KECK GEOLOGY CONSORTIUM

PROCEEDINGS OF THE TWENTY-FIFTH ANNUAL KECK RESEARCH SYMPOSIUM IN GEOLOGY

April 2012
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Students: *EMILY JOHNSON*, Whitman College, *BENJAMIN CARLSON*, Union College, *LUCY MINER*, Macalester College, *STEVEN ESPINOSA*, University of Texas-El Paso, *HANNAH HILBERT-WOLF*, Carleton College, *SARAH OLIVAS*, University of Texas-El Paso.

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Students: *KATHRYN KUMAMOTO*, Williams College, *EMILY CARBONE*, Smith College, *ERICA WINELAND-THOMSON*, Colorado College, *THAD STODDARD*, University of South Dakota, *NINA WHITNEY*, Carleton College, *KATHARINE, SCHLEICH*, The College of Wooster.

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Keck Geology Consortium: Projects 2011-2012
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A GEOCHEMICHAL AND PETROLOGIC ANALYSIS OF THE HRAFNFJORDUR CENTRAL VOLCANO, WESTFJORDS, ICELAND

KATHARINE SCHLEICH, The College of Wooster
Research Advisor: Meagen Pollock

INTRODUCTION

Iceland is located along the Mid-Atlantic Ridge (MAR), the divergent plate boundary between the North American and Eurasian Plates. The MAR is expressed on land by a zone of active rifting and increased volcanism called the Neovolcanic Zone. Iceland is also a volcanic hotspot, located above a mantle plume that generates increased magmatic activity on the surface. The interaction between the MAR and the mantle plume leads to the process of rift relocation. As the plate boundary moves westward in relation to the hotspot, the rift dies out and the active rift relocates eastward towards the hotspot (Hardarson et al., 1997). This process leaves behind evidence of abandoned rift zones. The Hrafnfjordur central volcano erupted from the extinct Skagi-Snaefellsnes rift zone that was active between 15-7 Ma.

This project is part of a series of Keck projects examining central volcanoes throughout the evolution of the rift zones. The Hrafnfjordur central volcano represents the early hot spot centered portion of this process. While rhyolites in Iceland primarily erupt from central volcanoes, significant amounts of basalts and intermediates are also found in this setting (Jonasson, 2007). This project focuses on investigating the processes of formation that cause this wide variation in composition.

METHODS

The three main goals in the field were to identify and characterize geologic units, map the units, and collect samples for laboratory analysis. Geologic units were identified based on rock composition, phenocryst assemblages, outcrop characteristics, and visible contacts (if present). GPS coordinates were taken at each sample site and were plotted on a topographic map to create a GIS map of the field area (Fig. 1). Of the 39 samples collected, 20 were made into pressed pellets and fused glass discs for X-ray fluorescence (XRF) analysis, using the Rigauku ZSX Primus II, at the College of Wooster. These 20 samples were also cut into centimeter thick billets at the college of Wooster and sent off to be made into thin sections for petrographic analysis.

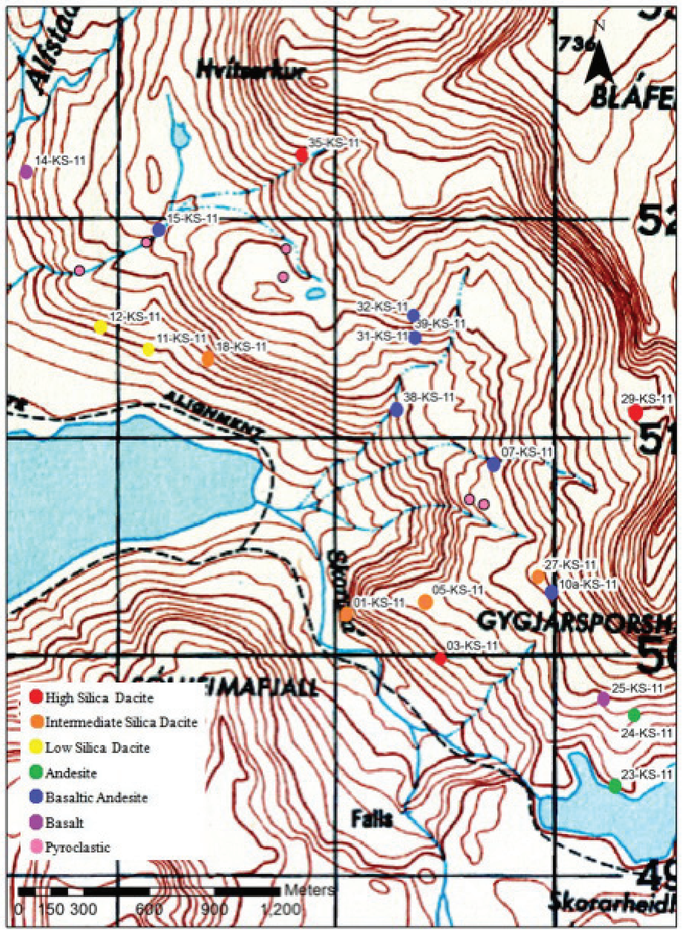

Figure 1. Field map showing location of the samples classified by total alkali versus silica content (Fig. 2).

FIELD DESCRIPTION OF ROCK UNITS

The four units observed in the field were the basalt, intermediate, rhyolite, and pyroclastic units. The

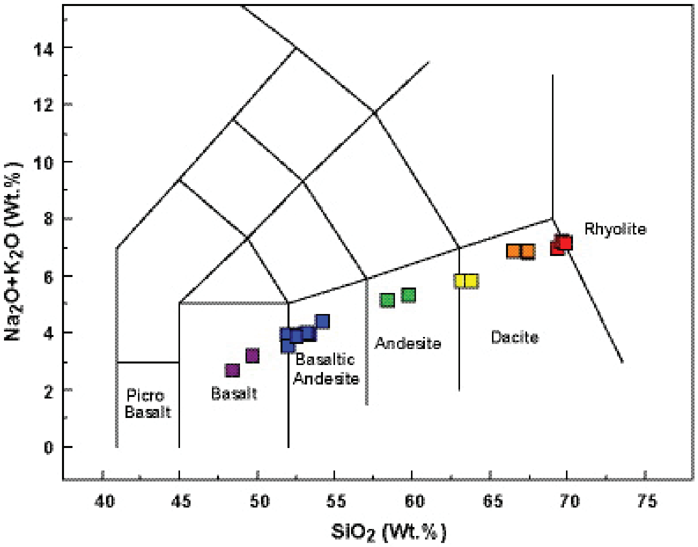

Figure 2. Total alkali versus silica graph (LeBas et al., 1986) of the 20 samples that underwent geochemical analysis. Symbols seen in this figure are consistent in subsequent diagrams.

basalt unit formed extensive, near-vertical cliffs composed of 5-16 m thick lava flows These samples of this unit had dark grey aphanitic groundmass and were sparsely porphorytic with plagioclase phenocrysts. Geochemical analysis shows that most lavas that classified as basalts in the field actually plot in the basaltic-andesite range (Fig. 2). The intermediate units formed thick massive flows that often showed platy jointing. The thick flow on the southern edge of the field area and a thinner flow on the north side of the field area were part of the intermediate unit. Samples had a dark grey aphanitic groundmass and contained 1-4% phenocrysts that were composed predominantly of plagioclase with minor amounts of pyroxene. After geochemical analysis, the intermediate unit was classified as predominantly dacite with minor amounts of andesite. A rhyolite unit was identified in the field but after geochemical analysis it was determined to be the part of the intermediate unit. The pyroclastic unit was found above the intermediate unit. It is composed of reversely graded ash and lapilli and a few large bombs up to 0.5 m in diameter.

PETROGRAPHY

Basalt and Basaltic-Andesite

The basalt samples have an ophitic to subophitic groundmass, composed of plagioclase, clinopyroxne, and opaques. Phenocrysts were not observed in hand sample or in thin section analysis. The basaltic-andesite samples have a relatively coarse-grained, felty matrix consisting of plagioclase, clinopyroxene, and opaques. Phenocrysts are sparse but include plagioclase and clinopyroxene. The plagioclase phenocrysts range from euhedral to subhedral and display cumulophyric texture in some samples. The clinopyroxene crystals are subhedral and show reaction rims in some samples.

Dacite and Andesite

The dacite samples have a fine, slightly porphyritic, felty matrix consisting mainly of plagioclase feldspar and clinopyroxene. Subhedral plagioclase, clinopyroxene, and resorbed hornblende phenocrysts are sparse (in total 1-4%). The plagioclase phenocrysts show compositional zoning as well as sieve texture. The resorption textures indicate a possible change in conditions within the magma chamber. The andesite samples have a fine, slightly porphyritic, plagioclase matrix and contain less than 1% plagioclase phenocrysts.

GEOCHEMISTRY

Twenty samples were analyzed for major and trace element composition using XRF. Figure 2, using the classification scheme of LeBas, et al. (1986), shows that the samples represent a wide variation ranging in composition from basalt to dacite. The dacite samples are split into three different groups, low-, intermediate-, and high-silica (Fig 2). Major element Harker variation diagrams show three main trends. The P_2O_5 and TiO_2 plots show an inverted “v” trend with an increase in concentration up to 55 wt% SiO_2 followed by a decrease in concentration. Curved trends are seen in CaO and Na_2O versus SiO_2 plots while the K_2O plot shows a linear increase with increasing silica. The trace element variation diagram of Zr verus SiO_2 shows a linear trend relating the high- and intermediate-silica dacite units that is not present in the low-silica dacite, andesite, basaltic-andesite, or basalt units. This trend projects to higher Zr dacites in another nearby Keck 2011 field area (Carbone, this volume). The Nb versus Zr plot shows the linear

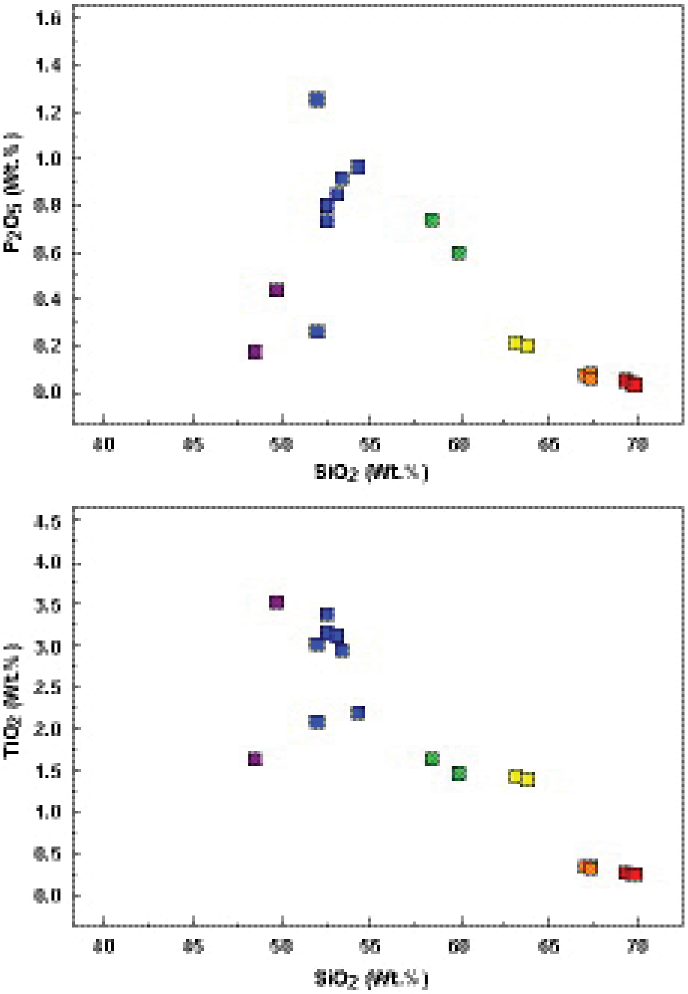

Figure 3. Variation diagrams of P_2O_5 and TiO_2 versus SiO_2. Symbols as defined in Figure 2.

trend relating the two higher silica dacite units, but a separate trend relating the other units.

DISCUSSION

The inverted "v" trends seen in the Harker diagrams of P_2O_5 and TiO_2 are consistent with fractional crystallization relating the basalts and basaltic-andesites (Fig. 3). The P_2O_5 plot suggests the fractionation of aptatite and the TiO_2 plot suggests the fractionation of ilmenite and titanomagnetite. CaO and Al_2O_3 both decrease with increasing SiO_2 suggesting fractional crystallization of clinopyroxene (Fig. 4). The andesite unit, however, is not related to this trend and lies on a trend visible when all Westfjords Keck data is plotted. This other trend could either reflect fractional crystallization of a different assemblage (perhaps reflecting a different magma chamber depth) or magma mixing. The low-silica dacites plot off both trends, perhaps on another regional trend, suggesting a different magmatic history (mixing or fractionation).

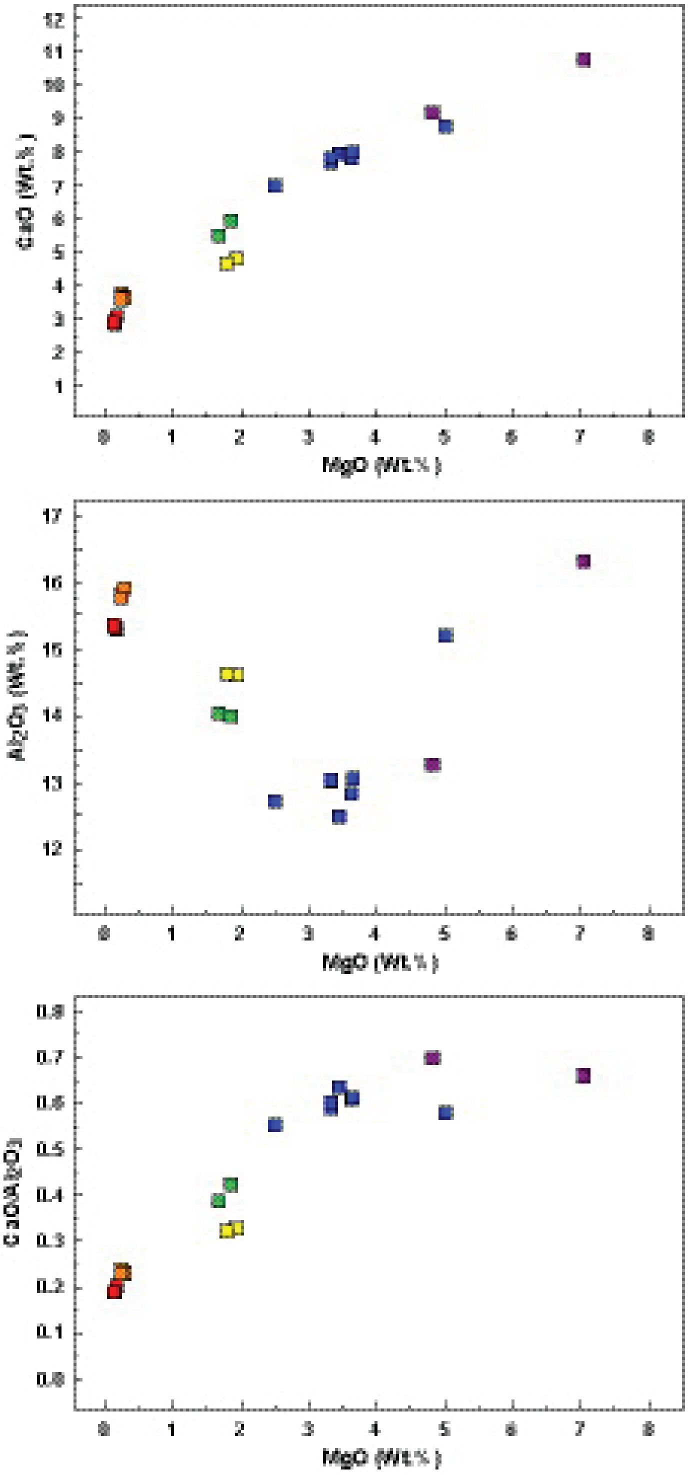

Figure 4. Variation diagrams of CaO and Al_2O_3 versus MgO and the CaO/Al_2O_3 vs. MgO. Symbols as defined in Figure 2.

Major and minor element trends suggest the possibility that the intermediate-silica dacite was formed by fractional crystallization from a basaltic parent. However, on a plot of Zr vs. silica (Fig. 5) the trend connecting the high-silica dacite and the intermediate silica dacite projects to a higher Zr, lower silica dacite (not shown) in an a nearby 2011 Keck study area (Carbone, this volume), and that composition cannot be the product of fractionation. The linear nature of this trend could be explained by fractionation or magma mixing. Textural evidence for magma mixing amongst the dacites includes zoning and sieved texture of plagioclase in the dacite samples. The resorbed hornblende could indicate magma mixing but more likely reflects decreasing magma water content due to decreasing pressure during ascent, which destabilizes the hydrous hornblende (e.g., Brown and Gardner, 2006). The end-members of mixing would be the high-Zr dacite in the other field area and the most evolved dacite sample (35-KS-11), or a rhyolite not represented in the sample set. If the suite reflects magma mixing, both end members would likely have originated by crustal melting. The linear trend relating these dacites could also be due to fractional crystallization if zircon is in the fractionating assemblage. The highest Zr sample would have been the original product of crustal melting from which the other dacites formed as a result of fractional crystallization. Whether the dacites are related by fractional crystallization or magma mixing, the fundamental origin of these silicic rocks appears to be by crustal melting, as argued by Jonasson (2007) for all silicic rocks in Iceland.

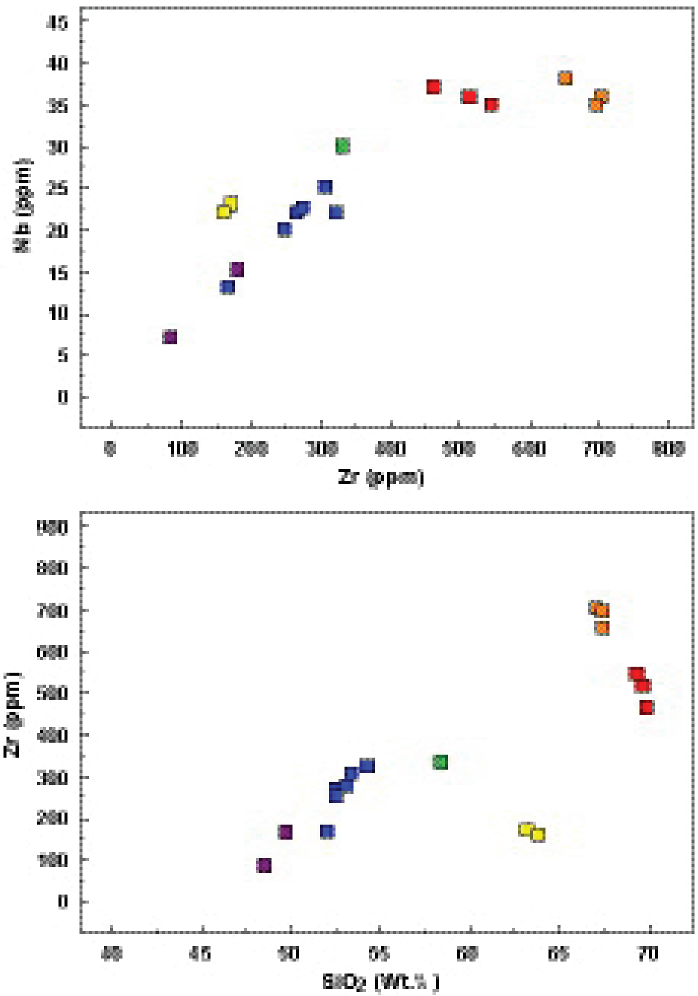

Figure 5. Trace element variation diagrams of Zr versus SiO_2 *and Nb versus Zr. Symbols as defined in Figure 2.*

CONCLUSION

Variation diagrams showing the fractionation of plagioclase, illmenite, titanomagnetite and clinopyroxene provide evidence that the basalt and basaltic-andesite units are related by fractional crystallization. The andesite unit is not related to this trend and lies on a distinct trend formed due to fractional crystallization of a different assemblage. The low-silica dacite lies on a possible regional trend reflecting a different magmatic history. The origin of the high-and intermediate dacite units appears to be by crustal melting. Chemical and textural evidence suggests that the linear trend relating these two units can be explained by fractional crystallization or magma mixing. The presence of multiple magmatic trends reveals the complex petrogenesis of the magmas of the Hrafnfjordur central volcano.

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