MAFIC MICROGRANULAR ENCLAVES IN A COARSE GRAINED GRANITE, VINALHAVEN ISLAND, MAINE: EVIDENCE FOR SILICIC MAGMA CHAMBER EVOLUTION

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INTRODUCTION

The dominant lithologic unit in the Vinalhaven Intrusion, a coarse-grained biotite-hornblende granite, has been shown by qualitative field observations to be texturally heterogenous with occurrences of magmatic enclaves in numerous locations. In order to better understand the processes contributing to enclave formation and in turn provide an important constraint on the processes that operated within the magmatic chambers of the complex, this study characterizes the spatial distribution and geochemical composition of magmatic enclaves in this unit using detailed textural and stratigraphic information along with enclave and granite whole rock geochemistry. This stratigraphic information includes field observations taken at various stratigraphic levels within the coarse-grained granite, paying attention to textural differences between levels, with particular interest in enclave nature and abundance. By combining enclave abundance data with whole rock geochemistry I am able to construct a two stage enclave petrogenesis model involving varying degrees of enclave hybridization and dispersal from source regions.

METHODS

The coarse grained granite (CGG) was examined in fine detail at 51 stations spread across several distinct areas of the granite body: two areas where coarse-grained granite is found within the gabbro-diorite unit near the base of the intrusion, an area that represents a transect which proceeds from the final contact between the gabbro-diorite and granite units towards the interior of the granite body and an area near the roof of the intrusion in which the granite contacts the volcanic country rock. At each locality, the relative abundance, composition, and size of enclaves within the coarse-grained granite were characterized. Local abundance was assessed using measuring tape to cordon off a well-exposed outcrop surface and then systematically counting the number of enclaves within each box while paying attention to enclave size and shape. Box sizes ranged from 3.90 square meters up to 71.37 square meters with a total observed area of 1461.80 square meters.

A total of 26 rock samples were collected from all localities. Granitic samples consisted of one or more CGG samples from each area with additional samples representing either felsic dikes or granitic rocks of interesting textures (porphyry or CGG with a significant matrix component). Enclaves represented the other sampled rock type, however, due to the difficulty of extraction, enclaves were not sampled as systematically as the granites. X-ray fluorescence spectrometry was used to determine major and minor element compositions for 25 samples. It should be noted that this work was conducted with the assistance of Alice Colman (this volume). I shared the same or similar field areas with Alice and several of the samples and enclave abundance counts used in this report come from her field areas.

RESULTS

Enclave Counts

For the purposes of conveying and discussing results, field sites are broken up into a gabbro-diorite area, west coast transect area, and an area near the roof of the intrusion. Mean average enclave counts for each field site are plotted on a map of Vinalhaven (Fig.1). Most noticeable on the map is the appearance of two areas, Smith Point and The Grange, where relatively high enclave abundances occur, with 3.51 and 2.17 enclaves per square meter respectively.

Outcrops of course grained granite that lie within the gabbro-diorite unit show a relatively wide variance in enclave abundance. Arey Neck yields the lowest number of reported enclaves per square meter with 0.20 while Coomb's Neck has an enclave density that is six times that number. Round Neck strikes a balance between these two with 0.94 enclaves per square meter.

Enclave abundance from the base of the CGG and gabbro-diorite contact up to the roof represented by the Dog Point to Leadbetter Narrows transect shows a decrease in enclave abundance as we proceed upstrike with abundances of 1.26 enclaves per square meter at

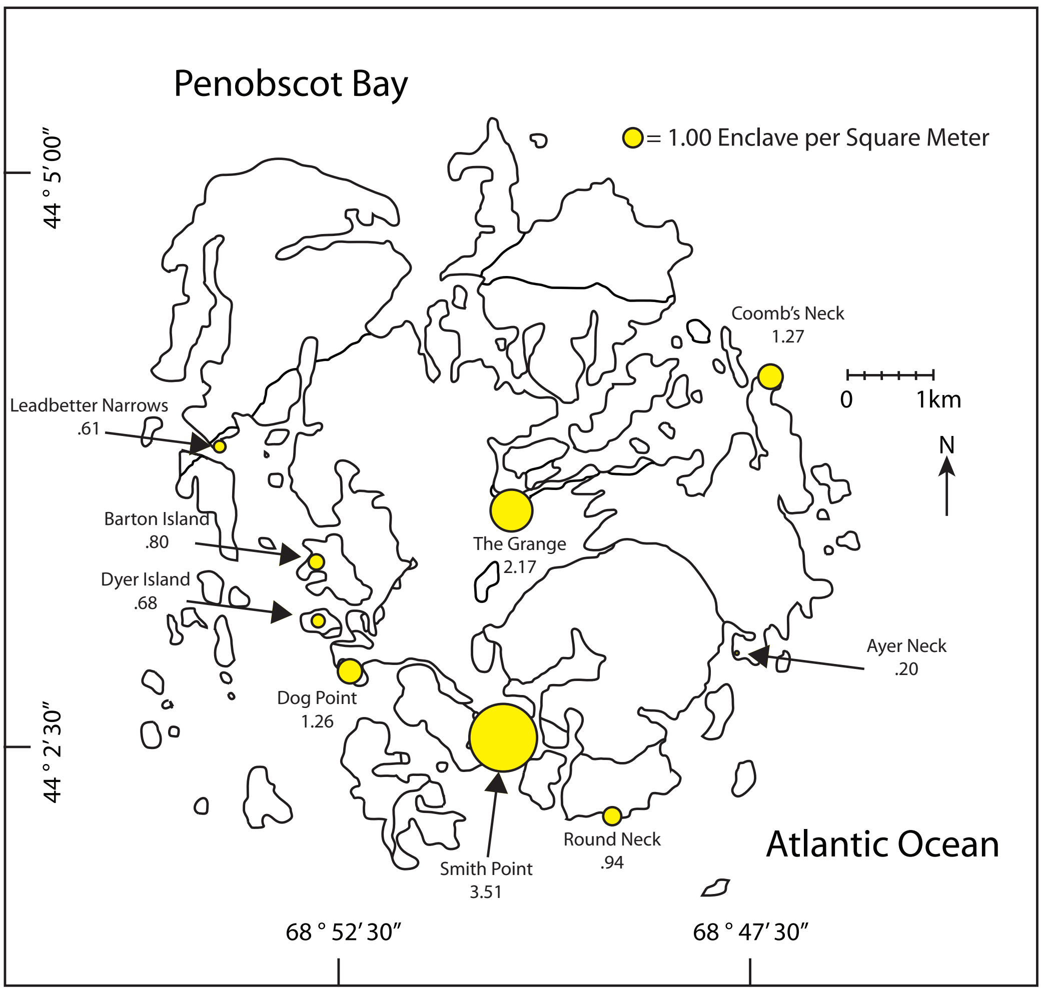
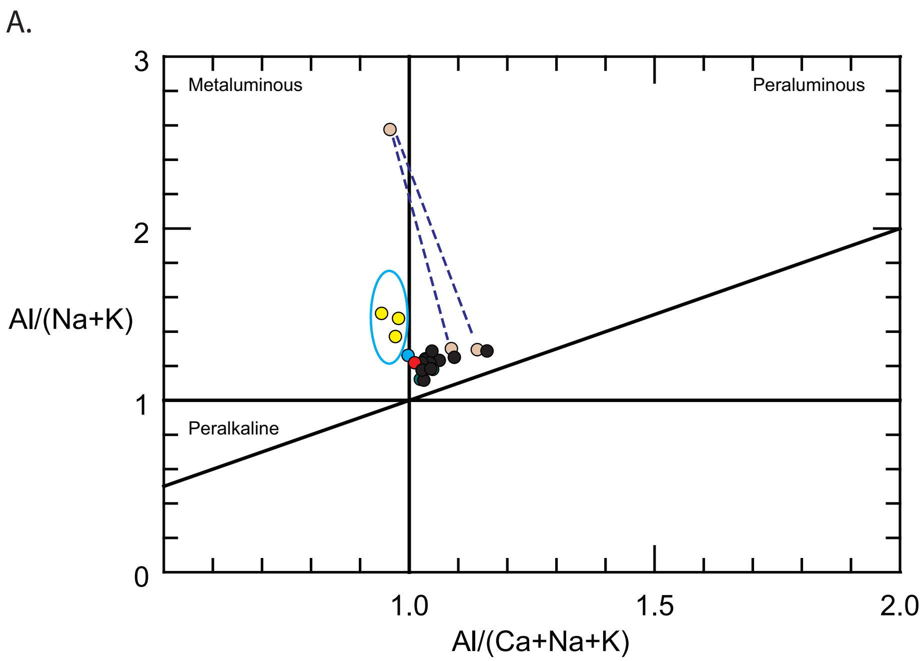


Figure 1. Mean average enclave abundance for locations on Vinalhaven Island. Numbers under place names are reported as enclaves per square meter. Transect area marked by Dog Point north to Leadbetter Narrows shows a overall decrease in enclave abundance. Large pulses are present at Smith Point and The Grange. Round Neck, Ayer Neck, and Coomb's Neck are all areas of course grained granite lying within the gabbro-diorite unit and they demonstrate a wide variance in enclave abundance numbers.

Dog Point dropping to less than half that value at Leadbetter Narrows. The roof of the intrusion represented by the outcrops at Leadbetter Narrows yields a relatively sparse abundance of only .61 enclaves per square meter.

Whole-Rock Geochemistry

Discrimination diagrams (Fig. 2) show that three of the four transect enclaves (WRG6-18A, WRG6-20A, WRG6-31A) group together into the metalumionous and granodiorite regions with one sample (WRG6-31A) bordering between granodiorite, trondhjemite, and tonalite.



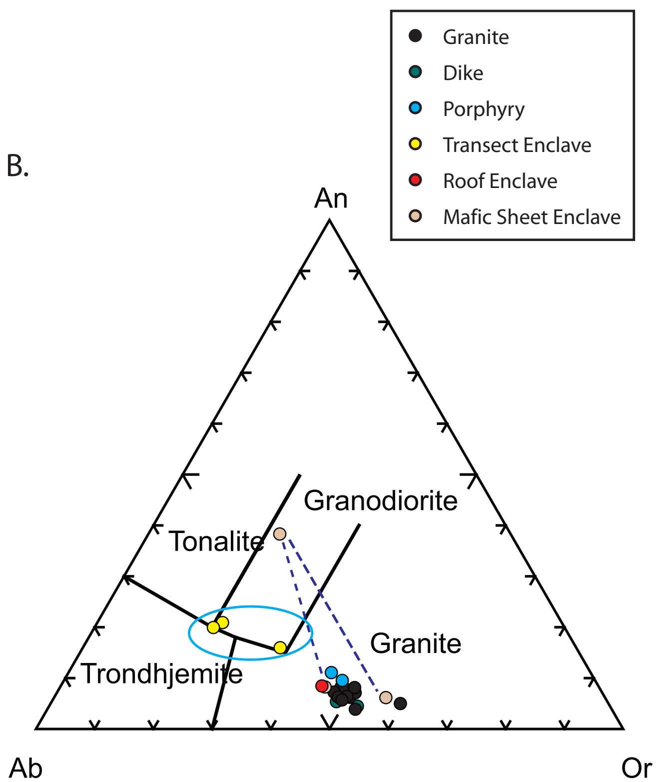


Figure 2. Discrimination diagrams for granitic bodies and enclaves from various locations. A) Al/(Na + K) versus Al/(Ca + Na + K) showing groupings of various samples. Note that granites plot in peraluminous space while transect enclaves, circled on diagram, are classified as metaluminous. Also of interest is the wide chemical discrepancy between mafic sheet enclave samples highlighted by the dashed line. Discrimination fields of Maniar and Piccoli (1989) superimposed. B) Normative albite, anorthite, and orthoclase plot of granitic and enclave samples. All granitic bodies plot solidly in the granite field while transect enclaves, circled on diagram, fall into granodiorite space with two samples bordering on tonalite. Again, a wide chemical variance between the three mafic sheet enclaves is observed as marked by the dashed line. Weight normalized according to Irvine and Baragar (1971) with petrographic fields of Barker (1979) superimposed.

The other transect enclave sample (WRG6-38A) plots with the granitic samples. Likewise, the single roof enclave sample (WRG6-50A) can be classified as a peraluminous granite. WRG6-48D plots high in both metalumionous and granodiorite space while the other mafic sheet enclave samples (WRG6-48B, WRG6-48C) plot together as peraluminous granites with a wide variance from WRG6-48D.

Harker diagrams of all samples for nine major elements display similar results (Fig. 3). Enclave samples WRG6-38A (transect) and WRG6-50A (roof) plot with the granitic bodies. The remaining transect enclave samples group together on most plots and show enrichments in the elements Fe, Mg, Ti, Mn, Na, and Ca and a depletion in K with respect to the granites.

A wide variance in mafic sheet enclaves is observed again in the Harker diagrams. WRG6-48B and WRG-48C are grouped together and separated from WRG6-48D. All three mafic sheet enclaves are enriched in Fe, Mg, and Ti and depleted in Na with respect to the granites. WRG6-48D is enriched in Mn, P, Ca and depleted in K with respect to the granites while the other two mafic sheet samples show trends similar to the granites in Mn, P, and Ca with enrichment in K.

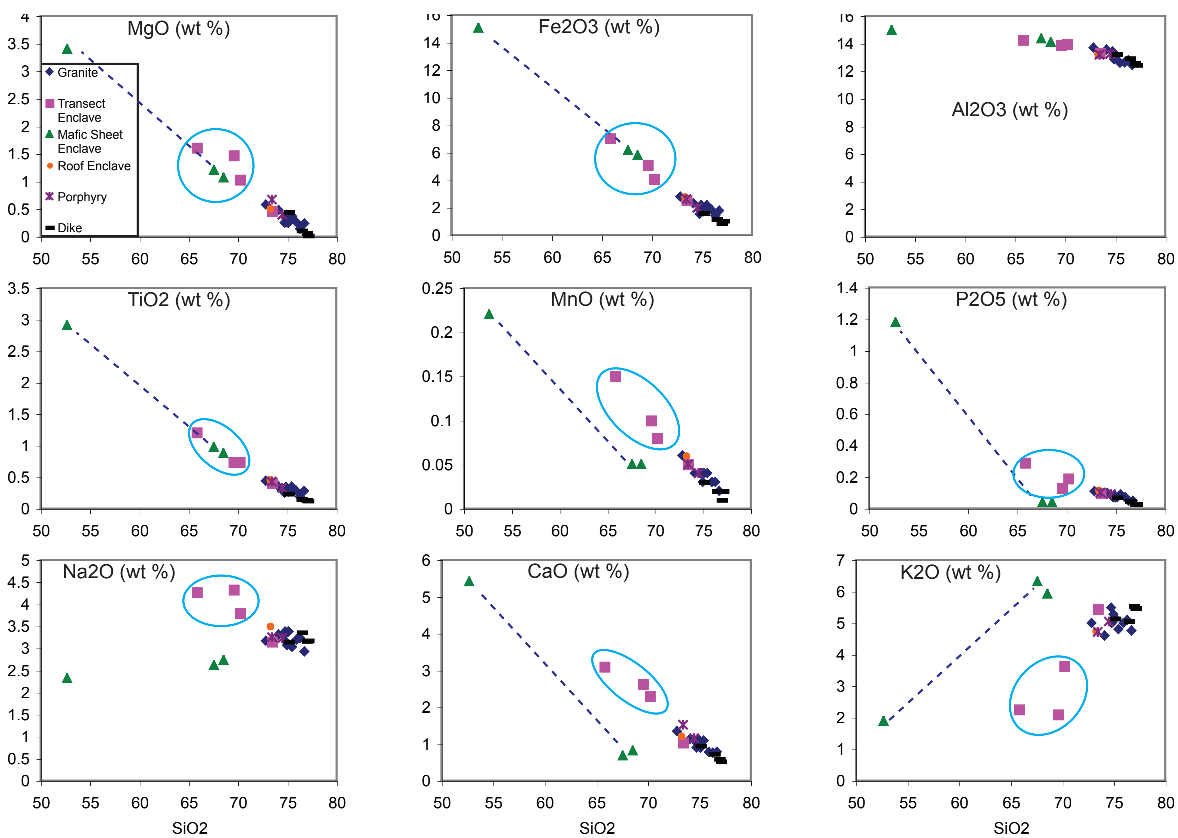


Figure 3. Harker diagrams for nine major elements. Granites, dikes and porphyry group together while enclave samples show a wide variance in percentages for each element. Three out of the four transect enclaves group closely together for almost all major elements as indicated by the circles. Dashed lines demonstrate the wide variance between WRG6-48D and the other mafic sheet enclaves for most elments.

DISCUSSION

I argue that a simplified petrogenesis model is possible when chemical data is examined alongside enclave abundance counts. The following model is summarized in Figure 4. If we accept the process of magma mingling as the model that best explains the presence of enclaves in the Vinalhaven Intrusion (a worthy claim given the chemical plots and observed field relationships), then based upon the discrimination (Fig. 2) and Harker Diagrams (Fig.3), we can assert that the transect enclaves saw relatively moderate to high hybridization and liquid interaction, the single roof enclave saw high hybridization and liquid interaction and the mafic sheet enclaves saw highly variable relative hybridization and liquid interaction ranging from low to high.

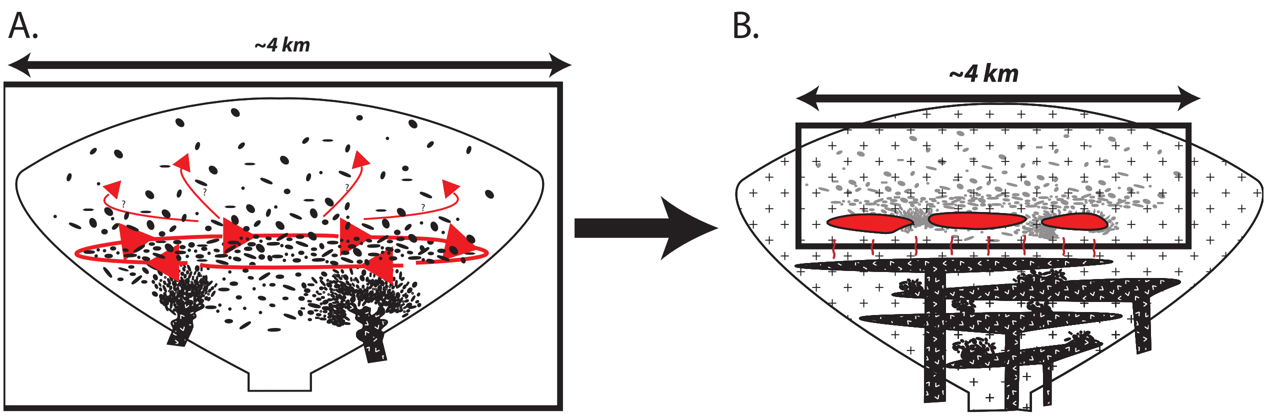


Figure 4. Conceptual model for two stage process of enclave peterogenesis. A. Early stage involves a mostly liquid granite interacting with mafic injections to cause dike fragmentation and enclave hybridization. Convective dispersal creates a homogenous basal layer of enclaves while swarms accumulate near dikes. The process of upward dispersal is unknown. B. Second stage involves a mostly solid granite in which mafic injections pond at the base of the chamber resulting in minimal enclave creation and thermal rejuvenation of the granite leading to porphyry formation. Note the scaling and that the chamber has grown in size since initial stages of enclave formation.

Combining these assertions about degree of hybridization with enclave abundance data, we can imagine enclave formation in the main CGG unit as occurring at a time when the granite was mostly or all liquid. This liquid nature allowed for ample hybridization and magma flow. Since enclave counts near the base of the CGG are relatively homogenous (except for the swarms at Smith Point), it is likely that convection, driven by thermal buoyancy and reduced viscosity and density contrasts between enclave and granite tied to hybridization (Vernon, 1991; Vasek and Kolker, 1999), distributed enclaves near the base of the chamber. Whole-scale turbulent convection was most likely not occurring during this stage of the intrusions history as enclave abundance is not homogenous throughout the CGG unit.

Source material for these enclaves undoubtedly came from the mafic intrusions present on Vinalhaven Island with dike fragmentation being a likely cause for hybridized enclaves (Fernandez and Barbarin, 1991; Tobisch et al., 1997). Enclave swarms at locations such as Smith Point and The Grange are probably the local result of these dike fragmentations, although no such dikes were observed at either location. It is important to note that many of the mafic intrusions on Vinalhaven Island are not fragmented or dispersed and this discrepancy speaks to a petrologic history more diverse than the one just put forth.

Presently observed mafic injections ponded on the base of the chamber giving rise to the varying textural structures observed in the gabbro-diorite unit (Wiebe et al., 2001). This ponding occurred at a time after the initial enclave formation discussed above and when the granite was more crystallized and therefore did not permit significant hybridization or convection of enclaves. It is likely that the mafic sheet enclaves owe much of their petrologic history to these events. Primitive enclaves in the mafic sheets (i.e. WRG6-48D) formed locally and experienced little liquid interaction and hybridization as evidenced by relatively basic mineral and chemical compositions. The more evolved enclaves are remnants of earlier enclave formation which experienced subsequent and repeated thermal rejuvenation. This argument is strengthened by the fact that WRG6-48B and WRG6-48C were emplaced within fine grained, apilitic, granite bodies lying in close proximity to porphyritic granitoids. This complexity in enclave formation history and lack of homogenous dispersal (a process facilitated by convection) explains the varying enclave numbers within the mafic sheets.

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