MAGMA MINGLING IN THE CADILLAC MOUNTAIN INTRUSIVE COMPLEX
— SOMMES COVE, MOUNT DESERT ISLAND, MAINE —

Frederick J. Vanden Bergh
Department Of Geology
The Colorado College
Colorado Springs, Colorado 80946

INTRODUCTION

Mount Desert Island, located off the southern coast of Maine, is dominated by the Silurian Cadillac Mountain Intrusive Complex (CMIC), one of many plutons within the Coastal Maine Magmatic Province (CMMP) (Hogan and Sinah, 1989). The Cadillac Mountain Granite (CMG) comprises the bulk of the pluton, and is bounded on the west by a complexly layered Gabbro-Diorite unit (G-D) (Wiebe, 1993) with excellent exposures along the coastal inlets and bays of the island. Suspected of being the result of magma mixing (Wiebe and Chapman,1993), a study conducted during June of 1993 in Sommes Cove, Mount Desert Island (MDI in Figure 1) gathered detailed field relations and samples for petrographic and geochemical data for the G-D unit. The data aid in the determination of crystallization histories and petrogenetic relationships between the various rock types within the unit, and in particular within Sommes Cove.

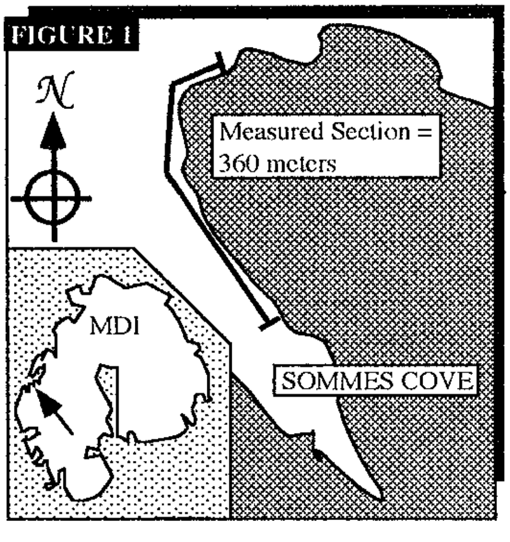
PREVIOUS WORK

The CMIC is an extensively studied pluton. Gilman et al., 1988 produced the geologic history and the bedrock geologic maps used as the base map for the current study. Hogan and Sinah, 1989 recognized the CMIC as a pluton likely affected by interaction of contemporaneous magmas. Seaman and Ramsey, 1992 have also written about magma mingling in the CMIC. Wiebe, 1993 classifies the pluton as a mafic-silicic layered intrusion (MASLI), similar to previously recognized mixing localities in the CMMP, and interprets the G-D unit as a sequence of many "macrorhythmic" layers. He considers these layers the result of repeated infusions of mafic magma into the granitic CMG chamber which pond on the cumulate mush at the base of the chamber, forming the numerous rock types of the unit through variable degrees of hybridization of the mafic and host liquids. He also describes numerous structures diagnostic of comagmatic interaction, as well as petrographic descriptions and geochemical analyses. Wiebe also suggests, as did Hogan and Sinah, that the rocks of the G-D unit do not result from the crystallization of a simple liquid and therefore geochemical data must be interpreted cautiously. Consequently, although geochemistry will be an important aspect of further research, the Sommes Cove study emphasizes field relations and petrography for the majority of rock types exhibited.

FIELD WORK AND OBSERVATIONS

Field work consisted primarily of detailed observation, measurement, and sampling of the G-D unit along 360 meters of coastline. A wide variety of magma mingling structures and numerous, interlayered rock types within the unit were documented. The dominant layering in this area strikes N39W and dips 23° to NE. From this data, a map and stratigraphic column (Figure 3) of the area were constructed, schematically detailing the most common mixing structures observed and revealing a true thickness for the layered section of 82.8 meters.

FIGURE 1



The layered section of Sommes Cove is a complicated sequence of intercalated rock units. Chilled gabbroic layers formed of discreet bodies, dubbed "pillows," are most commonly bounded by a more felsic, heterogeneous unit ranging in composition from diorite to quartz monzonite. Pillows are lobate in form, surrounded by a chilled rind approximately 2-3 centimeters thick that grades to coarser gabbro toward the center of the pillow. Underlying felsic material commonly intrudes upward through the chilled margin of the gabbroic layers forming "diapirs," the contact typically becoming wispy and diffuse higher in the layer and towards the center of the pillow (Figure 2). Tabular biotite within the felsics near the contact is parallel to the boundary appearing flow laminated, especially within the felsic diapirs. Oriented hornblende is also clearly seen concentrated at the contact, and less commonly in the central portions of the diapirs. A much larger gabbroic layer shows only a basal chilled margin with a cuspate/lobate contact with underlying granite (the most felsic unit of the sequence), the upper chill absent. Instead the layer grades rapidly upward to a heterogeneous, hornblende-rich quartz diorite, the most voluminous unit of the section's upper half. Between the large, gabbroic layer and the underlying granite is a thin (5-10 cm) layer of diorite that conforms to the irregularities of the contact. Numerous small, mafic enclaves, similar to those found throughout the CMIC (Wiebe, 1993), are concentrated here. The granite has a relatively abrupt but irregular basal contact with a quartz monzonite unit containing large potassium feldspar phenocrysts. One large inclusion of the overlying granite sits in the underlying quartz monzonite. This unit grades from quartz diorite down section similar to the diorite that dominates the upper layers.

A wide variety of dikes cross-cut the outcrops, their sharp, unmingled contacts providing an excellent contrast to the irregular, softer contacts within the layered section. Seven one meter wide basaltic dikes, trending approximately N10W, intrude the section. Several aplite dikes were also noted, one closely associated with an en-echelon pegmatitic dike system. A composite dike parallel to layering consists of an aplitic matrix containing lobate, chilled gabbroic pillows and sharply contacts the surrounding quartz diorite country rock.

PETROGRAPHY

The gabbros typically consist of randomly oriented plagioclase lathes ophitically contained within richly pleochroic amphibole. Many plagioclase crystals (Michel-Levy = An_{65}) show strong, normal zoning with some reversals. Biotite is common, particularly enriched along chilled margins. Olivine is essentially absent from the gabbros, but can be seen with thick pyroxene reaction rims in the composite and basaltic dikes. Augite, although more frequently seen in the gabbros than olivine, is also more common in the dikes where amphibole is rare. Apatite and epidote (from weathering) are ubiquitous accessories throughout the section. Zircon is rare, and sphene was noted along the contact between diorite and gabbro in one thin-section. Xenocrysts of quartz and potassium feldspar are present as far as two meters away from a contact, the kspar overgrown and rimmed by plagioclase, showing "rapakivi" texture. Chilled gabbros exhibit variably aphanitic textures, reflecting the compositional (and most likely temperature) contrast with the underlying material; the gabbro in contact with the granite is dramatically finer grained than pillows chilled against a dioritic matrix. Biotite and hornblende within chilled gabbros are flow laminated parallel to the contact.

The gabbro grades to a heterogeneous, hypidiomorphic diorite with plagioclase still the dominant phase. Amphibole and biotite are the primary mafics, with subordinate pyroxene exhibiting thick amphibole reaction rims. Quartz makes up less than 1% of the more mafic diorites, but can be found in greater percentages in the quartz diorites and quartz monzonite. These more felsic units contain large orthoclase phenocrysts that frequently contain partially resorbed plagioclase, biotite, and hornblende. Larger subhedral plagioclase and anhedral microcline are also common. Biotite is more abundant than amphibole; pyroxene is rare to absent. The diorite sandwiched between the granite and the gabbro is noticeably enriched in biotite. Apatite and epidote are the most common accessory minerals, and rare zircon was also noted.

The granitic unit of Sommes Cove consists of large, subhedral quartz and kspar grains, the latter partially including biotite, the dominant mafic phase. Hornblende is also present, but not as common as in the CMG, and plagioclase is rare. Some granophyric intergrowth was noted; apatite and zircon are prevalent. The aplites show similar but allotriomorphic mineral assemblages, with hornblende noticeably absent.

DISCUSSION AND FURTHER RESEARCH

The layered section of Sommes Cove reveals abundant field and petrographic evidence indicative of contemporaneous, interacting magmas. Hot, dense mafic influxes into the felsic chamber appear to have formed gabbroic layers that chilled against the partially solidified cumulate pile. For influxes of low volume, small gabbroic "pillows" resulted, chilled on all sides against the surrounding matrix. The larger, mafic intrusion chilled only along the bottom margin and quickly hybridized with surrounding liquid to a coarser, more dioritic composition. Petrographic textures exhibited in the dioritic units also suggest hybridization. As the denser, overlying mafics settled into the felsic cumulate pile, sedimentary-like load casts and diapirs resulted as the partially solid cumulate broke and rose through weak points in the chilled gabbroic rind (Figure 2). Flow lamination parallel to the contact in both the underlying felsics *and* chilled margin of the gabbro strongly support the claim that both were at least partially liquid at the time of emplacement. While in some cases these diapirs diffused relatively rapidly, others apparently remained coherent and rose considerable distances into the overlying layer. These "pipes" are evidenced by their cross-sections in the upper portion of the Sommes Cove sequence. Hornblende concentrations in the central portions of the diapirs and pipes are seemingly the result of flow segregation. Biotite and hornblende enrichement along the contact suggest hydrous diffusion and build up at these boundaries.

The Sommes Cove section displays essentially one complete, well-developed macrorhythmic layer. If one imagines the large, gabbroic influx as the basal unit, the layer then grades up through increasingly felsic, heterogeneous diorites/monzonites until a composition closely representative of the host liquid is reached in the granite. The unit is periodically interupted by smaller influxes of mafic magma, but their relatively low volumes does little to affect the evolution of the sequence. The somewhat abrupt transition from quartz monzonite to granite (Figure 3) may represent the highly hybridized upper boundary of the large mafic intrusion.

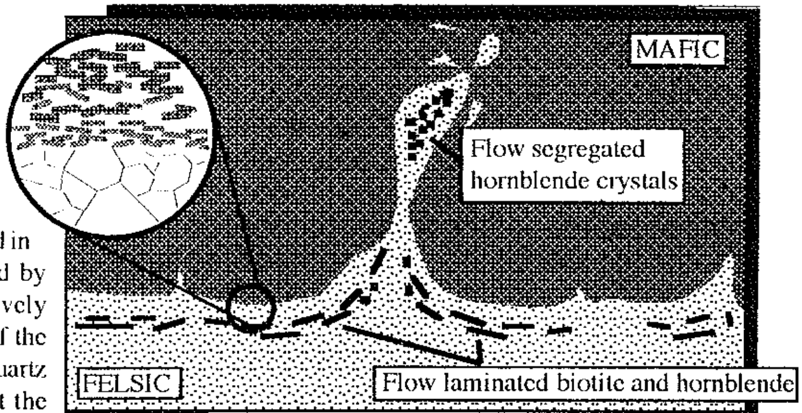


FIGURE 2 SCHEMATIC REPRESENTATION OF LOAD CASTS AND DIAPIRS. FLOW LAMINATION IS SEEN IN THE FELSICS AND IN THE MAGNIFIED VIEW OF THE CHILLED MARGIN.

Petrography does not strongly suggest a cogenetic relationship between the cross-cutting dikes and the units within the layered sequence. This conclusion is given cautiously, however, as the layered units are sufficiently far removed from their original liquids that any such assertions are equivocal. The felsic dikes, being more biotite-rich and amphibole-poor than the CMG may have closer ties to the Sommesville Granite, another unit of the CMIC.

At the time of this writing, the research of this study is in its infancy. Geochemical data will help determine more completely the petrogenetic relations and degrees of hybridization between units, both within the G-D unit and with the other units of the CMIC, assuming viable end-member compositions. Instrumental neutron activation analysis may enable investigation of immobile Rare Earth Elements that would provide clues to magma source areas and crystallization histories. Additional petrographic studies will help assess the role and consequences of double-diffusive convection that may result from the density inversions implied by this model.

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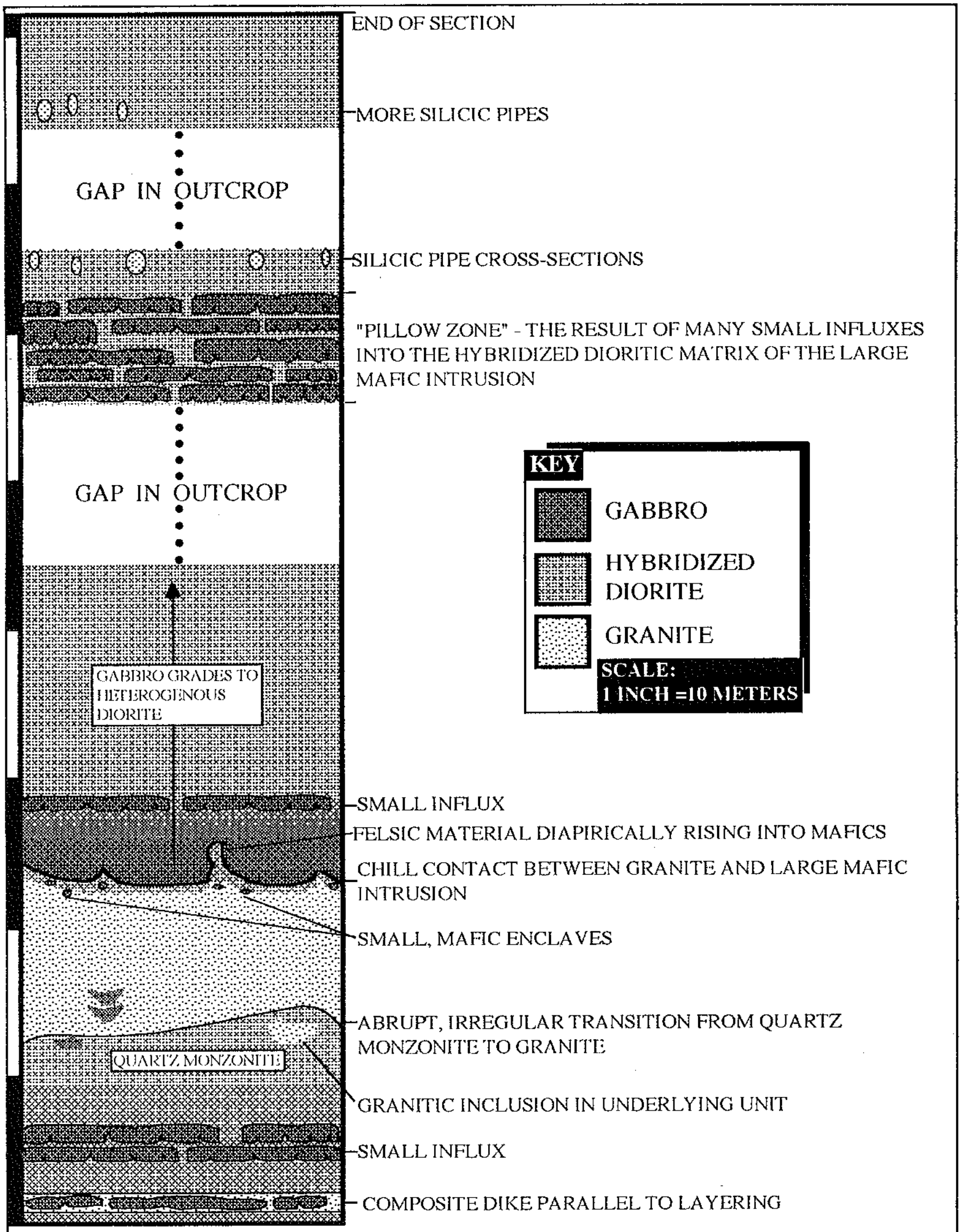

FIGURE 3 SCHEMATIC STRAT. COLUMN SHOWING MACRORHYTHMIC LAYERING, SOMMES COVE FIELD AREA. TOTAL TRUE THICKNESS = 82.6 METERS.