coarser with intergranular groundmasses and glomeroporphyritic textures. The porphyritic basalt at the bottom of this unit has a similar intergranular groundmass, but has a very large phenocryst content of around 20%. Plagioclases typically ranged from 3-4 mm in the upper flood basalts, with the porphyritic basalt having up to 9 mm plagioclases.

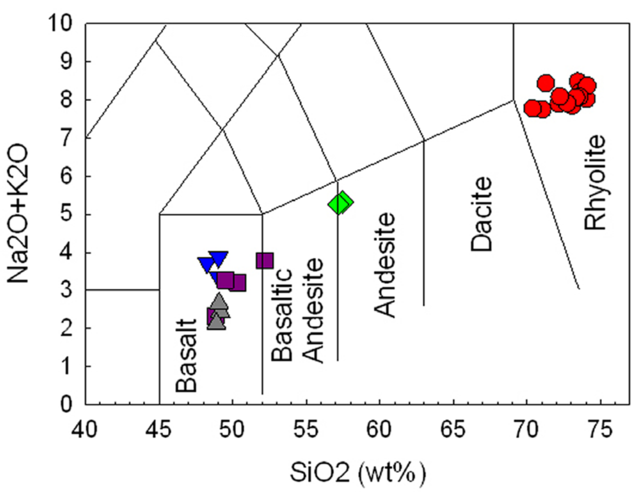

Figure 3. Total alkali vs. silica diagram showing the compositional diversity of the 25 samples taken from the field area (red circle= rhyolite, green diamond= andesite, blue triangle= lower basalt, purple square= upper basalt, grey triangle= basaltic dike).

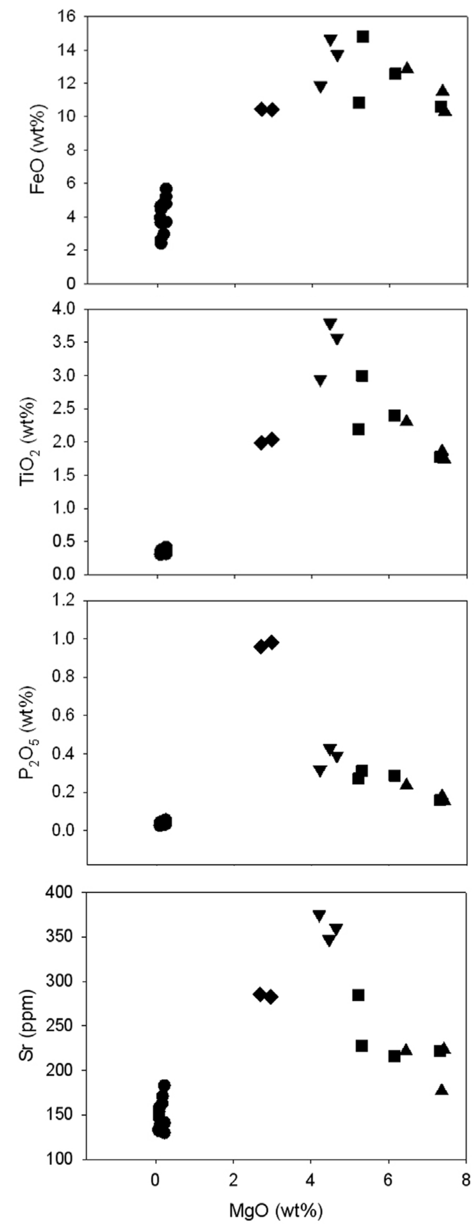

Figure 4. Fenner diagrams showing fractionation of Fe-Ti oxides, apatite, and plagioclase (red circle= rhyolite, green diamond= andesite, blue triangle= lower basalt, purple square= upper basalt, grey triangle= basaltic dike).

GEOCHEMISTRY

Samples span a wide range of chemical composition as seen in Figure 3. The basalts follow a tholeiitic trend and range from 48-52 wt% SiO_2, the rhyolites range from 70-74 wt% SiO_2, and the andesite is 57 wt% SiO_2. Harker and Fenner diagrams support the hypothesis that the andesites were a product of fractionation from a basaltic parent. Non-linear trends in P_2O_5, FeO, and TiO_2 plotted against MgO shows the crystallization of Fe-Ti oxides such as ilmenite and titanomagnetite at around 4 wt% MgO and the crystallization of apatite at around 3 wt% MgO (Fig.4). Fractionation of plagioclase was not very significant in the basalts, indicated by a linear decrease of CaO/Al_2O_3 vs MgO and an increase then decrease of Sr at around 4% MgO (Fig. 4). A linear decrease in Sc vs. MgO shows the removal of clinopyroxenes at an early stage in the basalts while a linear decrease in MgO vs. SiO_2 is consistent with olivine removal. Decreasing CaO and increasing Na_2O and K_2O, plotted against SiO_2, is also consistent with fractionation.

Samples from the upper basalt unit have a higher MgO content (5.21-7.32 wt%) than the lower basalts (4.21-4.65 wt%), suggesting that the upper basalts

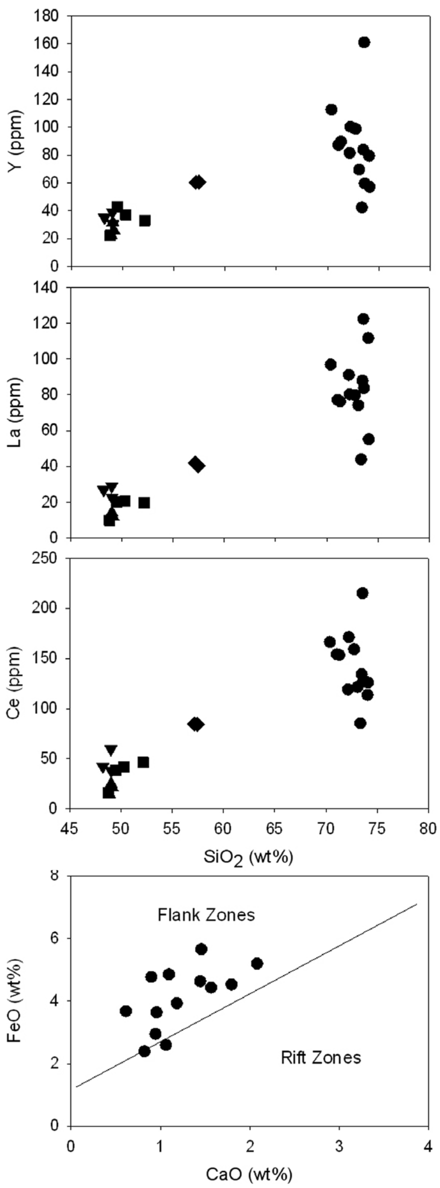

Figure 5. Harker diagrams showing wide range of trace element concentrations in the rhyolites, and an FeO vs. CaO plot showing the rhyolite classification for rift zones and flank zones (red circle= rhyolite, green diamond= andesite, blue triangle= lower basalt, purple square= upper basalt, grey triangle= basaltic dike).

are less evolved. This is consistent with the presence of olivine phenocrysts in thin section for some of the upper basalt samples, which may suggest that olivine fractionation was more significant at higher MgO concentrations than lower MgO.

Jónasson (2007) distinguishes between rhyolites formed in flank zones and those formed in rift zones. Rhyolites and trachytes found in flank zones are typically higher in Fe and lower in Ca than those formed in rift zones, which have been taken to indicate low water pressure in the source and low oxygen fugacity during formation. A plot of FeO vs. CaO for the Reykjarfjörður rhyolites shows that they are consistent with a flank zone formation (Fig. 5).

DISCUSSION

Production of highly evolved magmas can be attributed to either partial melting of a hydrothermally altered basaltic crust or extreme fractionation of a basaltic magma. Furman et al. (1992) propose that the silicic lavas formed at Austurhorn in southeastern Iceland can be attributed to fractional crystallization of a basaltic magma based on trends in major and trace elements. Gunnarsson et al. (1998) argue that partial melting of a basaltic crust is responsible for the formation of silicic magmas at the Torfajökull central volcano in south-central Iceland based on variable $\delta^{18}O$ signatures and trends in trace elements. Jónasson (2005, 2007) approaches the problem in a different way, proposing that partial melting of a basaltic crust can be viewed as near-solidus differentiation (removal of melt from a mostly crystalline source) and that fractionation can be viewed as a near-liquidus process (removal of melt from mostly liquid source). Jónasson (2007) also states that intermediate rocks are rare within Iceland, making the island compositionally bimodal. Intermediate rocks are often attributed to hybridization or mixing of magmas.

The formation of the andesites can be attributed to fractionation of a basaltic magma (near liquidus), with no evidence (chemically or in thin section) for magma mixing. Trends in both major and trace elements (described above) follow a direct path to the rhyolites suggesting that these were formed by further fractional crystallization. However, several trends in trace elements are not linear and are highly variable with La, Ce, and Y concentrations in the rhyolites all having wide ranges (Fig. 5). Unequal fractionation of phosphate minerals such as monazite and possibly xenotime at a very late stage in crystallization could account for these ranges.

CONCLUSIONS

Major and trace element data show that the rocks near Reykjarfjörður are genetically related, with both the andesites and rhyolites forming by fractionation of a basaltic magma. Geochemical data also show that the rhyolites formed in a flank zone environment, which has interesting implications for the hotspot-ridge interaction. As the Skagi-Snaefellsnes ridge drifted westward in relation to the hotspot, it may have become more flank-like in its character as it transitioned from rift formation to abandonment.

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