

KECK GEOLOGY CONSORTIUM

21ST KECK RESEARCH SYMPOSIUM IN GEOLOGY SHORT CONTRIBUTIONS

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Keck Director
Franklin & Marshall College

Keck Geology Consortium
Franklin & Marshall College
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Students: William Barnhart, Kat Compton, Rosalba Queirolo, Lindsay Rathnow,
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Geologic Controls on Viticulture in the Walla Walla Valley, Washington

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 Fella, Daniel Hadley, Caitlyn Perlman, Lynne Stewart

Origin of big garnets in amphibolites during high-grade metamorphism, Adirondacks, NY

Kurt Hollocher (Union College)
Students: Denny Alden, Erica Emerson, Kathryn Stack

Carbonate Depositional Systems of St. Croix, US Virgin Islands

Dennis Hubbard and Karla Parsons-Hubbard (Oberlin College), Karl Wirth (Macalester College)
Students: Monica Arienzo, Ashley Burkett, Alexander Burpee, Sarah Chamlee, Timmons Erickson
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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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Project faculty:

BRENNAN JORDAN: University of South Dakota

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Research Advisor: James Mills

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PETROLOGIC AND GEOCHEMICAL ANALYSIS OF THE ARNES CENTRAL VOLCANO REGION, WEST FJORDS, ICELAND

ELIZABETH DREWES: DePauw University

Research Advisor: James Mills

INTRODUCTION

Iceland is the only location where the Mid-Atlantic Ridge (MAR) rises above sea level. The anomalous elevation of the ridge at Iceland is usually interpreted as evidence of an underlying mantle plume. An alternative hypothesis proposes the enhanced magmatism may be due to melting of the remnants of 400 Mya subducted oceanic crust (Foulger and Anderson, 2005). The record of the rift system in Iceland shows that it has shifted position in the past. As the rifts drifted west relative to the proposed hotspot they were abandoned in favor of new rifts centered over the hotspot near the central portion of Iceland. The purpose of the project was to characterize the geology of a small region in the Westfjords region surrounding the Arnes central volcano. The Arnes central volcano lies at the midpoint of evolution for the 15-7 Ma rift and thus provides a sample of an intermediate stage in rift evolution (Jordan, 2007).

Iceland produces a wide range of volcanic rock including voluminous basalt, minor andesite, and a significant volume of rhyolite. The Arnes central volcano was used as the study area due to its location with regards to rift evolution and also because of the large volume of rhyolitic material produced by the central volcano. One of the questions addressed by this study is how are the rhyolites produced? Samples collected during the field season were analyzed using geochemical and petrographic methods to distinguish what magmatic processes may have been at work.

METHODS

Three main tasks were undertaken in the field: (1) identifying and characterizing geologic units; (2) mapping these units; and (3) collecting samples for laboratory study. A field classification scheme was developed for each rock unit based on the physical characteristics of the outcrop, such as color, texture, and phenocryst percentages. The extent of each unit in the field area was determined by identifying a change in rock composition, outcrop characteristics, and/or the presence of a visible contact. A number of GPS points were collected along contacts and plotted on to a 1:20,000 topographic map. The contacts could then be traced and connected to generate the map shown below (Fig. 1).

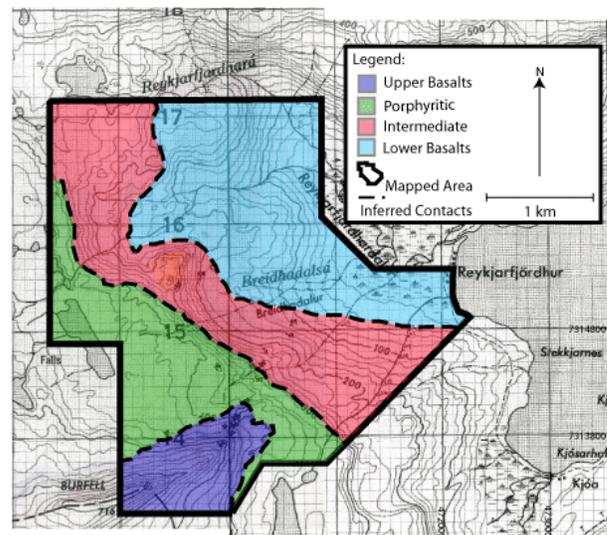


Figure 1: Geologic map generated of the field area showing inferred contacts between rock units classified by phenocryst type, percentages, and outcrop characteristics (field units may be different than the units determined by geochemical data.)

Fresh samples from each unit were collected for petrographic and geochemical analysis. Of the 22 samples collected, 17 were sent out for thin section preparation, and 13 samples were selected for geochemical analysis by X-ray fluorescence at Washington State University. Each of the samples for geochemistry was cut into centimeter thick slabs at DePauw University. Each slab was cleaned of any saw blade residue and crushed into one centimeter fragments.

DESCRIPTION OF ROCK UNITS

Using hand sample characteristics and field observations the units were divided into three lithologically distinct groups: group 1, basalt (lower and upper units); group 2, intermediate units; and group 3, a porphyritic unit. The distinguishing characteristics used to classify the rock units in the field were phenocryst percentages and outcrop character. The basalts ranged from grey to black, stony or aphanitic, and contained very low percentages (<1%) of phenocrysts of plagioclase and clinopyroxene. The

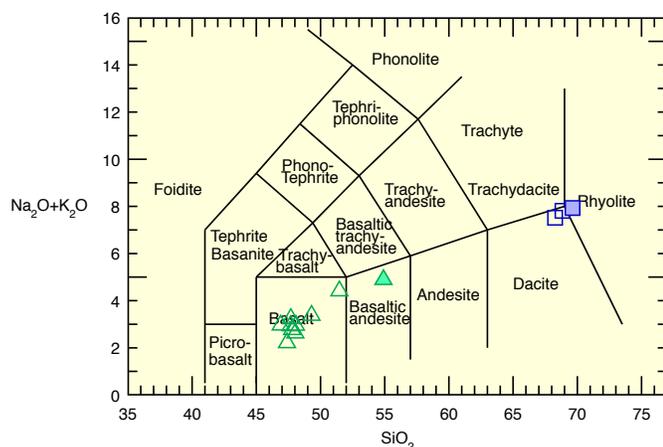


Figure 2: Le Bas, et al. (1986) total alkali content vs. silica classification diagram, which indicates that the samples range from basalt to rhyolite. Symbols seen in this figure are consistent in subsequent diagrams.

basalts also formed blocky, jointed, massive outcrops. The intermediate lavas were distinguished from the basalts due to the platy jointing and higher phenocryst content. Phenocrysts ranged from 1-4% and include both plagioclase and clinopyroxene.

Chemical data reveals that units classified as intermediate in the field are closer to basalt or rhyolite in composition rather than intermediate (Fig. 2). The porphyritic unit was a main cliff-forming unit in the area. The outcrops weathered to rounded blocks, unlike the units above and below. The high phenocryst content was the most distinguishing feature of the porphyritic unit, ranging from 7-20% of mainly plagioclase with less than 1% olivine.

PETROGRAPHY

Basalt, Basaltic Andesite, and Porphyritic Basalt - Field Classification: Groups 1 and 3

The basalt samples have a relatively coarse-grained felty to intergranular matrix consisting of plagioclase, clinopyroxene, and opaques. The phenocrysts present include plagioclase, clinopyroxene, opaques, and olivine. The phenocrysts range from euhedral to anhedral and show resorption and/or sieve texture in some thin sections. Some samples contain glomerocrysts of large plagioclase and clinopyroxene grains that most likely represent the cumulate assemblage that forms at the base of an evolving magma chamber.

The one sample classified as basaltic andesite is an extremely fine grained, felty rock with a large percentage of opaques present in the matrix, and a few larger, resorbed opaque phenocrysts. One part of the sample contains a texturally distinct area. The material in this area has a darker matrix and contains euhedral to subhedral plagioclase grains, anhedral resorbed olivine, and opaques in both the matrix and as inclusions in the phenocrysts.

Dacite and Rhyolite - Field Classification: Group 2

The matrix in these samples is very fine-grained with the grain sizes ranging from a dense microlitic matrix to a granophyric matrix. The phenocryst content in these rocks includes euhedral to subhedral plagioclase, clinopyroxene and a small amount of apatite (<<1%). Some plagioclase phenocrysts ex-

hibit normal zoning while others are homogeneous. Clinopyroxene phenocrysts are less abundant, partially to completely altered, and smaller in size than the plagioclase. Opaques occur in the matrix and as inclusions in the phenocrysts. Two thin sections displayed a swirling of a fine-grained matrix and slightly coarse-grained matrix possibly representing flow segregation within the lavas.

GEOCHEMISTRY

Thirteen samples were analyzed for major and trace elements (Ni, Cr, Sc, V, Ba, Rb, Sr, Zr, Y, Nb, Ga, Cu, Zn, Pb, La, Ce, Th, Nd, and U) by XRF. The rocks range in composition from basalt to rhyolite using the classification scheme of LeBas, et al. (1986) (Fig. 2). An AFM plot shows the samples to be tholeiitic. Spider plots, using the N-MORB normalization scheme of Sun and McDonough (1989) show the basalts to be slightly enriched in incompatible elements. The more evolved dacite and rhyolite samples exhibit a significant depletion of Sr, P, and Ti. Harker variation diagrams show a large variation in MgO values for the samples. The samples range from 0.1 wt% MgO to 9.5 wt% MgO with the latter representing the most primitive basalt sampled by the 2007 study of the Arnes central volcano region (Fig. 3).

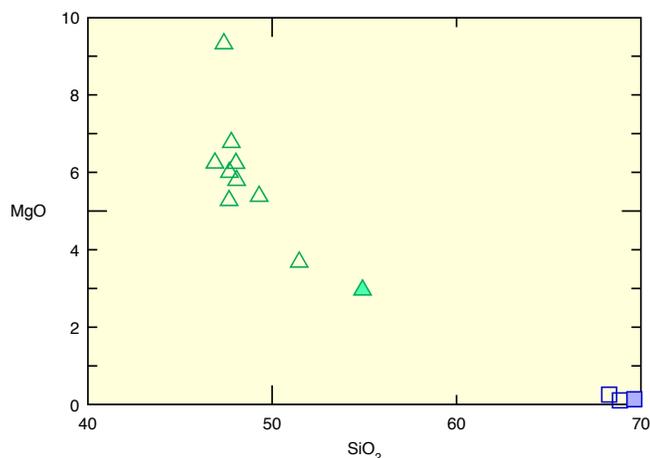


Figure 3: Harker diagram showing the range of MgO for samples. The most primitive samples contain 9.5 wt. % MgO and is the most primitive sample collected in the Arnes central volcano region for this study.

PETROGENESIS

Partial Melting

The N-MORB normalized spider plot shows the general enrichment of incompatible elements. This trend may be consistent with either partial melting of older crust or melt derivation from a slightly enriched source (Fig. 4) (Sun and McDonough, 1989).

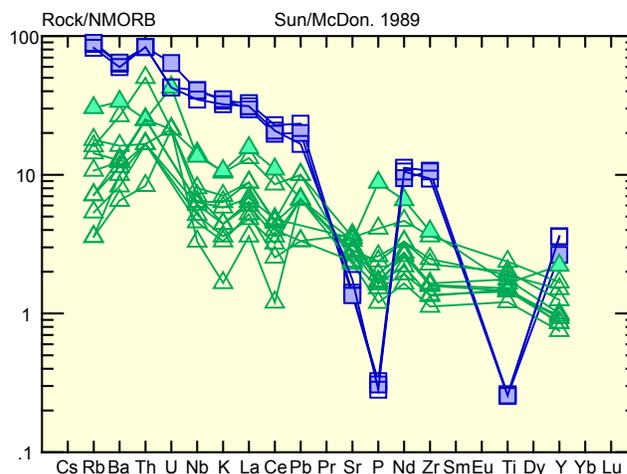


Figure 4: Spider diagram showing the depletion of incompatible elements relative to N-MORB. The diagram also shows depletion of Sr, P, and Ti, which is consistent with the fractionation of plagioclase, titanite, and ilmenite (and other iron-titanium oxide phases).

Fractional Crystallization

The Harker variation diagrams for MgO vs. Ni and Sc suggest the basalts follow a fractionation trend (Fig. 5). Depletion of Ni most likely reflects fractional crystallization of olivine, whereas the depletion in Sc suggests fractionation of clinopyroxene. The N-MORB-normalized spider plot also shows depletion of Sr, P, and Ti in the dacite and rhyolite samples (Fig. 4). This depletion most likely represents the fractionation of plagioclase (Sr), apatite (P), and ilmenite or other magnetite/titan-magnetite phases (Ti). All of the proposed fractionating minerals were observed in thin section.

Magma Commingling

Textural evidence present for commingling may be

present within a number of the samples analyzed. Both basalt and dacite samples show resorbed plagioclase and clinopyroxene phenocrysts, and glomerocrysts of plagioclase, clinopyroxene, and altered olivine. This may represent the cumulate phenocryst assemblage at the base of an evolving magma chamber or perhaps restite from crustal melting. In the dacites and rhyolites clots or pockets of darker material containing a separate size and textural population of phenocrysts are observed. Some of the samples also exhibit two distinct populations of plagioclase as indicated by zoning of one population and a population lacking crystal zoning and the bimodal size range. These textures and relationships may be consistent with magma commingling, however, chemical data does not strongly support this interpretation.

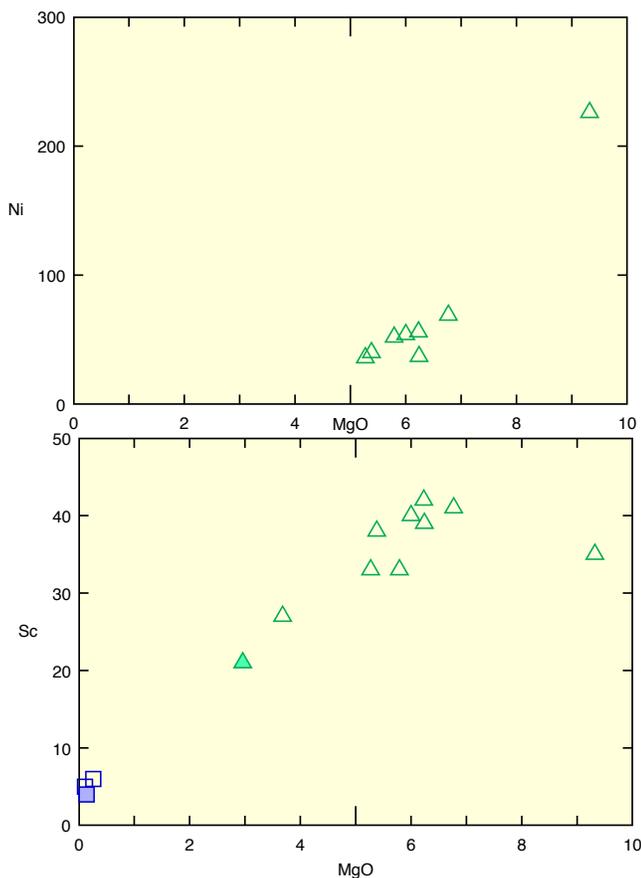


Figure 5: Harker diagrams showing the decrease in the trace elements of Ni and Sc with decreasing MgO suggesting fractional crystallization of olivine and clinopyroxene. Olivine and clinopyroxene are common phenocryst phases in thin section.

CONCLUSION

Major element oxides and trace element data suggest the rock suite has a complex petrogenetic history. Fractional crystallization to produce dacite and rhyolite is supported by the Harker variation plots and spider plot (Fig. 4-5). Harker variation plots show depletion of certain trace elements with decreasing MgO and are consistent with the fractionation of olivine and clinopyroxene. The rhyolites and dacite show the lowest values. The spider plots also show strong depletion of certain trace elements consistent with the fractionation of observed minerals. Petrographic data may suggest that magma commingling has occurred. The combination of these factors reveals the complexity of the magmatic system of the Arnes central volcano region.

REFERENCES

- Foulger, G. R. and, Anderson, D. L., (2005). A cool model for the Iceland hotspot. *J. of Volcanology and Geothermal Research* 141: 1-22.
- Jordan, J., 2007, The Arnes central volcano, Northwestern Iceland. 2007 Keck Geology Consortium Project Announcement, 1-4.
- LeBas, M.J., LeMaitre, R.W., Streckeisen, A., and Zanettin, B., 1986. A chemical classification of volcanic rocks based on the total alkali silica diagram. *J. Petrology*. 27:745-750.
- Sun, S.-s., and McDonough, W.F., 1989. Chemical and isotopic systematics of oceanic basalts: implications for mantle composition and processes. *Magmatism in the Ocean Basins*, Geological Society Special Publication No. 42, 313-345.