PETROGENESIS OF A SERIES OF MAFIC SHEETS WITHIN THE VINALHAVEN PLUTON, VINALHAVEN ISLAND, MAINE

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INTRODUCTION

Round Point, in the southeast of Vinalhaven Island, is located within the layered gabbro-diorite unit of the Vinalhaven Intrusion. This unit consists of numerous mafic replenishments within a silicic magma chamber, which hybridize to varying degrees (Hawkins and Wiebe, this volume). The Round Point field area contains a 300m thick series of mafic sheets along with a mafic feeder dike, as well as a macrorhythmic unit and composite dike.

This study focuses on small-scale variations in petrography and geochemistry within a macroscopically homogeneous sheet within the layered gabbro-diorite unit near Round Point in the southeast of Vinalhaven Island, in order to gain insights into magma chamber processes such as magma replenishment.

FIELD RELATIONS

Round Point (Fig. 1) is located within the gabbro-diorite unit and contains one macrorhythmic units and three mafic sheets. The macrorhythmic unit overlies coarse-grained granite, and has a chilled lower margin, load casts, and coarse-grained granite pipe structures. This unit (named the Round Point unit) is approximately 10m thick and hybridizes from gabbro to diorite upsection. This sheet is then cross-cut by a composite dike of fine-grained granite matrix and mafic pillows trending N60E.

Overlying the Round Point unit is a series (named the "Swamp series") 300m in total thickness of mafic sheets. The lowermost sheet (MS1) exhibits a chilled base and grades from fine-grained to coarse-grained gabbros upsection, with no evidence of hybridization. A fine-grained gabbro dike downsection appears to feed the sheet. The middle sheet (MS2) is medium-grained to coarse-grained gabbro and does not hybridize upsection. The uppermost sheet (MS3) is coarse-grained gabbro and does not exhibit hybridization within the study area. Contact relationships between mafic sheets within the series are ambiguous due to gaps in the exposed section. A simplified stratigraphic column is included in Figure 1.

Samples of coarse-grained granite, gabbros and hybrids, and mafic pillows were taken from the Round Point unit and the overlying composite dike. Samples of the sheets in the Swamp series were taken at the base of the lowermost sheet and upsection approximately every 10m on an up-dip traverse, proceeding laterally along strike when necessary to a location at which an up-dip traverse was possible.

Samples taken from the mafic dike and MS1 are hornblende gabbros. MS2 and MS3 are olivine gabbros. Hornblende is not present in MS2, while MS3 contains a few hornblende crystals rimmed by plagioclase. Plagioclase and olivine crystals in MS2 and MS3 display two distinct populations: small, euhedral crystals and large, resorbed and embayed crystals. The

mafic dike does not contain embayed crystals of plagioclase or olivine, while MS1 contains very few resorbed olivines. Fine-grained samples from the mafic dike and base of the MS1 exhibit radiating clusters of plagioclase crystals. Poikilitic pyroxenes generally contain iron-titanium oxides and acicular apatite crystals less than 0.5mm in length.

of the base of MS1 for approximately 40m to coarse-grained. Plagioclase crystals at this interval do not exhibit radiating textures. Olivines exhibit a bimodal distribution of 0.25-0.5mm diameter euhedral olivines and 1-2mm

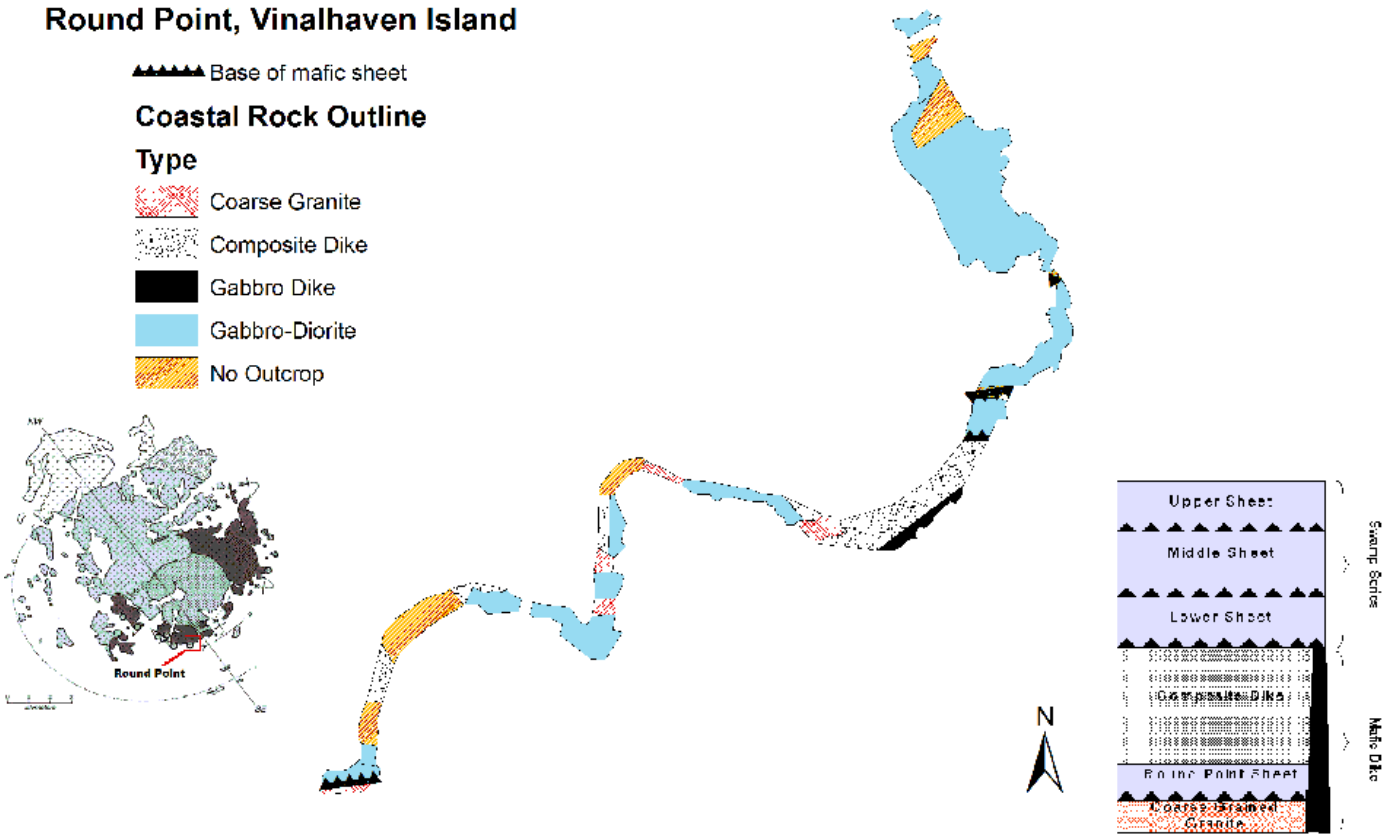

Figure 1. Generalized geologic map and simplified stratigraphic column of Round Point, Vinalhaven Island. Inset map of Vinalhaven Island modified from Wiebe et al., 2004.

PETROGRAPHY

The lowermost sample in the Swamp series, a very fine-grained gabbro, is interpreted as the chilled base MS1, and exhibits clusters of radiating plagioclase crystals and poikilitic clinopyroxenes. Grain size increases upsection

resorbed olivines. Resorbed olivines represent less than 10% of all olivines within samples from this section of the Swamp series.

MS2 and MS3 vary from the lower sheet in the percentage of resorbed olivines. Olivines in these samples also exhibit the bimodal size distribution, but larger (resorbed) olivines are approximately 50% of olivines within each sample. Also within these sheets are a number of plagioclase crystals up to 2cm in length with resorbed cores and thin (~0.2mm) euhedral rims. These samples grade from medium- to coarse-grained olivine gabbros.

MS3 contains hornblende crystals rimmed by plagioclase, as well as pyroxenes rimmed by plagioclase. These plagioclase rims are seen only in this section of the Swamp series, and make up less than 5% of the samples.

GEOCHEMISTRY

Samples from the Round Point area vary from 46 to 74 wt% SiO_2, while samples within the Swamp series range from 46 to 51% SiO_2. Samples excluding the Swamp series exhibit a linear relationship on variation diagrams which is consistent with mixing of mafic and silicic magmas. Using a fine-grained gabbro and fine-grained granite from dikes as endmembers, hybrid rocks vary consistently on variation diagrams from 20-45% silicic endmembers while coarse-grained granites are 75-90% silicic endmember. Figure 2 shows major and minor element concentrations for samples and a line of mixing between the chilled base of the lowermost mafic sheet and a late-stage fine-grained granite dike that can produce all rocks in the series except the two uppermost mafic sheets in the Swamp series.

MS1 and the mafic feeder dike follow the mixing trend of other samples in the study area. The upper two sheets are enriched in magnesium and depleted in silica and iron compared to MS1, as shown in Figure 2. MS2 is distinguished from MS3 because of the small variability and generally linear trend among samples in MS2, while MS3 is highly variable (Fig. 3). Pearce (1983) spider diagrams (Fig. 4) show that the lowermost unit is enriched in REEs compared to the middle and upper units. Large ion lithophile elements (LILE) profiles suggest that slight weathering of samples has likely occurred.

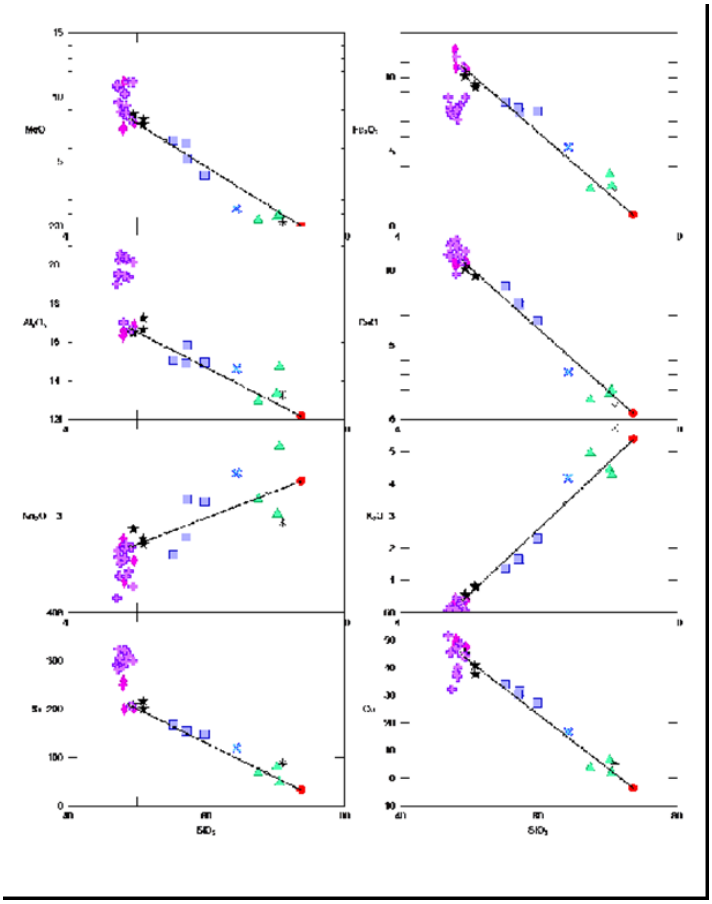

Figure 2. Major and trace element concentrations with mixing line. Plus signs denote samples from the Swamp series and stars are samples from the mafic dike.

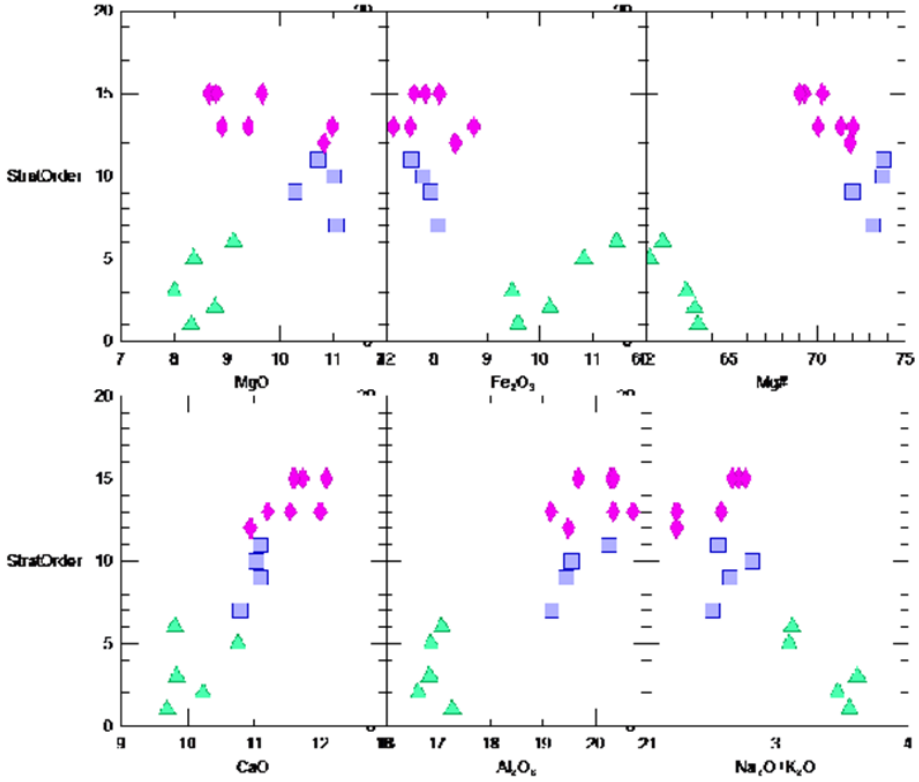

Figure 3. Major elements against stratigraphic order for three units within the Swamp series. . Each proposed mafic sheet is a triangle (mafic dike and MS1), square (MS2), or diamond (MS3). The middle and uppermost sheets in the Swamp series are distinguished based on subtle, yet significant geochemical variations.

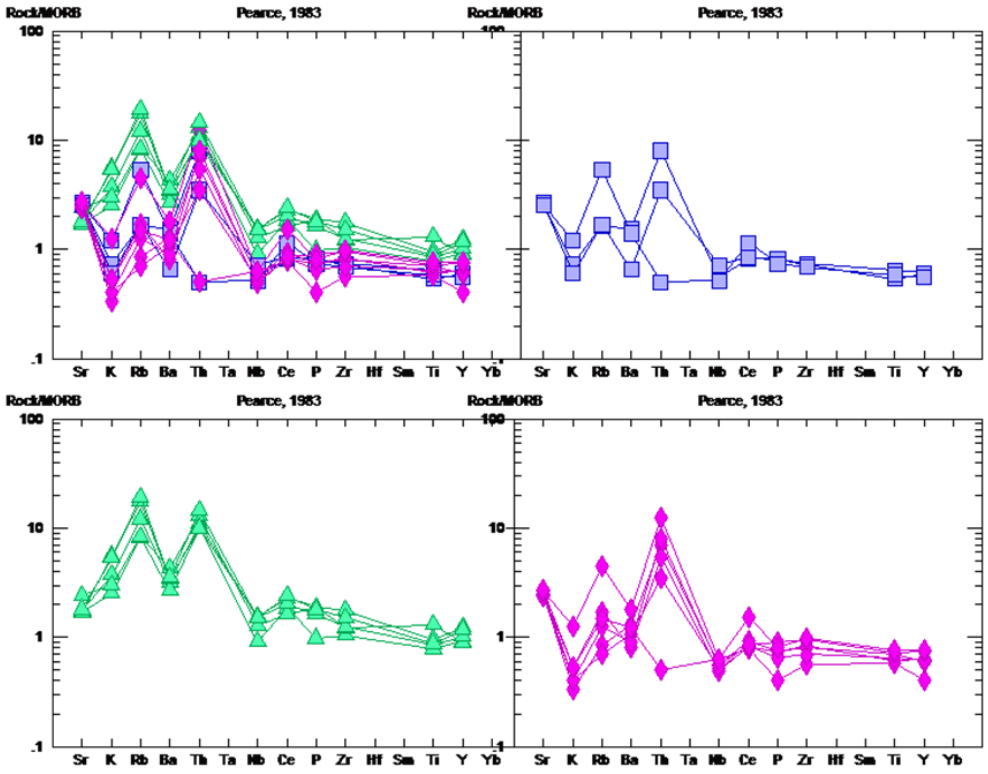

Figure 4. Pearce diagrams of the Swamp series, showing three units. The lowermost unit is enriched in REEs compared to the middle and upper units. LILE profiles are likely the result of weathering of pavement outcroppings.

SCANNING ELECTRON MICROSCOPY

SEM analyses of mineral phases were made using the JEOL JSM-5400LV with an iXRF energy dispersive x-ray spectrometer (EDS) and backscattered electron detector in composition mode at Western Kentucky University. Small, euhedral olivines not exhibiting resorbed textures had Mg/Fe and Mg# nearly identical to those of the whole rock analysis, whereas olivines showing resorbed textures (asterisks) had unstable compositions compared to the whole rock (Fig. 5-top). Spot analyses of plagioclase crystals show normal zoning, with enriched Ca and Al cores to relative enrichment in Na and Si towards the rims (Fig. 5-bottom).

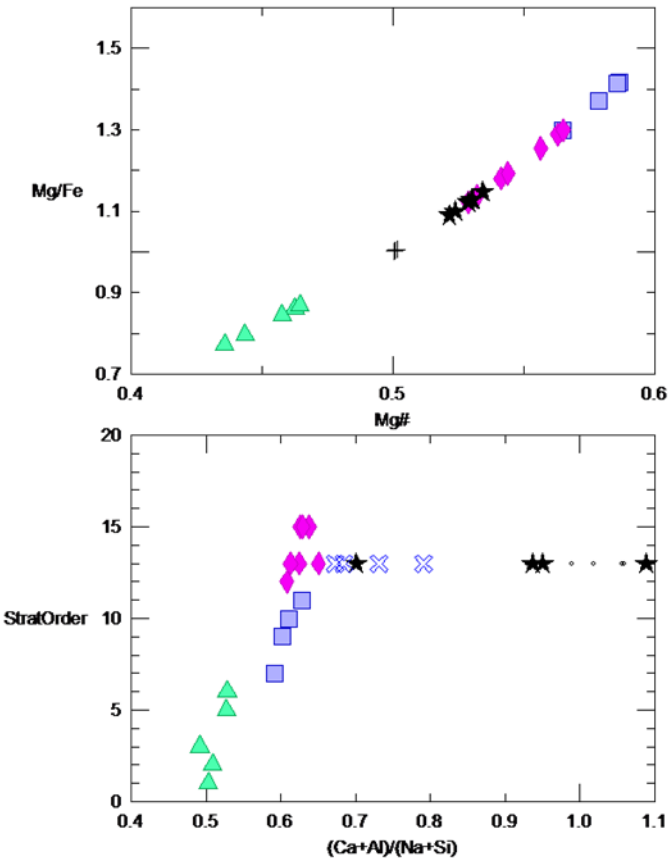

Figure 5. Plot of SEM analyses of olivines (top) and plagioclase (bottom) with whole-rock analyses showing resorbed olivines and plagioclase cores out of equilibrium in the system, while euhedral olivines and plagioclase rims are in equilibrium.

DISCUSSION

The Round Point unit is characterized by the replenishment of mafic magma, which ponded and began to hybridize with the overlying granitic magma. Geochemical analyses indicate that the uppermost exposures of this unit represent mixing of up to 45% of the granitic magma. Load casts and granitic pipes within the macrorhythmic unit indicate that the paleo-up direction is ~N60E. A composite dike is emplaced sub-parallel to the Round Point unit, containing a fine-grained granite to porphyritic granite matrix, mafic pillows, and angular blocks of MS1.

The Swamp series seems relatively homogeneous in the field and in hand sample. Petrography separates this series into three separate units. The lowermost unit (MS1) is distinguished by the lack of resorbed olivines, and represents the lowest 40m of the series. MS2 contains an abundance of resorbed olivines and covers 140m of the series. The MS3 contains resorbed olivines along with crystals such as hornblende and pyroxene rimmed by plagioclase crystals and represents the uppermost 120m of the field area.

Geochemistry supports petrographic evidence of three separate units within the Swamp series. MS1 is similar in composition to the mafic endmembers of the mixing line on variation diagrams, whereas the MS2 and MS3 are enriched in Mg and Al, and depleted in Si and Fe. Pearce (1983) spider diagrams show that the upper two units of the series are more primitive in composition than the lowermost unit, which is relatively enriched in REEs.

Two processes seem to be involved in the petrogenesis of the Swamp series. Mafic magma in the lowermost sheet assimilated a few olivine crystals into the melt during ascent into the magma chamber via the mafic dike at the base of the series. This sheet then ponded

at the base of the magma chamber and began mixing with overlying granitic melts. Mixing took place briefly (incorporating up to 5% of the silicic endmember) before new mafic magma entered the chamber and ponded above the first mafic sheet, separating the first mafic sheet and overlying granitic magmas. The second and third impulses of mafic magma accumulated olivines which then began to be resorbed through a number of possible processes: as olivines phenocrysts which formed first and later became unstable, as xenocrysts which were picked up during magmatic ascent, or disaggregated glomerocrysts representing a portion of an earlier cumulate pile assimilated by the mafic sheets. The lack of significant hybridization indicates a relatively short time span between new impulses of mafic magma in order to segregate each mafic sheet from the silicic magma within the chamber.

FUTURE WORK

Electron microprobe analyses are necessary to understand the nature of zoning in plagioclase crystals and to compare compositions of euhedral versus resorbed olivine populations. Analyses of the olivines will also help distinguish processes involved in accumulating the population of resorbed olivine crystals.

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