KECK GEOLOGY CONSORTIUM

21ST KECK RESEARCH SYMPOSIUM IN GEOLOGY SHORT CONTRIBUTIONS

April 2008

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Keck Director
Franklin & Marshall College

Keck Geology Consortium
Franklin & Marshall College
PO Box 3003, Lancaster Pa, 17603

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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 Fellah, 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)
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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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PETROGENIC AND GEOCHEMICAL ANALYSIS OF THE ÁRNES CENTRAL VOLCANO, NORTHWEST ICELAND

KAMILLA FELLAH: The College of Wooster
Research Advisor: Matthew Severs

INTRODUCTION

Iceland is almost entirely made up of Tertiary and younger volcanic rocks resulting from the interaction of a hotspot and Mid-Atlantic ridge (MAR). The excess magmatism from this interaction of the Icelandic hotspot and mid-ocean ridge resulted in uncommonly thick crust. The MAR is represented on land by rift zones where most of the volcanic activity and extension are taking place (Hardarson et al., 1997). The northwestward movement of the spreading ridge relative to the hotspot beneath Iceland causes repeated rift relocations, leaving behind abandoned rift zones. The Árnes central volcano was erupted in the 15 to 7 Ma Skagi-Snaefellsness rift zone, near the midpoint of the evolution of this rift.

The rhyolites in Iceland are restricted to these central volcanoes. The volume of silicic rocks in Iceland is about 10-12%, an unusually high percentage for an oceanic setting (Saemundsson, 1979), therefore, the presence of rhyolites in Iceland has sparked much interest and the origin of these rocks is hotly debated. Two major hypotheses have been suggested; partial melting of basaltic crust (Sparks, 1990; Sigmarsson et al., 1991; Gunnarsson et al., 1998; Jónasson, 2007; Lacasse et al., 2007) or fractional crystallization of basaltic parent magma (Carmichael, 1964; Wood, 1978; Macdonald et al., 1990; Furman et al., 1992; Maclennan et al., 2003), or in some cases a combination of the two. The focus of this study is the Tertiary Árnes central volcano in the Westfjords of northwest Iceland.

METHODOLOGY

Field study included characterizing volcanic stratigraphy, mapping the units and structures, and collecting samples. From the samples collected, thin sections were made and X-ray fluorescence (XRF) analyses were obtained in order to determine petrologic relationships between rock units. Additionally, a sample from each unit (basalt, intermediate, and rhyolite) was chosen for electron microprobe analysis (EMPA). Field observations and interpretation of geochemical analyses provide insight into the origin of the rhyolitic magmas of the area.

GEOLOGY OF THE STUDY AREA

The rocks in the area follow a general sequence (from bottom to top) of basalt, intermediate, and rhyolite (Fig. 1 and 2). The basaltic unit starts at sea level and reach to 100 to 200 meters above sea level. The field appearance of these flows is relatively thin, dark grey in color, and the hand samples range from aphyric to sparsely porphyritic. Stratigraphically above the basalts, starting at about 200 m, the intermediate lavas are thicker than the basalts, however the base was often difficult to identify.

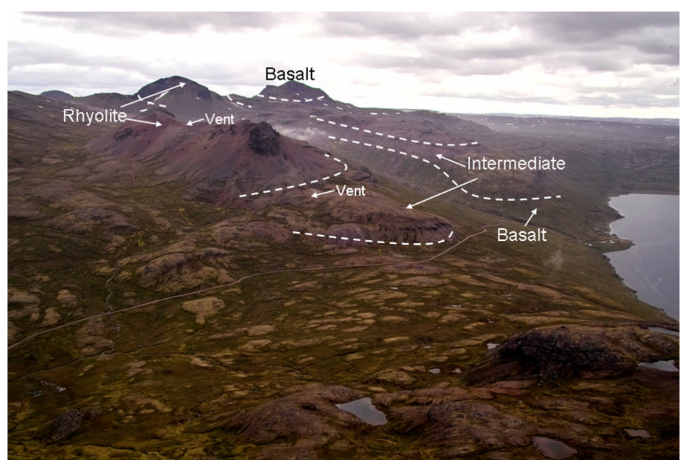

Figure 1: Photo by B. Jordan of the field area for this study, taken from the northeast. The units of basalt, intermediates, and rhyolites are indicated, as well as the observed contacts and two vents.

The intermediates form the unit between the basalts and the rhyolites, with features such as unaltered breccia contacts that indicated a close relationship to the underlying basalts. Where the base was seen, the contact was indicated by a breccia layer above the underlying basalts. The intermediates displayed the flow features and characteristics of a more viscous material than the basalt. Hand samples showed more abundant plagioclase and clinopyroxene phenocrysts (~5%).

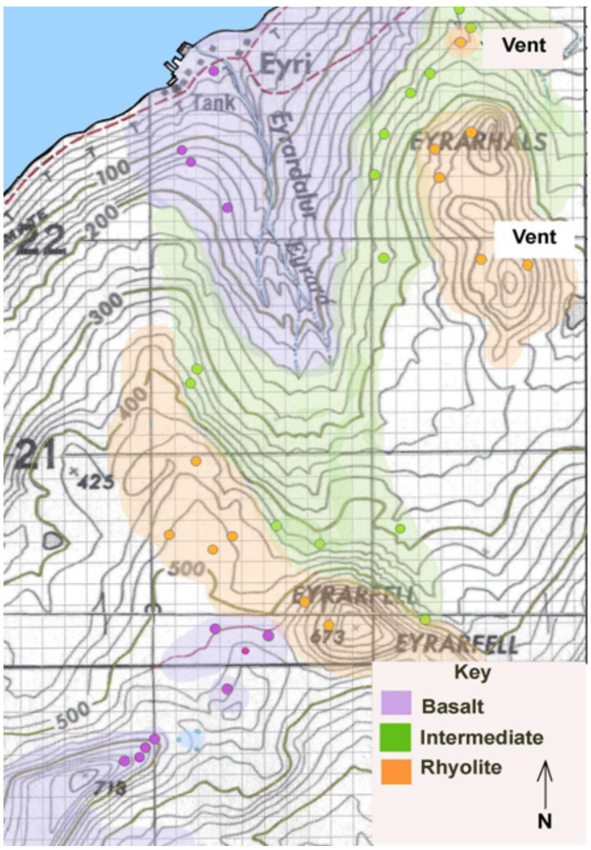

Figure 2: Map of the field area with the rock units indicated by the colors. The colored dots represent the site locations and the vents identified in the field are located on the map.

The rhyolitic unit is separated by a basal vitrophyre and breccia layer, and mineral assemblage suggest they are related to the underlying intermediates and basalts. In hand sample, the rock is more porphyritic. Plagioclase dominates the phenocryst assemblage with clinopyroxene in smaller abundance and smaller size, relative to the plagioclase phenocrysts. Two possible vents were identified and are indicated on the map (Fig. 2). Close to 600 m, another unit of basalt appears. The base flow of this unit is porphyritic with plagioclase phenocrysts of 5-10 mm. The flow is 40 m thick and overlain by the second flow, a very thin, aphyric layer (about 10 m thick). The next flows are similar to this, and atop the third flow is one that is similar to the first, being porphyritic, as well.

PETROGRAPHY

Seventeen samples were made into thin sections for petrographic study. The lower, nearly aphyric basalt lavas are made up of a groundmass of glass and oxides, containing microlites of tabular plagioclase, clinopyroxene, and a small percentage of olivine. The plagioclase grains show a trachytic texture due to flow which deflects around the subhedral phenocrysts. The porphyritic basalts have a phenocryst abundance of about 15%. The phenocrysts are plagioclase with smaller size clinopyroxene and are subhedral. EMPA showed plagioclase compositions in basalts carried An_{57} – An_{84}. The groundmass of the aphyric and porphyritic basalts is made up of plagioclase microlites, clinopyroxene, with glass and oxides exhibiting an intergranular texture.

The intermediate lavas typically have about 7% phenocrysts with 85% being plagioclase, 10% clinopyroxene, and 5% oxides. The groundmass is vitric with microcrystalline oxides. The intermediates show glomerophyric textures of plagioclase, clinopyroxene, and magnetite, with the larger grains enveloping the smaller ones.

The rhyolite phenocryst assemblage consists of mostly plagioclase, with some clinopyroxene, clustering in a glomerophyric texture. The edges of the plagioclase grains are sharp, and occasionally exhibit jagged rims. Plagioclase phenocrysts in all units exhibit oscillatory zoning on some of the phenocrysts.

GEOCHEMISTRY

Thirteen of the 29 samples collected were analyzed for major and trace element composition by XRF. The selected sample set from this study area (Area

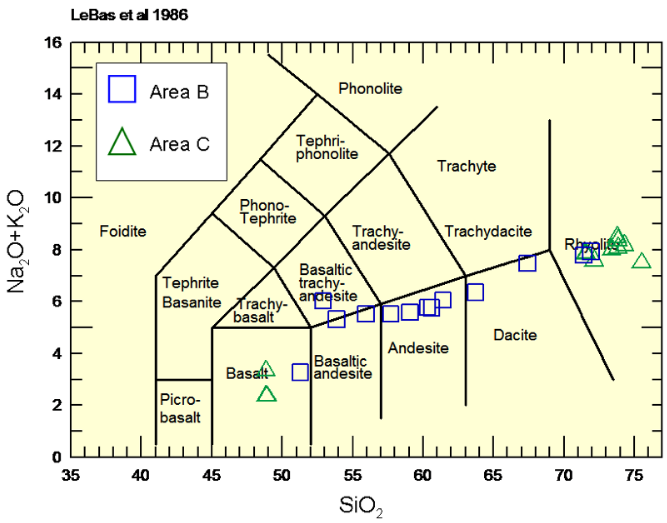

Figure 3: Total alkalis vs. silica graph of the rocks from Area B and Area C.

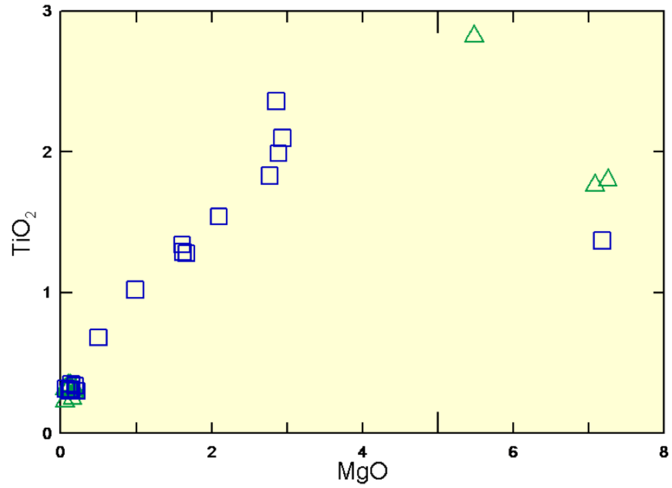

Figure 5: Variation diagram of P_2O_5 versus MgO. Symbols are the same as Figure. 3

C) did not include any intermediate lavas, so samples from the adjacent area (Area B, Perlman, this volume) are included in plots and discussed below. Figure 3 (after Le Bas et al., 1986) shows the samples from Areas B and C plotted to classify rocks based on total alkalis versus silica content. The basalts have ~5.4 to 7.3 wt% MgO indicating that they are moderately evolved. Variation diagrams are of TiO_2 and P_2O_5 versus MgO are presented in Figures 4 and 5. TiO_2 rises with decreasing MgO and begins to decline at 4 wt% MgO, indicating the point at which Fe-Ti oxides begin to fractionate. P_2O_5 shows a similar trend, with the fall of P_2O_5 at about 3 wt% MgO, marking the point at which apatite begins to fractionate.

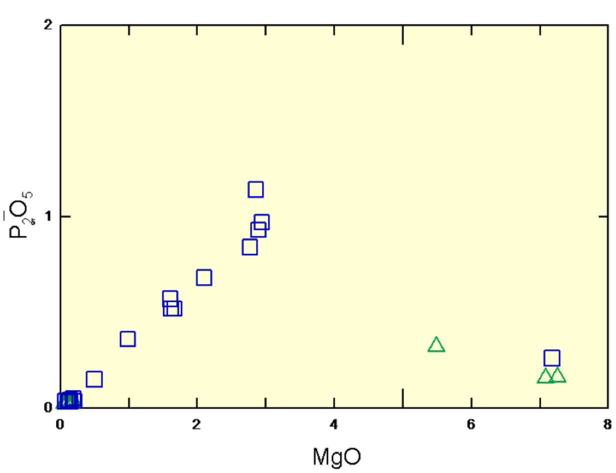

Figure 4: Variation diagram of TiO_2 versus MgO. Symbols are the same as Figure. 3

DISCUSSION AND CONCLUSION

Previous evidence invoked in the debate of the presence of rhyolites involves the presence or absence of intermediates, trace element trends for near-solidus and near-liquidus differentiation, petrography, geochemistry, and field observations. Field relations indicate a close temporal and spatial relationship between the intermediates, the basalts, and the rhyolites. Petrographic observations strengthens this relationship. In previous studies, intermediate compositions have been the key to understanding the relationships between basaltic and rhyolitic magmas in a system (e.g. Carmichael, 1964; Sigmarsson et al., 1991; Furman et al., 1992).

Bulk rock compositions from XRF analyses of the study area show the diversity of the rocks in the area and the intermediates are few, but present. The variation diagrams of TiO_2, showing the fractionation of the Fe-Ti oxides, and P_2O_5, showing the fractionation of apatite, contradict the idea that the intermediates could be produced by the mixing of basaltic and rhyolitic magmas. Geochemically consistent linear trends on Harker diagrams suggest the rocks are genetically related by fractional crystallization.

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