ANALYSIS AND INTERPRETATION OF MACRORHYTHMIC UNITS OF GABBRO-DIORITE INTERLAYERING AT AREY NECK, VINALHAVEN ISLAND, MAINE.

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INTRODUCTION

Extensive studies have been made of plutonic associations containing interlayered gabbroic, dioritic, and granitic rocks that contain evidence of mixing silicic and basaltic magmas (Smith, 1979; Wiebe 1974, 1992, 1993a and b). Recent studies have lead to a growing consensus that many of these associations resulted from the injection of mafic liquids into floored silicic chambers. The liquids then pond on the chamber floor and mix to varying degrees with the overlying silicic fluids.

The Coastal Maine Magmatic Province contains numerous plutonic complexes showing mafic-silicic interactions that can be explained by such mafic infusions into silicic chambers (Wiebe, 1992, 1993a). These composite plutons can provide important information on magma mingling and hybridization. Layered bimodal intrusions commonly contain sets of macrorhythmic units (2-50m thick) that grade up from basally chilled gabbro through intermediate diorite to granitic cumulates. Each unit is thought to represent a single mafic injection that ponded on the chamber floor, quenched at its base, and mixed and mingled with overlying silicic liquids along a double-diffusive boundary, forming heterogeneous intermediate hybrids.

The bases of macrorhythmic units commonly show lobed, load cast structures, along with fluid-escape structures such as pipes and diapirs rising out of the underlying silicic layers into the basally chilled gabbro.

Field, petrographic, and geochemical data indicate that the Vinalhaven Island pluton formed in a manner characteristic of layered intrusions found elsewhere in the world and at other locations within the Coastal Maine Magmatic Province. The purpose of this paper is to report on the results of a study that took place on Arey Neck, a small neck along the south-eastern shore of Vinalhaven Island that shows a clear outcrop of macrorhythmic units near the lower portions of the pluton. Field, petrographic, and geochemical evidence are used to document and interpret these units.

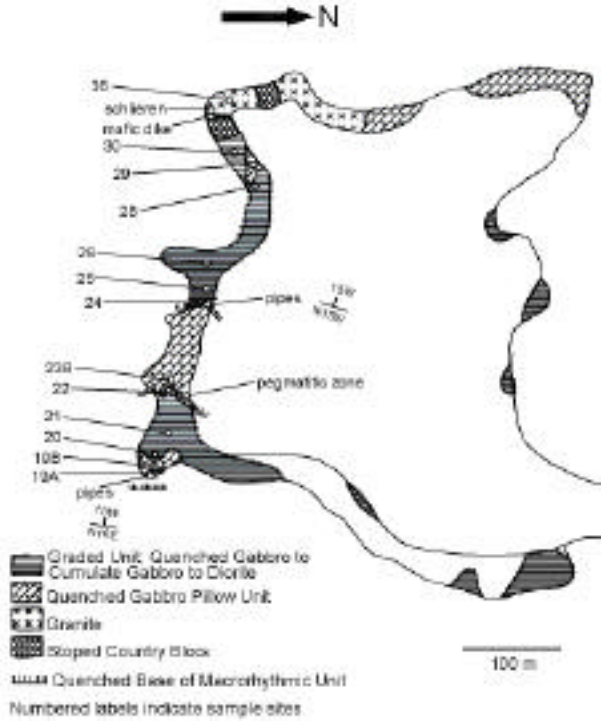
One month was spent field mapping and collecting 23 samples from representative macrorhythmic units. Thin sections made of all samples were analyzed for mineralogic and textural data, and 19 samples were analyzed with XRF (x-ray flourescence) for major and trace element signatures.

FIELD RELATIONS

Arey Neck is located along the south-eastern shore of Vinalhaven. (Fig.1). Exposures along the northern, eastern, and western edges are

sporadic, while the southern shore of the neck contains a nearly continuous series of macrorhythmic gabbro-diorite units that record periodic basaltic infusions onto the chamber floor. Previous studies have indicated that the layering along the lower shores of Vinalhaven dip gently toward the center of the island (Rhodes, 1999). The trend line of Arey Neck's southern exposure is approximately parallel to this dip direction.

Figure 1. Geologic map of Arey Neck.



There are three visibly distinct macrorhythmic units within the pseudostratigraphic layering. The lowermost unit is composed primarily of quenched fine-grained gabbro that grades through medium-grained cumulate gabbro to increasingly leucocratic diorite. The base of this unit also contains a thin section of chilled pillows within a fine-grained granitic matrix, below which lies a lens of exposed quenched gabbro containing pipe structures. The orientation of the pipes indicates a N10E striking paleohorizontal trend, and a current dip of 15W. The location of the base of the unit is inferred from the presence of pipes and, in part, from the lobed nature of the contact both above and below the pillow layer.

The increasingly felsic upward trend in the unit is abruptly truncated by a second macrorhythmic unit. Again, the contact is characterized by strongly lobed load casts. This second infusion unit consists of a thick sheet of quenched gabbroic pillows within a medium-grained intermediate matrix. These pillows grade laterally into massive quenched gabbro along the entire length of the exposed unit. The base of this massive gabbro contains water-rich pegmatitic zones that resemble the pipe structures found near the base of other pseudostratigraphic units. There is no observable vertical compositional variation across the length of this unit.

A third macrorhythmic unit rests atop the pillowed section. Again the presence of pipes is indicative of the load stress of the overlying, subsequently emplaced unit (pipes show a N15E striking paleohorizontal trend, and a 15W dip). This section contains the greatest range of vertical compositional variation. Quenched gabbro grades up to through medium-grained leuco-gabbro containing visible radiating plagioclase clusters surrounding acicular amphibole up to a leucocratic diorite hybrid containing large xenocrystic feldspar clusters. Crosscutting the upper, dioritic portion of the unit is a composite dike containing quenched gabbroic pillows. The vertical evolution of the material in the section is truncated by a large stoped country block. Above the stoped block is a large section of coarse-grained granite. The stoped block appears to have fallen through a partially crystallized granitic liquid, causing downward spiraling convection currents. This interpretation is evidenced by a very thin film of coarse grained granite located along the lower contact of the stoped block, between the country block and the underlying dioritic hybrid, as well as schlieren fabrics in the granite immediately above the country block, indicating some degree of convection or flow. The granite continues along the western shoreline (for approximately 100 m) before coming into a soft, gradational contact with a section of chilled hybrid pillows. A second stoped country block is also present in the granite, approximately 50m beyond the first. The limited exposure along the western shore, as well as its perpendicular orientation to the dip direction of the layering, make it difficult to link this unit to the well exposed

progression of macrorhythmic units along the southern shore.

PETROGRAPHY

There are four basic rock-type classifications used in this study: fine-grained quenched gabbro, medium-grained cumulate gabbro, diorite and granite.

The quenched, fine-grained gabbros (samples 19A, 19B, 23B, 24, 29) are dominated by normally zoned, euhedral to subhedral plagioclase lathes (frequently radiating). Dominant mafic minerals are clinopyroxene (subhedral to anhedral), equant olivine, and hornblende (subhedral). Biotite is also fairly common, but in lower modal abundances, along with minor anhedral orthopyroxene. Small bleb-like intergrowths of augite are present in some plagioclase laths, and are ubiquitous in the quenched gabbroic pillow sample 19B, which is also finer grained than any other quenched sample.

The medium-grained cumulate gabbros consist primarily of large, strongly zoned, blocky and tabular plagioclase. Large, subhedral clinopyroxene is also extensive, and is commonly rimmed with hornblende alteration. Equant olivine is common, and varies in size between samples. Hornblende is generally a minor mineral in these samples, but occurs frequently in sample 25. Accessory opaque minerals, including magnetite and illmenite, are ubiquitous, as is acicular apatite, which is particularly frequent in sample 26.

The diorites samples are strongly inequigranular, and dominated by subhedral plagioclase and large subhedral to anhedral hornblende. Alkali feldspar and quartz are also primary constituents, and occasionally occur in granophyric textures. Biotite and clinopyroxene are minor minerals. Most clinopyroxene occurrences are relics from alteration to amphibole. Opaque oxides, zircon and acicular apatite occur in minor amounts throughout. Textural and mineralogic evidence of hybridization is common in these samples. Such evidence of thermodynamic disequilibria includes amphibole-mantled clinopyroxene, rapakivi texture, general presence of reaction rims and alteration of large grains, and increased zonal arrangement of melt inclusions in plagioclase.

GEOCHEMISTRY

Major and trace element signatures provide important information about the origin and evolution of the sampled rock units. Major and trace element concentrations were determined using XRF at Franklin and Marshall College.

The quenched and cumulate gabbros contained 45.75-50.46% SiO_2 and 6.63-10.37% MgO. The suite is relatively enriched in compatible elements (205-361 ppm Cr, 82.2-228 ppm Ni) and depleted in incompatible elements (91-191 ppm Zr, 1.7-5.6 ppm Nb, 0-2.6 ppm Th, 17.6-38.2 ppm Y, 21.2-105 ppm Ba, 5.4-26.7 ppm Rb).

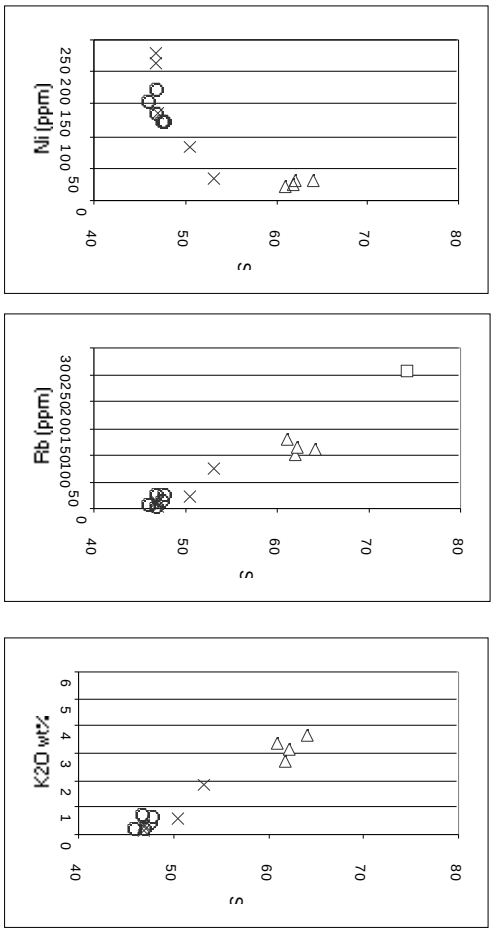
The intermediate dioritic suite contained 60.98-64.03% SiO_2 and 1.53-2.24% MgO. The samples showed a wide range of chemical variation, but relative to the gabbroic samples, the diorites were depleted in the compatible elements (57-85 ppm Cr, 23-30 ppm Ni) and enriched in the incompatibles (256-342 ppm Zr, 10.4-12.9 ppm Nb, 8.3-11.5 ppm Th, 45.7-57 ppm Y, 216-355 ppm Ba, 99-131.2 ppm Rb).

Previous studies have indicated that compositional variation across the suites is a result of both crystal fractionation and hybridization, with hybridization playing a dominant role (Mandernach, 1999). Various degrees of fractional crystallization and crystal accumulation should not influence the ratios of any two incompatible elements. Zr vs. Nb and Rb vs. Ba plots were made to determine whether the ratios of these incompatible elements change with their changing concentrations (not shown), as any variation in these element ratios between sample suites should reflect direct hybridization. In both plots, the diorite ratio falls between the ratios of the gabbroic suite and the granite, indicating that the intermediate diorite compositions resulted from the hybridization of the granitic and gabbroic end-members.

The role of fractional crystallization can be seen in the Ni silica variation plot in figure 2. The linear trend expected from pure magma hybridization is not seen in these plots. This is

most likely a result of Ni's compatibility with olivine, and the fractional crystallization of this element. Most other silica variation diagrams show linear trends.

Figure 2: SiO2 variation diagrams



DISCUSSION

Arey Neck contains three major macrorhythmic units. Each unit shows characteristic pipe or pipe-like structures near the basal quench. Petrographic and geochemical data indicate that compositional variation across the macrorhythmic units is a result of both fractional crystallization and magma hybridization. Field relations support a scenario in which spatially and temporally discreet mafic injections pond on the chamber floor and mix and hybridize with overlying silicic liquid across a double-diffusive boundary. Since hybridization can only occur along this boundary, it seems likely that slight compositional variations in the gabbroic base of a unit are predominantly a result of fractionation, with hybridization playing an increasingly large role higher in the unit. Pipes near the base of the macrorhythmic units indicate that the layers are dipping approximately 15 degrees to the west, toward the center of island, and striking approximately N10-15W. This supports the existing model of the orientation of the units.

Petrographic analysis of dioritic samples reveals a wide variety of mineralogic and textural evidence of the thermodynamic disequilibria of crystal grains caused by the mixing and hybridization of compositionally discrete magmas. Reaction rims and other characteristic disequilibria textures are common throughout all of the intermediate dioritic samples.

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