A PHREATOMAGMATIC BASALTIC DIKE, LANGADALSFJOLL, ICELAND

SCOTT PATRICK PELLETIER
Pomona College
Sponsor: Dr. Richard Hazlett

INTRODUCTION

During the course of field investigations in the Langadalsfjoll Ridge in north-central Iceland, we discovered an atypical intrusive feature: a splaying eruptive dike. The dike contains intermingled units of solid pre-eruptive intrusive rock ("subvolcanic lava") and largely palagonitized volcanic breccia. It crops out across a steeply dipping (25-30°), southwest facing mountainside, extending from a ravine to a plateau (Figures 1,2). The connection between the dike and its possible eruptive products has eroded away.

The purpose of this study is to describe this unique feature and to model a thermodynamic element confirming that the separate components of the dike, described below, were derived from a common source. This latter portion of the study is still in progress at the time of writing (February, 2004).

Description of Outcrop

The dike has a vertical exposure of about 150 meters (Figure 3). The lower terminus of the dike is 3.1 meters wide and consists wholly of sparsely phenocrystic lava. At a distance upslope of 18 vertical meters, the first breccia appears as a 1-1.5 meter wide pod elongate with the length of the dike. Ascending further, the breccia component increases. More pods appear, and within the central portion [80-120m] of the dike, the pods become elongate panels of breccia separated by finer through-running dikes of mafic lava enclosed within the master dike. The through-running dikes are individually 1-4 meters in width. At 120 meters vertical distance, the master dike splays into anastomosing branches almost wholly

filled with mafic lava across a width of approximately 10 meters. These branches continue to spread further to the highest point of the outcrop, corresponding to the level of the mountaintop plateau.

Description of Dike Rock

Non-trachytic aphanitic olivine tholeiite makes up the subvolcanic lava trending the length of the dike. It is almost uniformly non-vesicular, with the exception of the first few meters of lava above the lower terminus. The lava is nearly aphyric basalt bordered by a tachylitic chilled zone. The thickness of this margin ranges from 3 to 8mm.

Two types of volcanic breccia make up the remainder of the dike: breccia with a high degree of palagonitization and breccia with a low degree of palagonitization. Sharp irregular contacts separate these two types of breccia. There is no preferential concentration of palagonite within the dike breccia. Both types of breccia are entirely matrix supported and almost entirely polymictic (the oligomictic exception being the very little breccia that appears above 130m). All clasts are randomly oriented. Sorting is poor and all samples exhibit open-packing. The clast/matrix ratio is difficult to determine precisely due to a seriate texture, but in defining the clasts as optically conspicuous, the observed ratio is consistently 30%/70%. We separate the clasts into the following categories: accidental lithic fragments (basalt, rhyolite, and pumice), juvenile clasts (scoria), cognate intrusives (vitric clasts), and micro-gabbro/micro-gabbro diabase clasts. Accidental clasts match compositionally the older rocks composing the vent walls, juvenile clasts correspond to those

making up many Strombolian volcanic deposits, and cognate intrusions (autoliths) have been lifted away from the margin of the intrusion (Fisher and Schmincke 1984: Best, 2003).

The basalt and rhyolite lithic clasts comprise 10-50% of the total fragment population. They are highly angular and generally lapilli-sized (2-64mm), although their size ranges from microscopic to block-sized (>64mm). These clasts are aphyric to slightly vesicular. The basalt clasts are grey and texturally uniform and the rhyolite clasts are red and banded. The juvenile scoria fragments comprise 50-90% of the total clasts. They are gray, sub-rounded to highly angular, generally lapilli-sized but with a size range up to block size. The pumice occurs in trace concentrations, is ash (<2mm) to lapilli-sized but generally under 5mm in diameter, rounded, and white to buff in color.

The cognate vitric fragments are sideromelane, ash to fine lapilli (up to 4mm)-sized, and occur in trace concentrations. The micro-gabbro/micro-gabbro diabase particles are hypabyssal, intergranular, ash-lapilli sized, and occur in trace concentrations. The crystal grains are plagioclase and pyroxene.

The more palagonitized breccia exhibits a higher percentage of lithic fragments as clasts, whereas the clasts within the less palagonitized breccia are primarily scoriaceous. There is a correlation between wallrock at a given depth and clast composition. Clasts porphyritic basalt and rhyolite occur in the breccia at the same level and immediately below these beds, but not above. Some of the larger blocks of basalt (1m) can be stratigraphically and physically matched with reentrants in the wall of the dike to show their positions of origin.

Palagonitization is a low temperature alteration of sideromelane that results from the hydration of glass and oxidation of iron. Surface area of the sideromelane particles, permeability and porosity, temperature, and chemistry of pore solutions are the main factors controlling the rate of palagonitization (Fisher and Schmincke, 1984). In hand sample, the main effect of the palagonitization on the appearance of the volcanic breccia is alteration of the originally dark gray matrix. The less-palagonitized breccia shows minimal effects of alteration in hand-sample--a barely discernible yellow tinge--but when viewed in thin-section, shows substantial palagonite in the form of a plaque. The more palagonitized breccia has a distinctive dark yellow.

Interpretation and Hypothesis

The mingling between a solid mafic fill and palagonitized volcanic breccia probably represents the preserved vent facies of a phreatomagmatic fissure eruption similar to those taking place at lower elevations in the northern or eastern rift zones of Iceland today. A model explaining the feature begins with the shallow intrusion of a basaltic dike. At some point during the magma's ascent, fragmentation occurs simultaneously with or shortly preceding explosive volcanism.

By analog with observations elsewhere (e.g.- Kilauea Volcano) palagonitization very likely took place within a few weeks to a few years after eruption with the slow degassing of primary vapors and the incorporation of steam from surrounding groundwater sources (Hazlett, 2002). Since water vapor is not the dominant component in juvenile vapors, we assume that interaction with groundwater played a dominant role in the palagonitization and possibly was the main fuel for explosive volcanism.

The splaying out of the dike probably reflects decreasing crustal stress as the tip of the dike approached the surface. This also implies that the original surface lay near the present level of the late Miocene mountain-top plateau. In support of this, Williams and McBirney (1979) state that intrusions that are responsible for heating porous water-saturated horizons probably have depths of only a few hundred meters. Because expanded water vapor acts as a wedge to open a channel in advance of the intruding magma, the surface was probably breached with the aid of phreatomagmatic explosions (Williams and McBirney 1979).

During breaching and eruption, a downward migration of phreatomagmatic explosion foci would occur. Release of pressure on gas-charged horizons as a "decompressional

wave" would act as a positive feed-back stopped by loss of volatile pressure as eruption progressed (Williams and McBirney, 1979). The fragmentation front, in this case, seems to diminish in energy with depth, as indicated by the decreasing breccia component with depth in the dike.

As the phreatomagmatic explosions continued, the wall rock broke and shattered. The abrasive flow of gas, fragments, and magma served to further separate pieces from the wall rock. Fragments however did not move far from its point of origin within the vent, at least during the terminal stage of the eruption when the current exposure was emplaced. This indicates that the pipe was congested with fragments by this time. Compaction and settling may have served to shift materials downward at least a few meters in some places. Since most of the clasts are angular, we can deduce that transport was primarily in a plug-flow mode, with little opportunity for rounding. This also suggests a condition of solids congestion in the conduit. A transition from early explosive phases to effusive phases must have taken place to account for the presence of the late-stage veins of subvolcanic lava that intrude the breccia.

can be stratigraphically and physically matched with reentrants in the wall of the dike to show their positions of origin.

Palagonitization is a low temperature alteration of sideromelane that results from the hydration of glass and oxidation of iron. Surface area of the sideromelane particles, permeability and porosity The mingling between a solid mafic fill and palagonitized volcanic breccia probably represents the preserved vent facies of a phreatomagmatic fissure eruption similar to those taking place at lower elevations in the northern or eastern rift zones of Iceland today. A model explaining the feature begins with the shallow intrusion of a basaltic dike. At some point during the magma's ascent, fragmentation occurs simultaneously with or shortly preceding explosive volcanism.

By analog with observations elsewhere (e.g.- Kilauea Volcano) palagonitization very likely took place within a few weeks to a few years

after eruption with the slow degassing of primary vapors and the incorporation of steam from surrounding groundwater sources (Hazlett, 2002). Since water vapor is not the dominant component in juvenile vapors, we assume that interaction with groundwater played a dominant role in the palagonitization and possibly was the main fuel for explosive volcanism.

The splaying out of the dike probably reflects decreasing crustal stress as the tip of the dike approached the surface. This also implies that the original surface lay near the present level of the late Miocene mountain-top plateau. In support of this, Williams and McBirney (1979) state that intrusions that are responsible for heating porous water-saturated horizons probably have depths of only a few hundred meters. Because expanded water vapor acts as a wedge to open a channel in advance of the intruding magma, the surface was probably breached with the aid of phreatomagmatic explosions (Williams and McBirney 1979).

During breaching and eruption, a downward migration of phreatomagmatic explosion foci would occur. Release of pressure on gas-charged horizons as a "decompressional wave" would act as a positive feed-back stopped by loss of volatile pressure as eruption progressed (Williams and McBirney, 1979). The fragmentation front, in this case, seems to diminish in energy with depth, as indicated by the decreasing breccia component with depth in the dike.

As the phreatomagmatic explosions continued, the wall rock broke and shattered. The abrasive flow of gas, fragments, and magma served to further separate pieces from the wall rock. Fragments however did not move far from its point of origin within the vent, at least during the terminal stage of the eruption when the current exposure was emplaced. This indicates that the pipe was congested with fragments by this time. Compaction and settling may have served to shift materials downward at least a few meters in some places. Since most of the clasts are angular, we can deduce that transport was primarily in a plug-flow mode, with little opportunity for rounding. This also suggests a condition of

solids congestion in the conduit. A transition from early explosive phases to effusive phases must have taken place to account for the presence of the late-stage veins of subvolcanic lava that intrude the breccia.

Modeling

To support the hypothesis that the volcanic breccia component and the subvolcanic lava come from the same source and are the results of different phases of the same eruption, I am implementing a thermodynamic model (Fast Fourier Transform in Microsoft Excel) to examine the temperature distribution within both the dike and the host rock as a function of time. I hope to constrain the initial volcanic breccia temperature that was necessary to produce a chilled margin of the dimensions measured (3-8mm). This work will be presented in conference.

REFERENCES CITED

Best, M.G., 2003, Igneous and Metamorphic Petrology, Blackwell Publishing, Malden, 729 p.

Carrigan, C.R., Plumbing Systems, *in* Sigurdsson et al., 2000, Encyclopedia of Volcanoes, San Diego, p. 219-236.

Fisher, R.V., and Schmincke, H.U., 1984, Pyroclastic Rocks, Berlin, 472 p.

Hazlett, R.W., 2002, Geological Field Guide Kilauea Volcano: Hawai'i Natural History Association, Volcano, 162 p.

Williams, H., and McBirney, A.R., Volcanology, 1979, Freeman, Cooper & Co., San Fransisco.

Figure 2: White line indicates approximate location of dike. Line is 300 m in length.

Figure 1: Aerial photo of central Langadalsfjoll Ridge. Box is enlarged in Figure 2. North is to top.
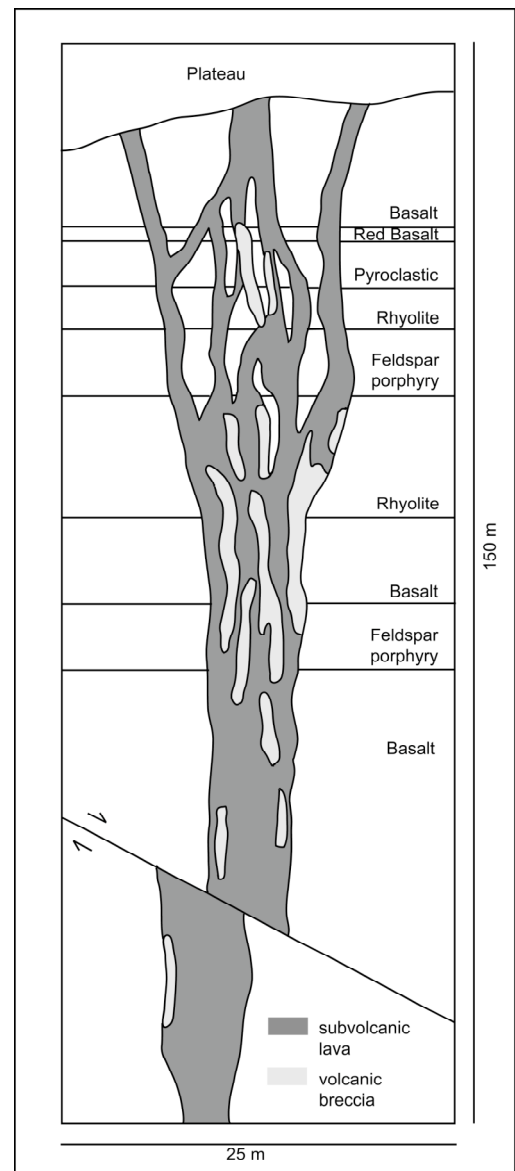

Figure 3: Approximate outcrop field map of Langadalfjoll breccia dike.