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Origin of Gabbroic Xenoliths within the Lone Mountain Dacite Intrusion, Big Sky, Montana: A Field and Petrographic Analysis

BY EMILY CLEMENT

Emily is an Earth Science major graduating in 2006. Her project, funded with an ATP gran, allowed her to conduct research in the lab at Big Sky, Montana. She and her mentor, Dr. Michael Krol, are continuing to research both geochemical and microstructural analysis.

Abstract

Lone Mountain represents a dacite laccolith that intruded in Late Cretaceous time ~68 Ma. This intrusion resulted in contact metamorphism of the sedimentary country rock resulting in formation of a thin zone of black hornfels. Field work reveals the presence of abundant, 1-9 cm sized gabbro xenoliths and lesser amounts of siltstone inclusions within the dacite intrusion. Compositionally, the Lone Mountain dacite consists of hornblende + plagioclase + biotite + quartz + opaques. Whereas the gabbroic xenoliths consist of pyroxene + hornblende + plagioclase + minor chlorite.

This study is concerned with the origin of the gabbroic xenoliths and their relation to the dacite intrusion. A major question we answer is, does the gabbro and dacite represent magmatic differentiation of an initial mafic magma or are the xenoliths an older crystallized mafic pluton intruded by a younger intermediate composition Lone Mountain dacite? Petrographic evidence suggest the two may be related based on their similar mineral assemblages.

INTRODUCTION

The geology of southwest Montana has involved a long and complex history of magmatic activity spanning tens of millions of years. Igneous rocks found within the Gallatin Range record just a small piece of a much larger geologic story. This portion of Montana was intruded by a series of medium-sized plutons related to the subduction of the Farallon tectonic plate beneath western North America some 70-50 million years ago. This was a time of intense and compositionally diverse magmatism that affected a large area of the North American Cordilleras (Feeley, 2003). Current models for the origin and evolution of these magmatic bodies involve either; 1) the generation of mantle-derived mafic magmas that differentiate and change composition over time, or 2) magma mixing of a mafic magma with a felsic, crustal component resulting in a hybrid magma (Feeley, 2003; Feeley & Cosca, 2003).

Lone Mountain represents a large laccolith or mushroom shaped pluton that intruded and crystallized ~ 70 Ma (Kellogg & Harlan, unpublished data, 1994; Tysdal et al., 1986). It intruded a sequence of Cambrian to Cretaceous-aged sedimentary rocks that consist of sandstone, siltstone, and shale. The goal of this project is to determine the mineralogy and compositional variation in these rocks. In addition, we attempt to explain the presence of gabbroic xenoliths found within the Lone Mountain dacite.

MESOSCOPIC ANALYSIS

The core of the mountain is composed of predominantly igneous dacite with the flanks of the mountain composed of moderately dipping sedimentary rocks. Samples were collected mainly along the southern, eastern, and northeastern sides of the mountain (Figure 1). Due to the presence of >3 feet of snow, much of the mountain was closed off due to possible avalanche threats.

Most samples of the Lone Mountain dacite contained hornblende and plagioclase crystals set in a fine-grain matrix or groundmass. The dacite intrusion is completely undeformed and possesses an original, igneous porphyritic texture. On the east side of the mountain at lower elevations, sedimentary strata is tilted with an average strike and dip of bedding being N33E/53NW. This unit consists of alternating layers of fine-grained, tan colored siltstone and white volcanic ash (Figure 2). A minor fault cutting this sedimentary sequence was observed and had an orientation of N33E/59NW. Along the most southeastern part of the mountain, a conglomerate unit was collected (Figure 3). This conglomerate contained pebbles of well-rounded black chert and quartzite ranging in size from ~1 cm to 5 cm. Strike and dip measurement of bedding indicate an orientation of N25E/32SE. Beyond the intrusion zone, there was an outcrop with black siltstone, sandstone, and some more volcanic ash. This was at a higher elevation with a strike and dip of N20E/19SE. The alternating bedding measurements with units dipping towards the NW and SE suggest the sedimentary rocks were deformed into a broad anticline syncline structure, prior to the intrusion of the Lone Mountain dacite. Emplacement of the dacite may have additionally uplifted the surrounding sedimentary strata.

PETROGRAPHIC ANALYSIS

Dacite Intrusion

Samples were collected from the dacite intrusion along the on the east and southeast side of Lone Mountain (Figure 4). The matrix consists of an aphanitic to porphyritic texture. Samples analyzed contain minerals such as plagioclase + hornblende + biotite + quartz + opaques. Plagioclase occurs as subhedral phenocrysts within a finer grained groundmass. It exhibits albite twinning with grains approximately 1 -6 mm in size. Hornblende is found as subhedral crystals approximately 1-3 mm in size (Figures 5 and 6). Biotite crystals were found to be anhedral and only about 1-2 mm in size. Quartz occurs as anhedral grains with a much smaller grain size than that observed in plagioclase. Grain size typically varies between 1-2 mm. Figure 5 shows a representation of the distinct contact between the fine-grained dacite and a larger coarse-grained gabbroic xenolith. Figure 6 displays a fine-grained dacite with plagioclase, quartz, biotite, and hornblende minerals.

Gabbroic Xenoliths

Samples of dacite containing abundant mafic xenoliths were collected along the east and northeast side of Lone Mountain (Figure 1). The gabbroic xenoliths are found to be predominantly phaneritic in texture (Figure 7). Pyroxene is the most abundant mineral present and occurs as subhedral to anhedral grains 0.5-1 cm in size (Figure 8). Hornblende occurs as 0.5 to 0.7 cm in size. Minor amounts of chlorite are also present as subhedral grains. Subhedral plagioclase crystals with albite twinning are present as 1-4 mm grains (Figure 9).

Two samples collected from the southeast side of Lone Mountain also contain coarse-grained xenoliths with similar mineralogy. Figure 10 shows exsolution textures in plagioclase grains. Minerals present include subhedral plagioclase, occurring as 4-6 mm in size, euhedral pyroxene, approximately 2-4 mm in size, and finally minimal quartz and biotite grains that were anhedral and only 1-2 mm in size.

Sedimentary Country Rocks

Several samples were collected from the sedimentary country rock in order to evaluate the effects of thermal metamorphism related to the intrusion of the Lone Mountain dacite (Figures 11-13). One sample was collected from an interlayered sequence of cross-bedded sandstone and shale. Petrographic analysis reveals a very fine-grained matrix with quartz, plagioclase, minor orthoclase, and opaque minerals. Grains were well rounded and moderate to moderately-sorted (Figures 12). Little petrographic evidence was observed indicating these rocks experienced any significant thermal effects.

A sample collected on the eastern side of Lone Mountain was composed almost entirely of fine-grained quartz with minor plagioclase feldspar. This quartz sandstone consists of angular grains approximately 1-3 mm in size (Figure 13). The furthest sample collected from the intrusion was a fine-grained sandstone composed almost entirely of rounded, anhedral quartz. Grains range in size from 1-2 mm and are cross-cut by quartz veins.

Ultramafic Rock

A small body of ultramafic rock was collected east of Lone Mountain at the lowest elevations. It contains plagioclase + hornblende + clinopyroxene + minor chlorite. Plagioclase has albite twinning and occurs as subhedral grains 2-4 mm in size. Hornblende is subhedral with clasts from 3-6 mm in size. Clinopyroxene grains are subhedral with clasts 2-7 mm in size. The minor chlorite is found around the edges of the plagioclase grains suggesting secondary alteration (Figure 14). The significance of this unit is beyond the scope of this project, but it could represent an even older phase of more mafic magmatism.

DICSUSSION

Based on petrographic analysis of 20 thin sections, it can be determined that the mineralogy of the Lone Mountain dacite contains plagioclase, hornblende, quartz, and biotite. The gabbroic xenoliths found within the dacite contain plagioclase, hornblende, and pyroxene. The igneous textures preserved in the dacite and xenoliths are distinguishable from one another. The dacite is mainly aphanitic to porphyritic whereas the xenolith is commonly phaneritic. On the basis of mineralogy, the Lone Mountain laccolith is classified compositionally as a dacite whereas the xenoliths are gabbros.

The question remains whether these gabbroic xenoliths represent an early magmatic differentiation from an initial magma, or if these xenoliths are an older plutonic rock later intruded by dacitic magma. Magmatic differentiation is the process in which magma can change composition by crystallizing and segregating different minerals over time, thus affecting the compositions of the residual magma. Some possible magmatic differentiation events that could have happened on Lone Mountain are assimilation; the mixing of two or more magmas; various degrees of partial melting from the same source; or two distinct melting events from two distinct sources.

On the basis of mineral assemblages, both the dacite and gabbro xenoliths are similar, with only minor differences suggesting they may in fact be genetically related. The next step in our project is to pursue a geochemical approach this upcoming year and investigate the chemistry of these rocks, in an effort to determine if a genetic relation exists.

FUTURE WORK

During the fall 2005 and spring 2006 semesters I will be preparing samples for geochemical analysis. Samples of Lone Mountain dacite and gabbroic xenoliths will be analyzed for major and trace elements using x-ray fluorescence at Hartwick College in New York. The goal will be to determine bulk rock chemical signatures of the xenoliths and dacite, and see if they are similar. Similar chemical signatures, especially trace elements, would tend to support our hypothesis that the Lone Mountain dacite represents a magmatic differentiate of an initially mafic magma with the gabbroic xenoliths being the early crystallized phase.

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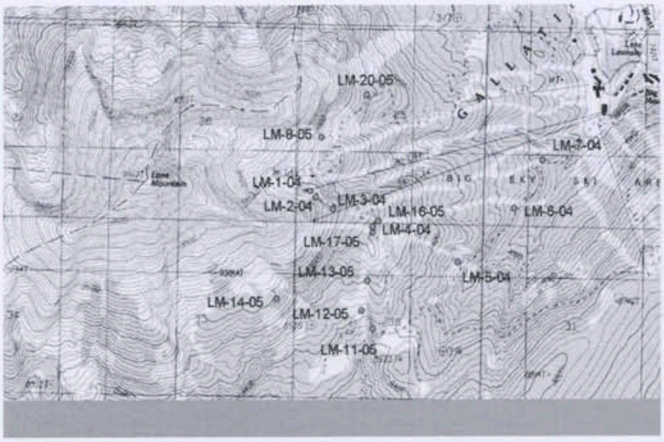

FIGURE 1: Portion of the a 7½ minute topographic map showing Lone Mountain and sample locations used in this study.

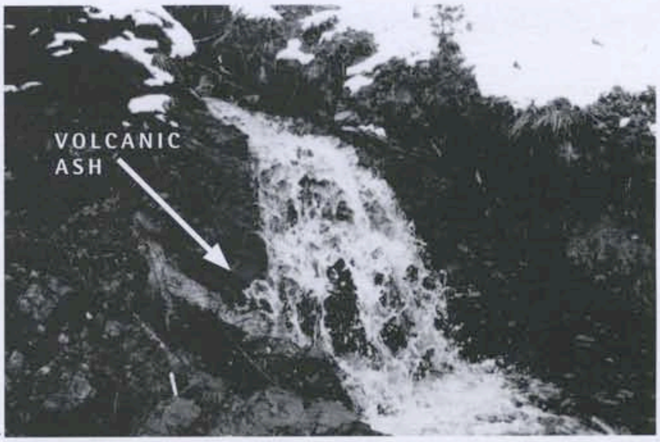

FIGURE 2: Photograph of deformed and tilted layers of alternating siltstone and volcanic ash layers in country rock adjacent to the Lone Mountain dacite intrusion.

FIGURE 3: Photograph of a coarse-grained conglomerate that is part of the Cretaceous-aged country rock intruded by the Lone Mountain dacite.

FIGURE 4: Photograph of typical open horseshoe pit exposure of dacite pluton.

FIGURE 5: Photomicrograph of fine-grained dacite and larger coarse-grained gabbroic xenolith within dacite intrusion.

FIGURE 7: Photograph of mafic xenolith within a dacite rock.

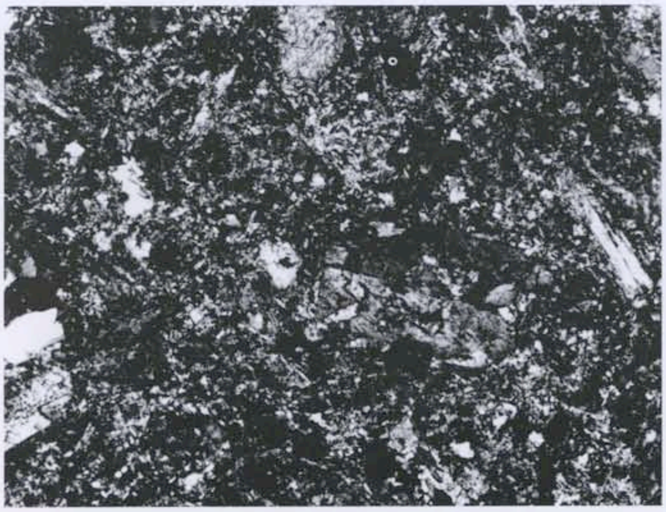

FIGURE 6: Photomicrograph of fine-grained dacite that consists of plagioclase, quartz, biotite, and hornblende.

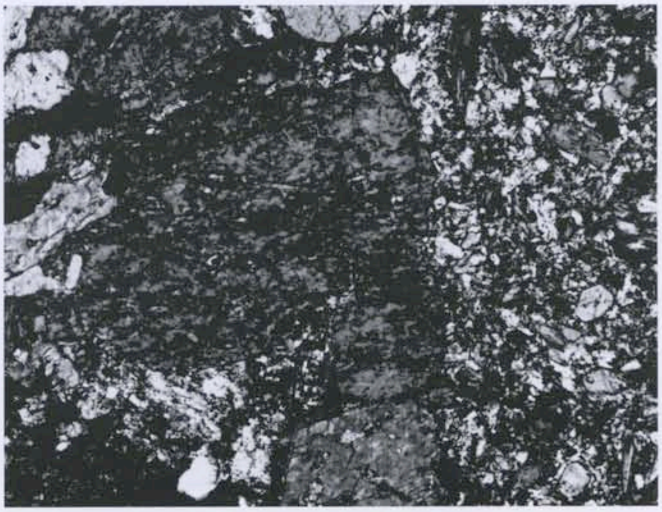

FIGURE 8: Photomicrograph of coarse-grained gabbroic xenolith (left) and fine-grained dacite (right). Xenolith consists of mainly pyroxene and plagioclase, whereas dacitic rocks consist of plagioclase and hornblende with minor pyroxene.

FIGURE 9: Photomicrograph of a large plagioclase phenocryst within a sample of gabbroic xenolith (LM-4-04).

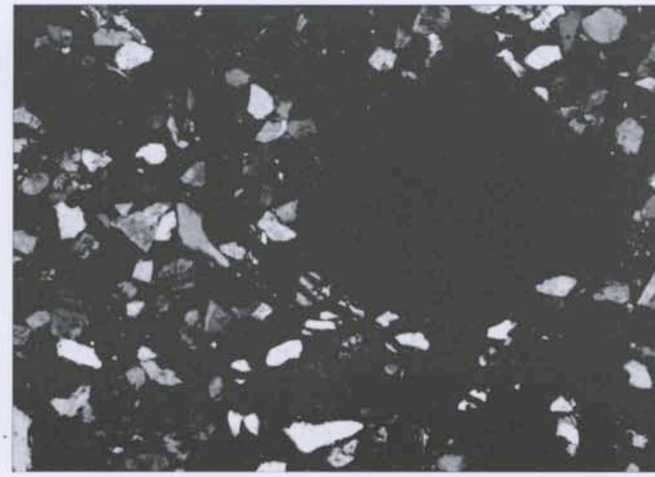

FIGURE 11: Photomicrograph of the sedimentary country rock adjacent to the dacite intrusion. Angular shaped quartz grains are cut by brittle fractures from top left to lower right.

FIGURE 10: Photomicrograph of fine-grained plagioclase and larger hornblende phenocrysts.

FIGURE 12: Photomicrograph of extremely fine-grained clay-rich matrix with rounded quartz, plagioclase, and opaque grains. Sample is from the sedimentary sandstone country rock.

FIGURE 14: Photomicrograph of an ultramafic body that contains crystals of plagioclase (gray) and clinopyroxene (bright blue interference colors).

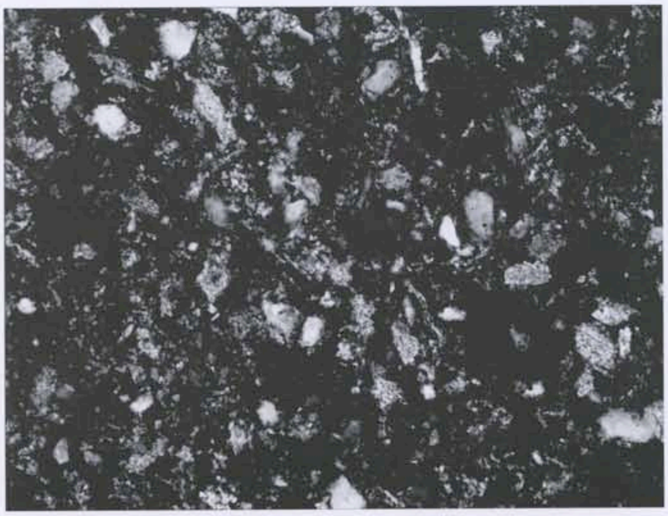

FIGURE 13: Photomicrograph of quartz vein cutting a quartz-rich siltstone of the country rock.

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