Evidence of Periodic Basaltic Injections into the Crystalline Mush of the Cadillac Mountain Granite Magma Chamber, Mount Desert Island, Maine

Elizabeth M. Symchych
Carleton College
Northfield, MN 55057

Introduction

The west coast of Mount Desert Island, Maine contains the hybridized, layered gabbro-diorite units found in the Cadillac Mountain intrusive complex. My field area was a 150 m long stretch of excellent outcrop on the southwestern coast of Stewart Head (see Wiebe, this volume). The outcrops display the interlayered macrorhythmic units of silicic, gabbroic, and heterogeneous intermediate rocks which resulted from the repeated injection of basaltic magma into the Cadillac Mountain granite (CMG). While the CMG was crystallizing within the magma chamber, basaltic magma intruded and spread laterally across the chamber floor, ponding in topographic lows over the newly formed silicic crystalline mush and displacing upward less crystalline silicic magma (Wiebe and Chapman, 1993). I will refer to the process of displacing less crystalline magma as filter pressing. This process results in two types of fine-grained granitic rocks: crystal-rich rocks, which will be referred to as compaction cumulates, and fluid-rich rocks, which rose diapirically during the filter pressing.

The goals of this project are to evaluate the hypothesis that the basaltic magma injected the granitic magma chamber, and to determine the crystalline state of the granite into which the magma was intruded. For these purposes, field relations proved to be invaluable. My field area followed the strike of two macrorhythmic units so I was able to follow these units laterally as well as vertically. Petrographic and chemical data were also obtained to establish mixing relationships between the gabbroic and granitic rocks. From these data, I was able to constrain the crystallizing history of the gabbro-diorites.

Field Relations

Both of the macrorhythmic units within my field area consist of multiple gabbroic injections at the lowest stratigraphic levels (Fig. 1). The boundaries between felsic and mafic material commonly are defined by chilled margins up to 5 cm in width within the gabbro. The grain size, especially for plagioclase, increases in the gabbro with distance from the chill; from 0.2-0.5 mm at the chill up to 0.5-1.0 mm at the center of the intrusion. Between the chilled injections are pockets and lenses of fine grained, felsic rock up to 5 cm thick. Locally, this felsic magma appears to have segregated into two parts: the compaction cumulates, which remained trapped between the gabbroic layers, and the fluid-rich rocks which rose diapirically into and around the gabbro (Fig. 2a).

In sharp contact above the gabbro is an intermediate rock type. This layer has a maximum thickness of 12 cm, and everywhere lies between the gabbro and the granite. Above the intermediate rock is medium grained granitic rock, typically a homogeneous, biotite granite. The most silicic, medium grained layers in the gabbro-diorite unit closely resemble the CMG (Wiebe and Chapman, 1993). Within the granite are lenses of finer grained felsic rock which appear to have been a late stage fluid, concentrated and mobilized within the main body of granite (Fig. 2b). Some of these lenses contain small enclaves of mafic material plucked from the gabbroic chill below.

Other indications of late stage fluid movement are apparent in the granitic material in outcrop. Thick gabbroic layers generally display prominent load-cast structures that project downward into underlying silicic layers (Fig. 2c). Granitic material immediately beneath these load-cast structures typically shows a strong foliation in outcrop. Small diapiric masses of fluid-rich felsic rock extend upward from the compaction cumulates trapped beneath the mafic load-casts.

Evidence that mafic magma was injected into the silicic chamber is provided by a mafic feeder dike that cross-cuts lower mafic layers and connects to partly brecciated chilled mafic lobes in an overlying silicic mush (Fig. 2d). These lobes will be referred to as "ghost lobes". Flow foliation in the felsic matrix around these mafic lobes is evident in outcrop.

Petrographic Data

I examined 26 thin sections of representative samples from the three main rock-types in my area. These thin sections include 9 gabbroic, 3 intermediate and 14 granitic rocks. The gabbros are fine grained rocks, 0.5-1.0 mm, composed mainly of euhedral plagioclase laths (20-55%), hornblende (20-60%), and biotite (5-30%). The chilled margins have diabasic texture while the dike shows lineation of plagioclase as a result of flow foliation.

The intermediate rocks are medium grained, 1.0-3.0 mm, granodiorites with plagioclase being the most common mineral (35-45%) followed by biotite (10-30%), potassium feldspar (15-20%) and interstitial quartz (15-20%). Only one sample, taken from the side of the "ghost lobe" resulting from the brecciated dike, contained lineated plagioclase laths (Fig. 2d).

The granitic rocks can be divided into coarse grained and fine grained varieties. The six coarse grained granitic samples, representing members of the CMG, have a grain size of 2.0-5.0 mm and contain plagioclase (25-40%) with some crystals displaying antiperthitic textures, potassium feldspar including both orthoclase and microcline (15-40%), quartz (15-30%), and mafic minerals including biotite and hornblende (12%).

The fine grained granitic rocks have similar mineralogies to the coarse grained rocks but the modal percentages vary. These rocks are comprised of crystals averaging from 1.0-3.0 mm in length. Plagioclase (35-45%) crystals in three of the thin sections display myrmekitic texture commonly on the boundary shared with other feldspars. Potassium feldspar (10-40%) crystals, principally orthoclase with lesser amounts of microcline, commonly are anhedral. Quartz (20-30%) is typically anhedral and interstitial. Mafic minerals are mainly biotite (3-20%) and minor amounts of highly altered relict hornblende.

One sample of quartz monzonite, the compaction cumulate rock, was compared with a fluid-rich biotite granite for evidence of filter pressing (Samples from Fig. 2c). The fluid-rich rock contains coarser quartz (1.0-2.0 mm as compared to 0.5-1.0 mm) and potassium feldspar (1.5-2.0 mm vs. 0.5-1.0 mm), a lower percentage of plagioclase (32% vs. 50%), and myrmekitic texture. This texture does not appear at all in the crystal-rich thin section. The fluid-rich rock also exhibits flow foliation as seen in the lineation of biotite crystals and plagioclase laths.

Geochemical Data

Twenty one samples were analyzed using X-ray fluorescence (XRF) at Carleton College and inductively coupled plasma techniques (ICP) at Franklin and Marshall College in Lancaster, Pennsylvania. The gabbroic rocks are tholeiitic (Fig. 3). Both the dike and the gabbroic intrusions are tholeiitic, but the dike is from a more primitive source (Fig. 4). The dike on average contains 3% more SiO_2, 4% less Fe_2O_3, and 1% less TiO_2 than the gabbroic intrusions. The coarse grained granitic rocks are more iron-rich than the fine grained granites (Fig. 4). The fine grained granites on average contain 6% more SiO_2, 2% less Fe_2O_3, and 4% more Al_2O_3 than the coarse grained granites, indicating that these rocks are more highly evolved, late-stage crystallization products. Both the Harker and AFM diagrams support the theory of the intermediate, granodioritic rocks resulting from mixing between the gabbroic and granitic rocks.

Discussion

Field, petrographic and chemical data provide evidence for the interpretation of the relationship between the gabbroic dike and the gabbroic layers observed in my section. The similar texture and chemistry of the dike and gabbroic layers indicate a genetic relationship. The formation of the "ghost lobes" just above the dike can be explained by a pulse of the gabbro stemming from the dike and intruding the felsic crystalline mush, forming pillows which subsequently failed brittlely and separated (Mattson, 1986). The cracks between the angular chunks of brecciated mafic material were then filled in with the partially crystalline felsic matrix, resulting in the flow foliation observed at the outcrop and in thin section.

The evidence for filter pressing and fluid movement is especially evident from field relations and thin section petrography. The geochemical data are consistent with filter pressing and support the theory, but do not prove it. The lineation of biotite and plagioclase coupled with the growth of myrmekite in the fine-grained felsic rocks indicate flow due to filter pressing. Hibbard (1987) has shown that the growth of myrmekite in two feldspar granitic systems with at least 10% intercrystalline fluid is the product of hydrous magma crystallization rather than subsolidus processes. Hibbard (1987) also indicates that the CMG must have contained less than 30% melt in order for the strain to result in flow foliation.

Summary

The field, petrographic and geochemical data lead to the following conclusions:

1) The dike, of more primitive chemistry than the gabbroic intrusions, was injected later than other gabbroic layers in my section, yet before the CMG finished crystallizing.

2) The granitic material can be divided into coarse and fine grained types. The coarse grained granites represent the CMG as seen in other areas on the island. The fine grained granites represent a later-stage, fluid-rich end member of the CMG and can be divided into two types due to filter pressing: compaction cumulates, the crystal-rich remnants of filter pressing, and the fluid-rich rocks which rose diapirically into and around the gabbroic rocks. The fluid-rich rocks contain myrmekite indicating high concentrations of fluid due to filter pressing.

3) The textures observed in the felsic rocks indicate that the granite must have contained between 10-30% melt.

4) Thick gabbroic intrusions display load-cast structures which extend down into the felsic layers. Flow foliation is observed in the felsic material beneath these "load casts".

5) The chemistry of the intermediate, granodioritic rocks indicates that they are the resultant of magma mixing between the granitic and gabbroic rocks.

Stratigraphic column of two gabbrodiorite macrorhytmic units on Stewart Head, Mount Desert Island, Maine

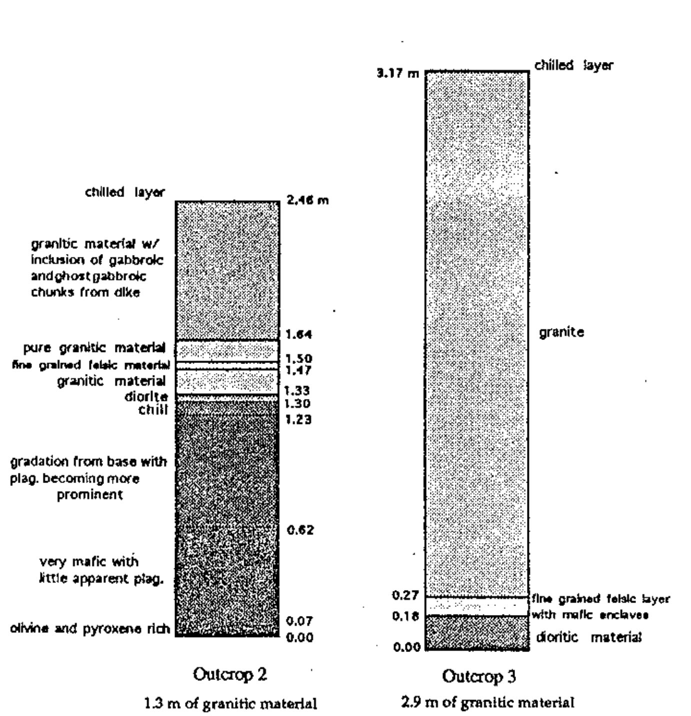

Figure 1: Stratigraphic columns of two macrorhythmic units on Stewart Head. Outcrop 2 lies below Outcrop 3

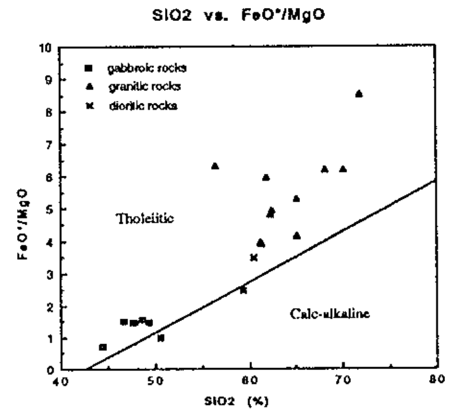

Figure 3: SiO2 vs. FeO*/MgO diagram of all samples. The field is divided into tholeiitic and calc-alkaline. The one gabbroic sample that plots in the calc-alkaline field is the dike.

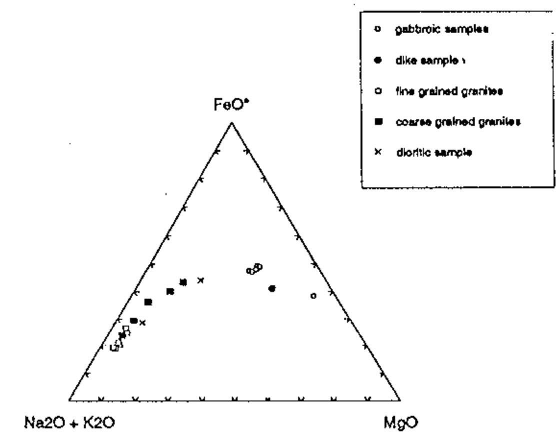

Figure 4: AFM diagram of all samples. The one gabbroic sample that plots as more primitive than the dike is an olivine and pyroxene-rich layer fractionated from a gabbroic intrusion.

References

Hibbard, Michael J., 1987, Deformation of incompletely crystallized magma systems: granitic gneisses and their tectonic implications, Journal of Geology, vol. 95, p. 543-5611.

Mattson, Steven R., 1986, Petrochemistry of the silicic-mafic complexes at Vestruhorn and Austurhorn, Iceland: evidence for zones/stratified magma, Journal of Volcanology and Geothermal Research, vol. 28, p. 197-223.

Wiebe, Robert A. and Chapman, Marshall, 1993, Layered gabbro-diorite intrusions of coastal Maine: basaltic infusions into floored silicic magma chambers: Field Trip Guidebook for Northeastern United States: 1993 Boston GSA, Cheney, J.T. and Hepburn, J.C., eds. Contrib. No. 67, Dept. of Geol. and Geog., Univ. of Mass., Amherst, Mass., p. A1-A29.

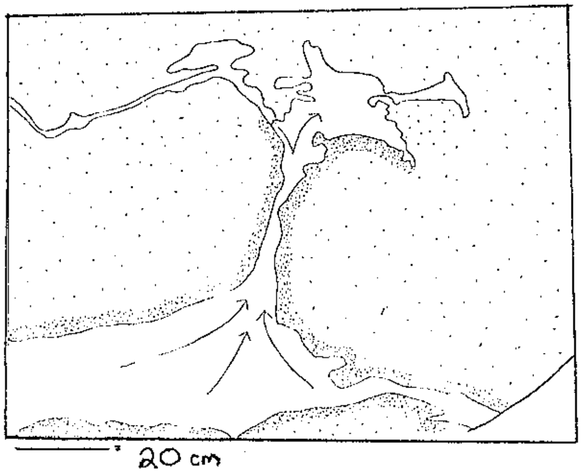

Figure 2A: Diapir of fine grained, fluid-rich felsic rock (white area) surrounded by gabbroic rock (dotted area, with higher concentrations of dots denoting chilled margins). Arrows indicated flow direction of felsic material.

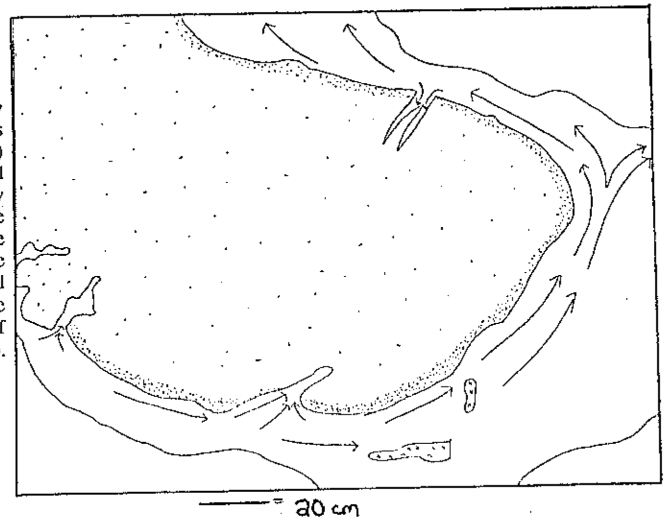

Figure 2C: Chilled gabbroic pillow (dotted area, with higher concentrations of dots denoting chilled margins) sinking into fine grained felsic material (white area). Arrows indicate flow foliation. Fluid-rich rocks are from the upper levels of the fine grained felsic rocks, while the compaction cumulates are located below the gabbroic pillow. Within the compaction cumulates are two rafts of coarse grained granite (crosses).

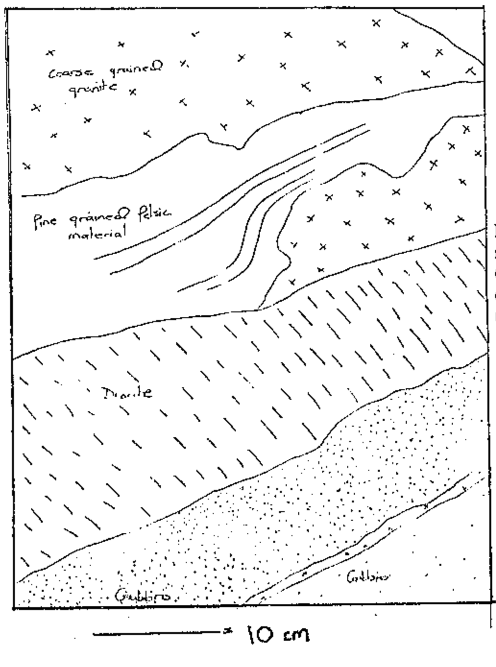

Figure 2B: Close view of the gabbro-diorite rock units. Gabbro (dots) with chilled margin (concentrated dots), diorite (oblique dashes), coarse grained granite representing the CMG (crosses), and a lens of fine grained felsic rock (white area with lines indicating flow foliation).

Figure 2D: View of the same outcrop in Fig. 2B. Coarse grained granite (crosses) is injected with fine grained felsic rock (white area with arrows indicating flow foliation), and underlain by diorite (oblique slashes) and gabbro (dotted with concentrated dots denoting chilled margin). The "ghost lobe" is in the upper center with lines indicating foliation around the dioritic matrix containing chilled, brecciated mafic rocks.