KECK GEOLOGY CONSORTIUM

21ST KECK RESEARCH SYMPOSIUM IN GEOLOGY SHORT CONTRIBUTIONS

April 2008

Dr Andrew P. de Wet, Editor
Keck Director
Franklin & Marshall College

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

Dr Amy Rhodes,
Symposium Organizer
Smith College

Keck Geology Consortium Member Institutions:
Amherst College   Beloit College   Carleton College   Colgate University   The College of Wooster The Colorado College
Franklin and Marshall College   Macalester College   Mt. Holyoke College Oberlin College Pomona College Smith College Trinity University
Union College Washington and Lee University Wesleyan University Whitman College Williams College

2007-2008 PROJECTS:

Tectonic and Climatic Forcing of the Swiss Alps
John Garver (Union College), Mark Brandon (Yale University), Alison Anders (University of Illinois), Jeff Rahl (Washington and Lee University), Devin McPhillips (Yale University)
Students: William Barnhart, Kat Compton, Rosalba Queirolo, Lindsay Rathnow, Scott Reynhout, Libby Ritz, Jessica Stanley, Michael Werner, Elizabeth Wong

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)
Students: Monica Arienzo, Ashley Burkett, Alexander Burpee, Sarah Chamlee, Timmons Erickson Andrew Estep, Dana Fisco, Matthew Klinman, Caitlin Tems, Selina Tirtajana

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

Funding provided by:
Keck Geology Consortium Member Institutions and NSF (NSF-REU: 0648782)

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

Funding provided by: Keck Geology Consortium Member Institutions and NSF (NSF-REU: 0648782)

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

A DECLINING TERTIARY RIFT ZONE: NORÐURFJÖÐUR, ICELAND

CAITLYN PERLMAN: Colgate University
Research Advisor: Karen Harpp

INTRODUCTION

Iceland is located at the junction of the Mid-Atlantic Ridge and the Greenland-Iceland-Faeroes Ridge, a region of active oceanic crust formation. The volcanic stratigraphy spans the Tertiary and Quaternary periods (Thordarson and Hoskuldsson 2002). Excessive magmatism occurs in Iceland as a result of a plume believed to be located beneath the island. The interaction of the plume and the spreading center induces rift relocation; as the spreading center migrates away from the plume the active rift is abandoned and a new rift forms closer to the plume's center, leaving a trail of inactive rifts (Thordarson and Hoskuldsson 2002).

Arnes central volcano, located in the Westfjörds of northwest Iceland, was erupted about 11 Ma in the now-extinct Tertiary Skagi-Snaefellsnes rift zone, which was active between 15 and 7 Ma. Gentle regional dips 2-4^{o} east are consistent with the area being west of the former spreading center. Extensive rhyolite flows are found in this region; roughly 7% of Iceland is composed of rhyolites from central volcanoes. This study aims to define the crustal magmatic processes of the rift in the mid-point of its evolution. I present results from a detailed field study of the Arnes central volcano at Norðurfjörður. My results include major and trace element analyses of samples from lava flows mapped in a ~4 km_2 field area in the northern portion of the Arnes central volcano.

FIELD RELATIONSHIPS/PETROGRAPHY

Multiple flows occur in the region, ranging from basalt to rhyolite; the latter are located higher in the stratigraphic column. The field area is characterized by a prominent ridge in which lavas are successively layered. Multiple basaltic dikes intrude the area with variable orientations. Along the eastern edge of the area, a basalt flow is truncated across a narrow gully by a rhyolite flow along the same contour. Polished material and gouge was found at the site of truncation, suggesting the presence of a fault. Evidence of a post-eruptive basalt intrusion at the gully's end underscores the fault hypothesis. Lavas in the area range from basalt to rhyolite. Three units were mapped in the area and classification was based on SiO_2 content; the units were basaltic, intermediate, and rhyolitic.

Unit differentiation in the field was made based on observations of hand sample characteristics and flow boundaries, namely baked soil horizons and glassy margins. Basalts were characterized by 1-2% phenochrysts less than 1 mm in diameter with fine-grained groundmasses. Flow thickness ranged from about 4 to 10 meters. Andesite dominated the field area, occupying roughly 300 meters of the total stratigraphic thickness, with individual flows ranging in thickness from 20 to 50 meters. Hand samples contained about 3-4% phenochrysts of feldspar, clinopyroxene, and highly altered olivine. Centimeter-scale flow banding was prevalent.

Rhyolites were found at the top of the ridge and occurred in flows ranging from 10 to 80 meters thick. Phenochryst content was about 3-4% of feldspar, clinopyroxene, and altered olivine. Some samples contained as much as 7% phenochrysts. Individual phenochrysts ranged in diameter from 1 to 3 mm. Inclusions of clinopyroxene within feldspar, and visa versa, were common in all samples. Glomerochrysts of feldspar and clinopyroxene are also prevalent. Ferroaugite is found in some of the more evolved material (Fig. 1).

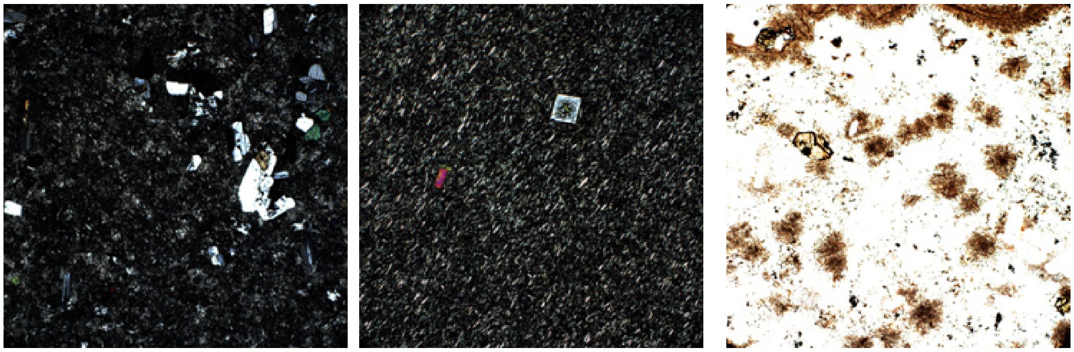

Fig. 1a Fig. 1b Fig. 1c

Figure 1: Photomicrographs of basalt and rhyolite: a) sample CP-05-09, rhyolite. Glomerochrysts of feldspar, clinopyroxene, and olivine present. Approximately 3-4% phenochrysts; feldspar phenochrysts are notably embayed, possibly the result of the injection of new magma into a fractionating magma chamber or multiple phases of crystallization; b) sample CP-05-12, basalt. Crystalline matrix with 1-2% phenochrysts, mostly feldspar and clinopyroxene, c) sample CP-05-09 plane light. Ferroaugite is prevalent.

MAJOR AND TRACE ELEMENT GEOCHEMISTRY

Major and trace element compositions were determined using X-ray fluorescence (XRF) and inductively coupled plasma mass spectrometry (ICP-MS) analyses, respectively. The lavas define a trend consistent with progressive fractional crystallization from basalt to rhyolite, indicated by a single differentiation trend beginning with the most MgO-rich sample (Fig. 2). This assemblage is consistent with a tholeiitic magma series, in which the initial parent melt is generated from decompression melting. The lavas follow a similar trend to those mapped at the Austurhorn intrusive complex (Furman et al. 1992). Major and trace element analyses suggest extensive fractional crystallization of plagioclase feldspar, clinopyroxene, Fe-Ti oxides, apatite, and monzanite (Fig. 2). Plagioclase crystallization is indicated by decreasing MgO concentration and increasing SiO_2 concentration. Crystallization of Fe-Ti oxides begins at the inflexion points on the MgO and FeO vs. SiO_2 graphs. Fractional crystallization of apatite and monazite is indicated by decreasing concentration of P_2O_5 (Fig. 2) and Y (Fig 3.), respectively, with increasing SiO_2 content.

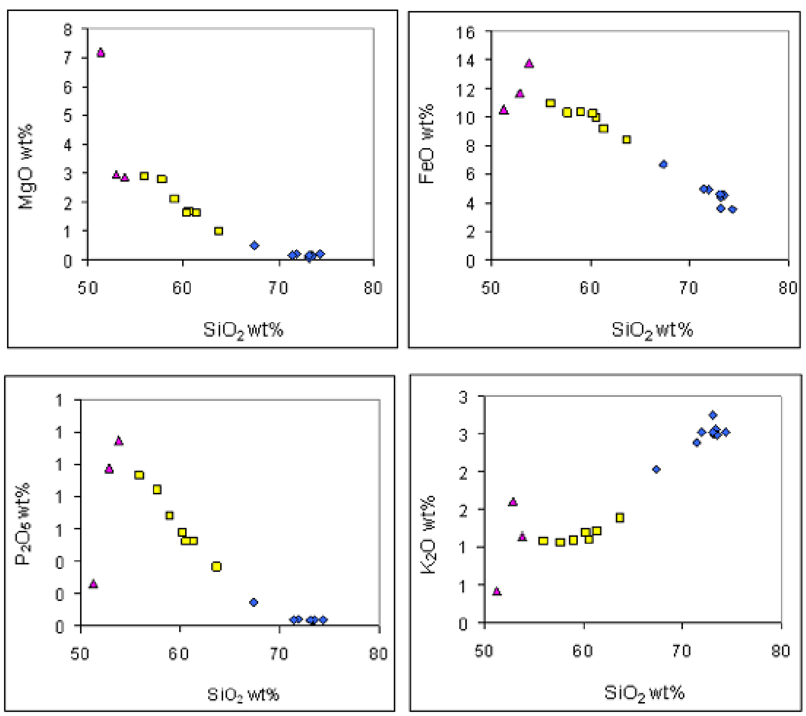

Figure. 2: Major elements versus SiO_2. Fractional crystallization represented in progression from basalt (pink triangles) through andesite (yellow squares) to rhyolite (blue diamonds.); Major crystallization phases include feldspar, clinopyroxene, FeTi oxides, apatite, and zircon.

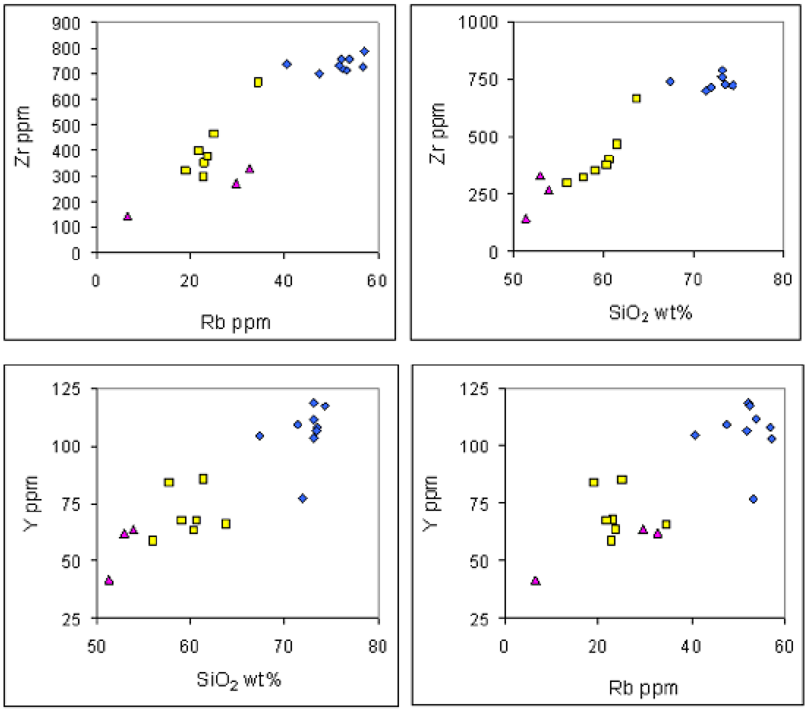

Figure 3: Plots of Zr and Y versus Rb and SiO2. Fractional crystallization of apatite and monazite is represented

Fractional crystallization was modeled using the MELTS algorithm (Ghiorso and Sack, 1995), with crystallization beginning at ~1200 °C and ending at ~900 °C. Chemical variations are consistent with the most evolved rhyolite being related to the most primitive basalt by 90% fractional crystallization at 1 kb, about 3 km depth (Fig. 4). As the most primitive basalt in the data set was already evolved, a higher degree of fractionation would be required from a primitive basaltic magma.

Models were generated at both 1 kb and 3kb pressures; the best fit for all elements occurred at 1 kb. The MELTS model successfully reproduced the trends of most major elements, with the exception of TiO_2. The greatest accuracy occurred for P_2O_5 and NaO, which displayed little deviation from the trends.

The rare earth element (REE) diagram reveals progressive light-REE enrichment with increasing degree of fractional crystallization. The spider diagram is normalized to the most MgO-rich sample in the suite (Fig. 4). Increasing concentrations of incompatible trace elements from basalt to rhyolite indicate fractional crystallization. Olivine crystallization is marked by the decrease in Ni content with increasing MgO, and decreasing concentration of V with increasing MgO marks the crystallization of Fe-Ti oxides.

DISCUSSION
COMPARISON TO OTHER RIFT ZONES

Arnes is one of various tertiary central volcanoes exhibiting extensive rhyolite flows and intermediate lavas. The 1992 study by Furman et al. investigated the petrographic relationships of tertiary basaltic and rhyolitic samples in the Austurhorn intrusive complex in southeastern Iceland. Structural relationships indicate the complex developed along a short-lived rift

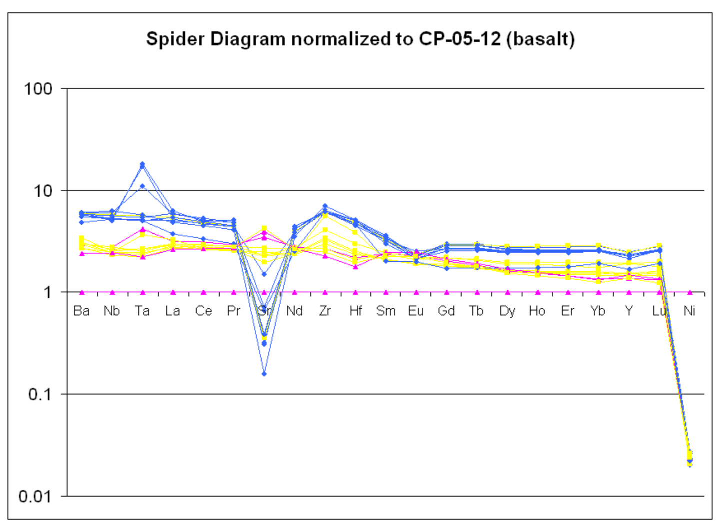

Figure 4: Spider diagram normalized to the most MgO-rich sample. Fractional crystallization is represented by increasing concentrations of incompatible elements

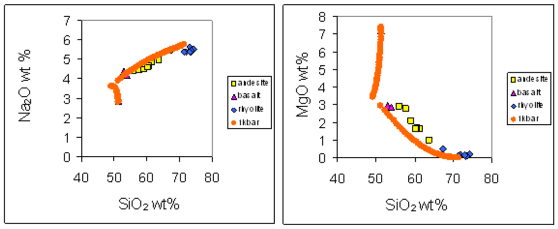

Figure 5: Graph of data with MELTS Algorithm series. The predicted fractional crystallization path is from a magma chamber at 3.3 km, 1 kbar, depth. The trends correspond well, indicating that the samples are dominated by fractional crystallization from a shallow magma chamber.

segment from a magma chamber at a pressure of ~1 kb. Major and trace element analyses indicated that rhyolites were produced predominantly by fractional crystallization from a basaltic parent magma. The data from Furman et al. (1992) suggest fractional crystallization of feldspar, clinopyroxene, magnetite, ilmenite, apatite, and zircon. The data from Furman et al. and my data produced at Norðurfjörður exhibit similar trends of fractionating phases from shallow magma chambers speculated to be located about 3 km deep. Furman et al. (1992) concluded that single, curvilinear differentiation trends of major elements plotted against SiO2 and MgO suggest that the rocks at Austurhorn evolved from a basaltic parent by fractional crystallization.

CONCLUSION

Major and trace element analyses using XRF and ICP-MS indicate that the lavas at Norðurfjörður evolved by means of fractional crystallization from a basaltic parent magma in a shallow chamber. Stratigraphic relationships of lavas at Norðurfjörður suggest successive emplacement of increasingly evolved material. Given our analyses, field relationships, and the comparison to the Austurhorn intrusive complex, rhyolite generation at Arnes central volcano occurred predominately via fractional crystallization in a wanging magma supply. As the propagating rift migrated, magma replenishment ceased and the isolated chamber fractionated until extinction.

REFERENCES

Furman, Tanya, Frey, Fred A., Meyer, Peter S., 1992, Petrogenesis of evolved basalts andrhyolites at Austurhorn, southeastern Iceland; the role of fractional crystallization, Journal of Petrology, v.33(6), p.1405-1445.

Ghiorso, Mark S., and Sack, Richard O., 1995, Chemical Mass Transfer in MagmaticProcesses. IV, A Revised and Internally Consistent Thermodynamic Model for the Interpolation and Extrapolation of Liquid-Solid Equilibria in Magmatic Systems at Elevated Temperatures and Pressures, Contributions to Mineralogy and Petrology, v. 119, p. 197-212

Thordarson, Thor and Hoskuldsson, Armann, 2002, Classic Geology in Europe 3: Iceland, Terra Publishing, p.16 – 160.