The geochemistry and tectonic setting of the Vinalhaven Diabase, Coastal Maine Magmatic Province

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INTRODUCTION

The Vinalhaven "Diabase" (VHD) is located at the northwest corner of Vinalhaven Island in Penobscot Bay, ME. It is a massive mafic to intermediate volcanic to subvolcanic unit likely of Siluro-Devonian age, with associated breccias and vesicular rocks. This unit has been described in other studies (Smith, 1907; O. Gates, in prep.) but no detailed petrographic and geochemical data have previously been reported. The field relationships, petrography, and geochemistry of this study will be used to determine what, if any, relations the VHD has with the gabbro of the Vinalhaven Pluton located to the south (Mitchell and Rhodes, 1989) or the numerous mafic dikes (Cheversia, this volume) found throughout Vinalhaven. These data will also be used to compare Vinalhaven to the volcanic-plutonic relationships of the Silurian Cranberry Island-Cadillac Mountain Complex at Mt. Desert Island, farther east along the Maine coast (Seaman et al., 1995.)

FIELD INVESTIGATIONS

On the basis of previous mapping and field observations, (O. Gates, in prep.; Dow, 1965) samples of the VHD were collected in 18 localities in the northwest corner of Vinalhaven Island (see fig. 2 in Newton, this volume.) These were taken to provide as much regional coverage as possible. Samples of the massive VHD, breccias, vesicular rocks and sediments in contact with the VHD were collected to characterize the various aspects of the unit and attempt to determine its intrusive and/or extrusive nature, where field criteria were not definitive.

The VHD is remarkably homogenous in outcrop, entirely dark grey, fine grained, and containing <1 cm quartz "eyes" distributed throughout the unit at 5-10 cm intervals. In all locations (except the point just north of Leadbetter Narrows) the VHD is associated with a breccia of volcanic and sedimentary clasts. At two locations (Brown's Head and Hopkins Point; see fig. 2 in Newton, this volume) the VHD is associated with a vesicular flow rock. Though the contact between the VHD and the Silurian Seal Cove formation is exposed in a number of sites, no evidence for contact metamorphism of the mudstones of the Seal Cove formation could be found and the nature of the contact remains enigmatic.

PETROGRAPHIC FEATURES

The VHD is predominately aphanitic but is characterized by <1 cm quartz "eyes" (xenocrysts) with prominent rims, and by spongy cellular plagioclase. The groundmass consists of fine-grained plagioclase, and to a smaller extent, clinopyroxene. The quartz "eyes" usually show pervasive cracking, while the rims contain pyroxene and amphiboles, opaques, epidote, muscovite, and chlorite. These rims vary greatly in size and in mineral combinations. The vesicular rocks are more porphyritic, characterized by large, more defined plagiolcase laths in the groundmass, along with a larger portion of clinopyroxene. Round to elongate vesicles are locally filled with quartz, or, to a lesser extent, calcite.

GEOCHEMICAL ANALYSES

Eighteen samples were selected for geochemical analysis on the basis of relative freshness of the sample and to provide geographic coverage. Seven samples were sent to Oregon State University for Instrumental Neutron Activation Analysis (INAA) to obtain trace element data, but the results have not yet been received. Major and minor elements, along with additional trace elements, were analyzed by X-ray fluorescence (XRF) at the University of Massachusetts at Amherst. Additional chemical data for mafic dikes were obtained from Cheversia (this volume.)

SiO_2 content ranges from 52.6% to 61.7% in both massive and vesicular samples. While the quartz xenocrysts could have added modestly to the SiO_2 content, their small size and relative sparseness would not account for the high SiO_2 values reported. Total alkali values range from about 4.0% to 7.1% for both types of samples.

To minimize problems of contamination and/or alteration, trace elements were used whenever possible to define and compare lithologies of the VHD. According to the Zr/TiO_2 vs. Nb/Y classification of Winchester and Floyd (1977), all samples plot as either andesite basalt or andesite (Fig. 1). When plotted on a Pearce-type spider diagram (Fig. 2), the samples sow very tight clustering, exemplifying the homogenous nature of the VHD and related vesicular mafic rocks. Fig. 2 also shows the relatively enriched nature of the VHD as compared to MORB values.

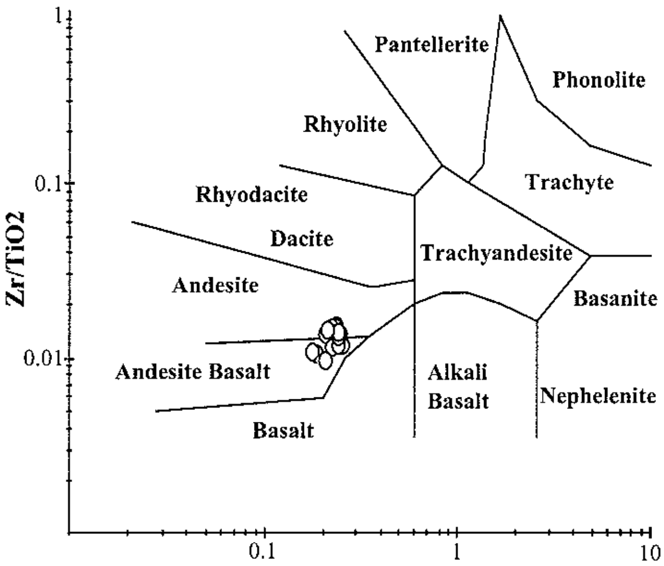

Fig. 1 Winchester and Floyd (1977) classification diagram of the VHD.

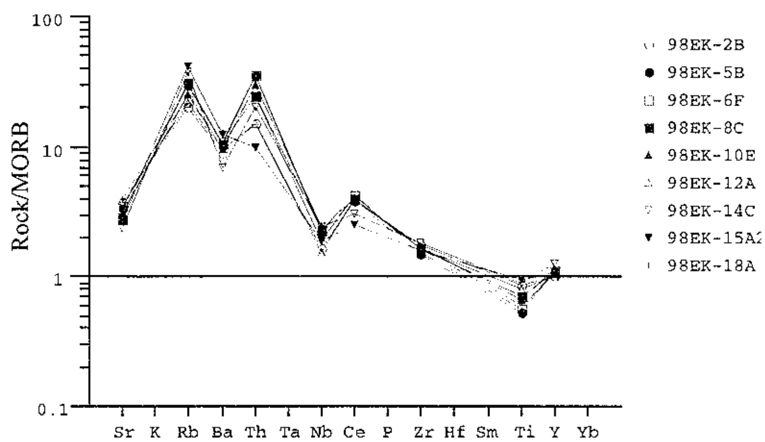

Fig. 2 MORB-normalized trace element abundances in the VHD.

TECTONIC SETTING

The completion of INAA work will allow the most reliable tectonic discriminant diagrams (using the most immobile elements) to be applied to the VHD. In the meantime, diagrams using other minor and trace elements have been employed to provide preliminary results which are somewhat contradictory. On Ti/100 vs. Zr vs. Sr/2 diagrams (Pearce and Cann, 1973), all the samples plot within the calc-alkaline basalt (CAB) field, which is usually associated with arc-volcanism (Fig. 3.) Using minor elements, on a TiO_2 vs. MnO x 10 vs. P_2O_5 x 10 diagram (after Mullen, 1983), all but three samples plot within the Island Arc Thoeliite field (IAT) (Fig. 4). By comparison, mafic dikes found on Vinalhaven and studied by Cheversia (this volume) generally have a more dispersed distribution on the $TiO_2/100$ vs. Zr vs. Sr/2 diagram, and plot within the ocean floor basalt (OFB) field (except for four samples which plot within the CAB field.)

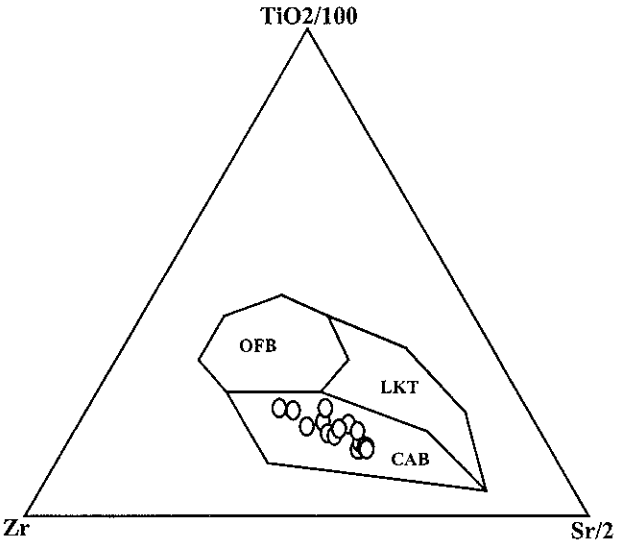

Fig. 3 Pearce and Cann (1973) tectonic discriminant diagram for the VHD

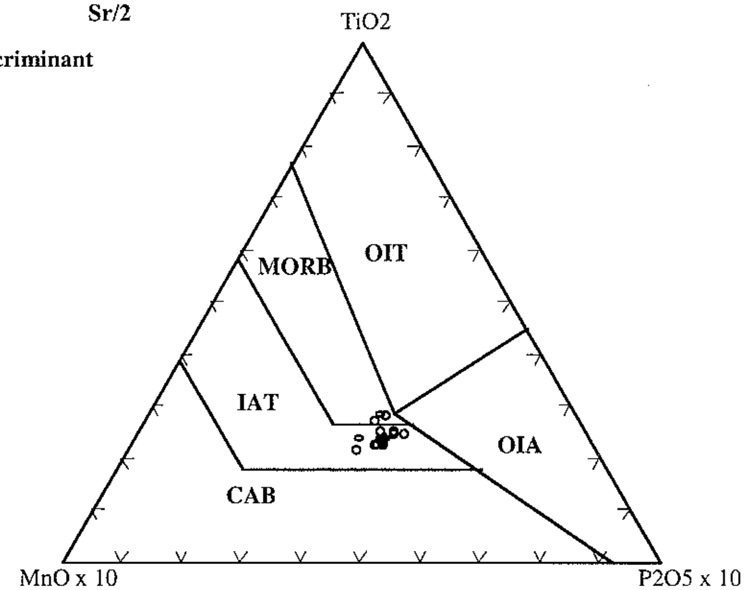

Fig. 4 Mullen (1983) tectonic discriminant diagram of the VHD using minor elements.

DISCUSSION AND CONCLUSIONS

The Vinalhaven "Diabase" shows characteristics that are inconsistent with its name. Petrographic analysis shows little to none of the ophitic texture of a true diabase. Geochemical data show that the VHD plots as an andesite or basaltic andesite. The tight clustering of both the vesicular and massive VHD shows that these are likely from the same source magma. Though no conclusive evidence could be found in field relationships for contact metamorphism, it appears that the VHD was both an extrusive and intrusive unit.

Comparison with data in Mitchell and Rhodes (1989) indicates that the VHD is not chemically the same as the gabbro of the Vinalhaven Pluton to the south. The presence of the small quartz xenocrysts in the VHD indicates that there must have been some hybridization of the original basaltic magma with a more felsic magma before the emplacement of the unit. Extensive co-mingling of mafic and felsic magmas characterize especially the lower part of the Vinalhaven granite pluton at the south end of the island.

The intermediate nature of the VHD would also lessen the possibility that this unit and the felsic volcanics of Vinalhaven (Newton, this volume) represent an example of back-arc bimodal volcanism, as found at the Cranberry Island-Cadillac Mt. Complex (Seaman, et al., 1995.) Discriminant diagrams show that the VHD may instead be the result of island arc volcanism, produced during the closing of the Iapetus Ocean. This is consistent with the regional understanding of coastal Maine (Rankin, 1994; Stewart, et al., 1995), especially the Coastal Maine Magmatic Province itself.

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