MAGMA MINGLING AND MIXING IN THE GOULDSBORO PLUTON PETITE MANAN POINT, MAINE

John S. Lien
Department of Geology
The Colorado College
Colorado Springs, Colorado 80903

Introduction

The Gouldsboro Pluton, located just northeast of Mount Desert Island on Petite Manan Point, Maine, is one in a group of Silurian to Early Carboniferous plutons collectively known as the Coastal Maine Magmatic Province (CMMP, Hogan and Sinha 1989). The CMMP extends from Penobscot Bay to Passamaquoddy Bay. CMMP plutons intrude four accreted terranes. The Gouldsboro Pluton intrudes the Ellsworth-Coastal Volcanic Terrane (ECVT), the outboard terrane accreted during the Appalachian-Caledonide orogeny. The Gouldsboro Pluton is bounded to the north by the Steuben Granite and the ECVT. Eastern and Western margins of the Gouldsboro Pluton are bounded by the Pleasant Bay/Jonesport mafic pluton and the Milbridge mafic pluton, respectively. The Gouldsboro Pluton is classified by Hogan and Sinha (1989) as a dominantly granitic pluton that has mingled and/or mixed with a mafic magma. My study of the Gouldsboro Pluton, on Petite Manan Point, conducted from mid June to early July, 1994, focused on field relations, geochemistry, and petrography and led to a detailed characterization and classification of the pluton, with interpretation of its petrogenesis.

Field Relations

The Gouldsboro Pluton outcrops on all of Petite Manan Point. Field study focused on shoreline exposures because the interior of the point was heavily vegetated, and outcrops are poor. The field area contains four distinct rock types, with distinctive textures. The most abundant rock in the area is the medium grained Gouldsboro Granite, containing mafic enclaves of various sizes (~0.04-0.5m). The mafic enclaves have both soft and chilled margins indicating the presence of contemporaneous and non-contemporaneous liquids. A crystal-poor porphyry and crystal-rich porphyry also exist in the field area, making up much lower volumes of the exposed pluton. The crystal-rich porphyry occurs in large, irregular, equant masses (~0.5-10m) within the Gouldsboro granite, with lesser amounts of crystal-poor porphyry. Aplitic granite makes up a small amount of the Gouldsboro granite, and occurs as small dikes or larger, amorphous masses. Miarolitic cavities containing pyrite are present in the small aplite dikes, and indicate shallow, hypabassal emplacement. Larger, pipe-like structures, completely or partially filled with terminated quartz crystals exist in the amorphous aplitic masses, and are consistent with shallow emplacement of the aplitic bodies.

The entire field area is cut by primarily mafic dikes trending N50W to N28E, and varying in width from 0.3m to more than 10 m. One composite dike also cuts the area just to the south of Chitman Point. The dike is composed of aplitic granite, basalt, and crystal-rich porphyry, and is ~7m wide. Contacts within the dike show no chill margins, indicating all three materials were contemporaneous liquids.

Petrography

Petrologic characteristics of the four main rock types in the area were determined through examination of twenty-eight thin sections. Plagioclase compositions were determined using A-normal section technique.

1) The Gouldsboro granite is a two feldspar granite with hornblende and biotite. The cores of the plagioclase are roughly An_{35} while the rims are roughly An_{20}. A few quartz grains in the Gouldsboro granite display ochelli texture, but granophyre is rather common, and resorption of the grains also occurred. K-feldspar has been sericitized and plagioclase has been partially replaced by epidote.

2) The aplitic granite varies widely in texture. Some samples contain large phenocrysts of quartz and plagioclase, with dominant K-feldspar. The quartz and plagioclase phenocrysts show resorption textures. Chlorite replacement of biotite and hornblende is widespread in the aplitic granite.

3) The crystal-rich porphyry contains the most striking textures of all the thin sections. Intensely resorbed quartz, plagioclase and K-feldspar phenocrysts are present. Biotite rims developed on K-feldspar and quartz. This texture is interpreted to reflect an excess of K^+ liberated during resorption. The rims are better developed around the K-feldspar, the possible source of the K^+-ion, than around the quartz, a simple nucleation site.

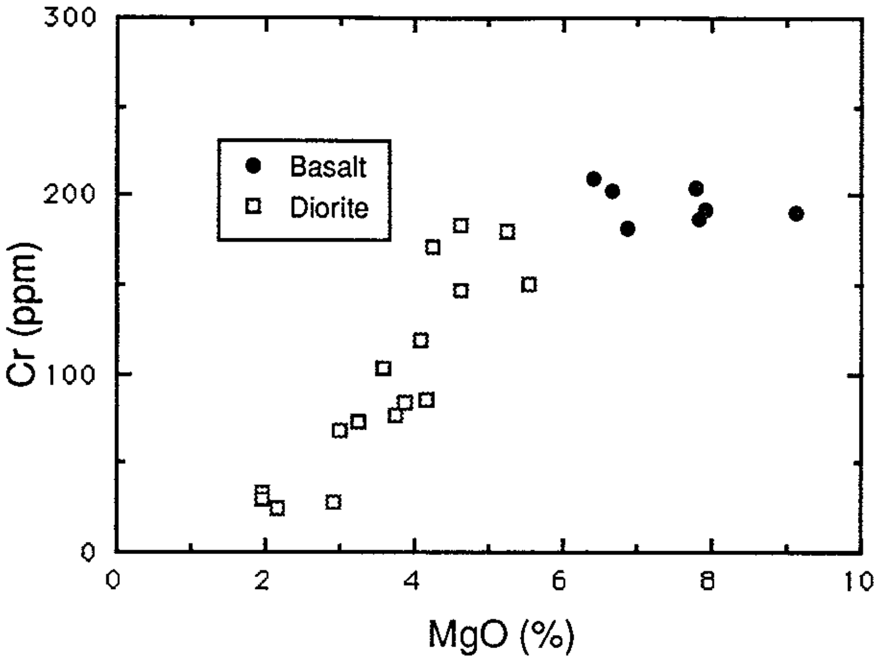

Fig. 3: Cr vs. MgO showing basalts and diorites from both macrorhythmic units.

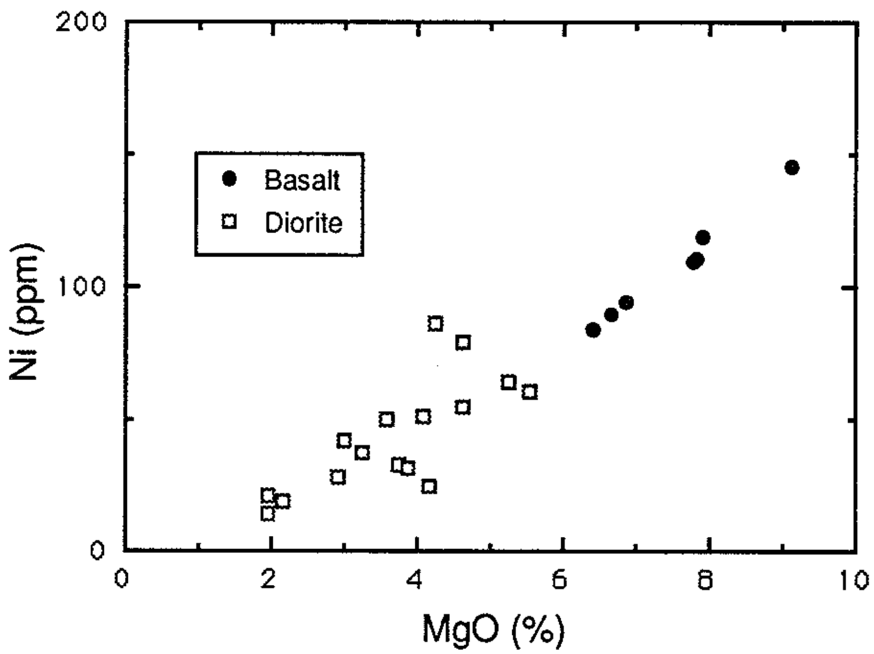

Fig. 4: Ni vs. MgO showing basalts and diorites from both macrorhythmic units.

4) The crystal-poor porphyry differs from the crystal-rich porphyry in the amount of phenocrysts, but exibits many of the same textures. The groundmass is composed of plagioclase, K-feldspar, and quartz, and is very fine-grained.

Geochemistry

XRF and ICP analyses were conducted on twenty-one samples at Franklin and Marshall College in Lancaster Pennsylvania. Bulk geochemical analyses show that the Gouldsboro Pluton is peraluminous to metaluminous. Silica content varies from 68.95 wt% to 78.04 wt%. Trace element patterns closely resemble those for the upper crust (Fig.1). On tectonic discrimination diagrams, the data show a post-orogenic, within-plate granite signature. Harker diagrams illustrate the expected enrichment and depletion trends for major oxides (Fig. 2; all samples).

Detailed study of sample traverses across the contacts between porphyries and granite contacts reveal small to no compositional differences. Analyzed samples were evenly spaced across 6-8 cm-long traverses across the boundaries. This is interpreted to mean that virtually no ionic exchange occurred across contacts, that complete homogenization of major elements occurred.

Summary

Field observations demonstrate that the Gouldsboro Pluton did undergo magma mingling /mechanical mixing. Soft pillow-like margins, with euhedral crystals protruding into the opposing material, indicate liquid-liquid interactions. The absence of chill margins between the pillow-like masses are also consistent with liquid-liquid interactions.

Petrographic study of the thin sections and hand samples show common mingling textures such as quartz ochelli, crystal rimming, resorption, and disequilibrium plagioclase, consistent with liquid-crystal interaction. The Gouldsboro granite in the area contained mafic enclaves, with the larger ones showing wisps of granite intruding them, another indication of liquid-liquid interactions.

Geochemical data indicate that mingling/mechanical mixing rather than chemical mixing occurred among the four rock types. Limited diffusion of ions took place. The mingling textures in the rocks may represent small viscosity or density differences, possibly due to variations in volatile content or SiO_2 concentration. Interpretation of the geochemical data for tectonic setting is that the Gouldsboro Pluton is a post-orogenic, within-plate granite. The pluton intruded the ECVT, and emplacement postdated the Appalachian -Caledonide orogen.

More sampling needs to be done on the basaltic and gabbroic dikes in the area as they are a possible expression of a deeper level heat source. Close attention should be paid to the hybridized granites or crystal-rich porphyries. Insufficient geochemical data were obtained in my study to allow full petrogenetic interpretation of the latter rocks.

References Cited:

Hogan J.P., and Sinha A.K.,1989, Compositional Variation of Plutonism in the Coastal Maine Magmatic province: Mode of Origin and Tectionic Setting, Maine Geological Survey, Studies in Maine Geology, v.4 , p.1-33.

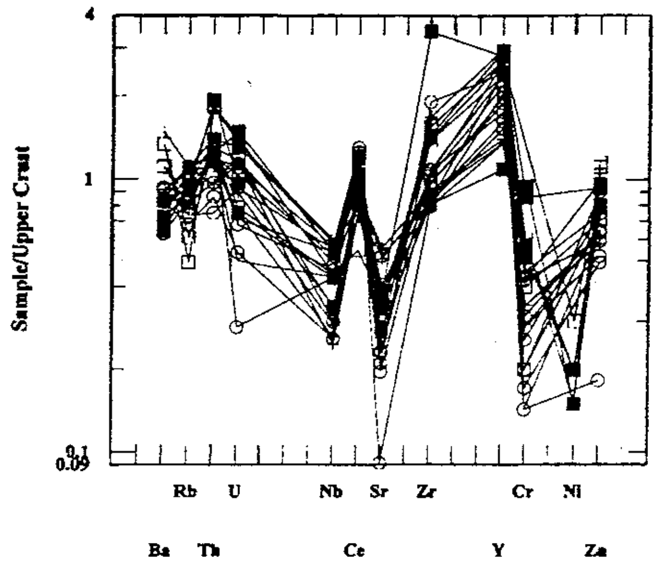

Figure 1: Trace element data normalized to upper crustal values.

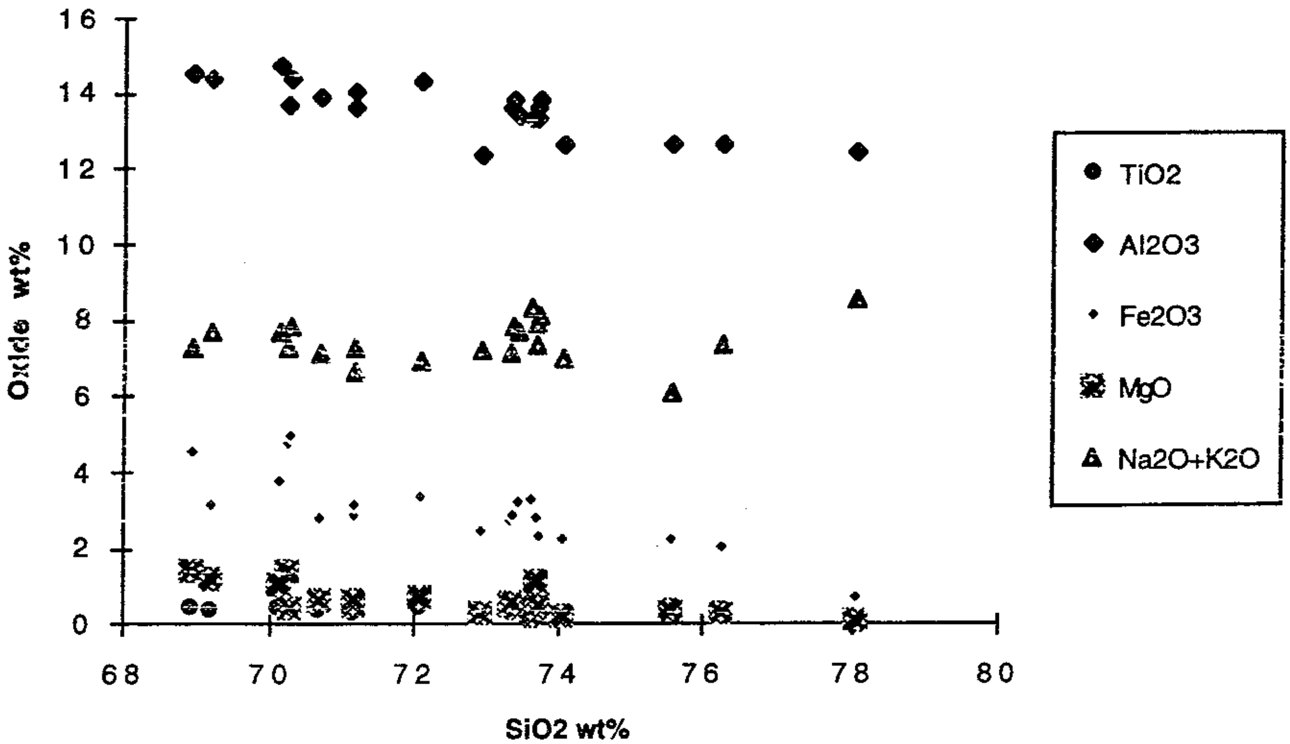

Figure 2: Harker diagram showing expected enrichment and depletion trends.