The Vinalhaven Rhyolite and Perry Creek Formations: felsic volcanic and volcaniclastic rocks of Vinalhaven Island, Maine

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INTRODUCTION

The northern section of Vinalhaven Island in Penobscot Bay, Maine (Fig. 1), is dominated by a volcanic complex of probable Silurian age consisting of a rhyolitic dome and associated pyroclastic rocks which are underlain and flanked by various breccia units and by one or more mafic to intermediate sills and flows of the Vinalhaven Diabase (Klemetti, this volume). The felsic units consist of the Vinalhaven Rhyolite (Smith, 1907) and the Perry Creek Formation (Gates, in preparation).

This project incorporates an in-depth description and stratigraphic study of the Perry Creek Formation, a unit which has not previously been discussed in detail, as well as providing new geochemical analyses for units of the Vinalhaven Rhyolite, for which no such data have previously been published. These analyses allow for better constraints on tectonic setting and for comparison with the granitic pluton in the southern portion of the island. The field and lab work conducted for this project may also serve to give a better understanding of the regional tectonic picture by complementing similar studies, such as that of the Cranberry Island Volcanic Series in and near Acadia National Park (Seaman et al., 1995).

FIELD INVESTIGATION

Perry Creek Formation. A detailed measured section of roughly 20 meters within the Perry Creek Formation was completed at the well-exposed southern tip of Brown's Head (Fig. 2). Both the upper and lower contacts of the Perry Creek were surveyed in less detail (approximate thicknesses of units and broader descriptions) at several other localities for comparison of the unit over a wider geographic range. These locations are at Hopkins Point, the entrance to Perry Cove, both the southeastern and southwestern coast of Crockett Point, the northwest side of Crockett Point (up-section from the Brown's Head measured section), and the outer islands south of Brown's Head (Fig. 2).

Field investigation of the lower layers of the Perry Creek Formation (Site 3) west of Hopkins Point also revealed samples of the trace fossil *Chondrites*. These presumed feeding burrows were found in a matrix of very fine-grained (3.5ϕ) maroon siltstone. They were filled with a different sediment that was reactive to a weak acid solution, indicating an interval of carbonate deposition possibly within the early stages of explosive volcanism. This unit resembles the lower exposures

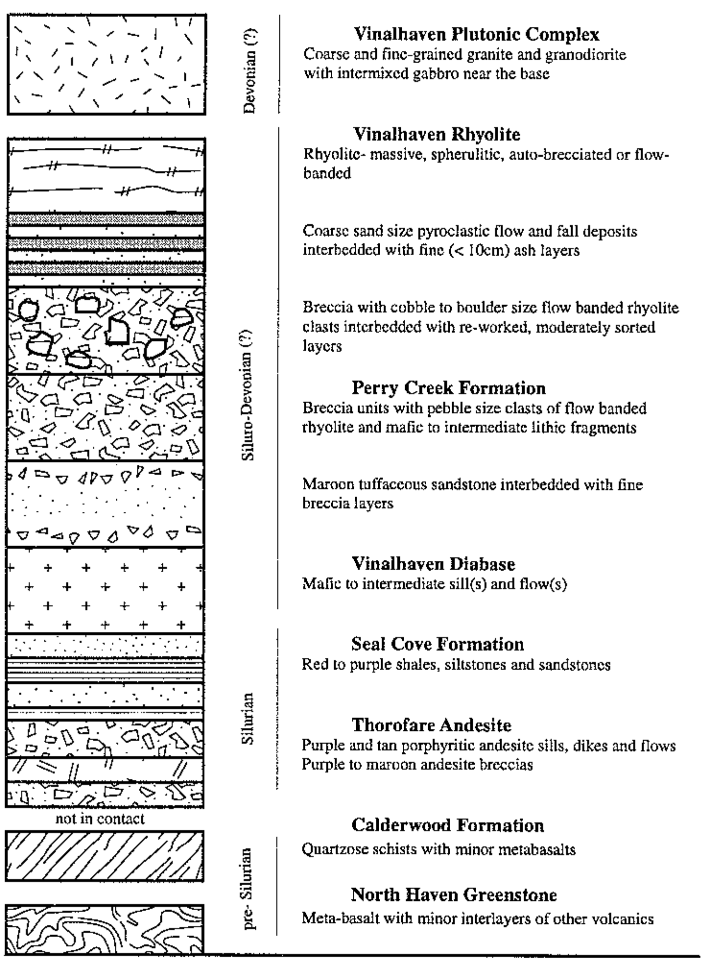

Figure 1. Schematic stratigraphic column for North Haven and Vinalhaven (pers. comm. Olcott Gates, 1998; Dow, 1965)

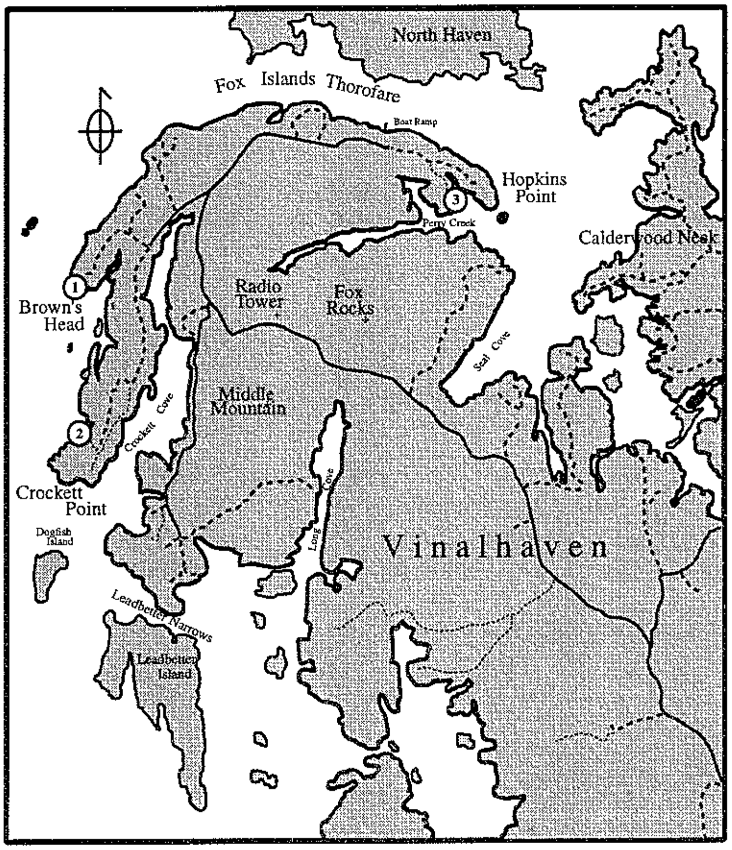

Figure 2. Study site locations of northwestern Vinalhaven.

of the Perry Creek Formation exposed on Brown's Head, but also conforms to the description of the Seal Cove Formation (Gates, in preparation). An erosional unconformity of unknown duration exists either between the Seal Cove and the Perry Creek or as an interval in the Perry Creek Formation.

The upper units of the Perry Creek Formation are breccia layers with pebble-sized clasts of flow-banded rhyolite and sparse lithic fragments of mafic to intermediate composition. Layers show variation in thickness from several centimeters to as much as 4.7 meters; they are variably matrix- or clast-supported and show evidence of mild to moderate reworking. Felsic lithic fragments become increasingly more dominant up-section. The boundary between the Perry Creek and the Vinalhaven Rhyolite consists of a thick breccia layer containing cobble to boulder sized fragments of flow banded rhyolite.

Vinalhaven Rhyolite. The Vinalhaven Rhyolite was examined and sampled at several coastal exposures as well as inland outcrops near Fox Rocks, Middle Mountain and the Radio Tower. The lithology and type of devitrification fabric (if present) were noted at all these sites. The exposures on the western coast of Crockett Point show some of the best-developed devitrification textures. Textures ranged from laminar flow in banded rhyolite to a sperulitic texture with individual spherulites ranging in size from 0.5cm to ~10cm in diameter. A progressive sequence from flow-banded to spherulitic to auto-brecciated rhyolite is seen down-section from the large outcrop interpreted as a cross section through an exogenous dome at Site 2. Both the Brown's Head rocks and those on the west side of Crockett Point show incredibly well preserved layers of airfall deposits. Medium bedded layers of ash (some containing accretionary lapilli) and breccia form a sequence roughly 10m in thickness. Thinly bedded (1-2 cm) layers of ash and tuff form a package roughly 15m in total thickness. The inland exposures of Vinalhaven Rhyolite are massive to spherulitic rhyolite and are occasionally tuffaceous, with several welded tuff horizons.

GEOCHEMICAL ANALYSIS

Nineteen samples were selected for geochemical analysis based on lithology, freshness of sample and geographic coverage across the northern portion of the island. Eight samples, including both ash and massive rhyolite, were sent to Oregon State University for Instrumental Neutron Activation Analysis (INAA) for selected trace elements. All nineteen samples, which included samples of flow banded rhyolite, welded tuffs, spherulitic rhyolite, ash deposits and a felsic dike on Crockett Point, were analyzed at the University of Massachusetts at Amherst for major, minor and trace elements by X-ray fluorescence (XRF). Data for the Vinalhaven Granites are from Mitchell and Rhodes (1989).

Figure 3 shows that most of the samples lie within the rhyolite field, although all three ash samples and one welded tuff as well as both the medium and fine-grained Vinalhaven granites plot as rhyodacites by the Winchester and Floyd (1977) method (Fig. 3). Despite a wide range of lithologies and sampling over an extensive area, all samples plot within a fairly narrow range of values. Although not depicted in these diagrams, the sample from the felsic dike is the one geochemical anomaly within the sample set and is likely not contemporaneous with the bulk of volcanism seen here.

Because of the age of these rocks, their weak metamorphism, and the potential for weathering and alteration, trace element data were used instead of the more standard total alkalis vs. silica diagram (Le Bas, 1983) to compare the volcanic samples with one another and with the granites to the south. MORB-normalized spider diagrams of the rhyolites

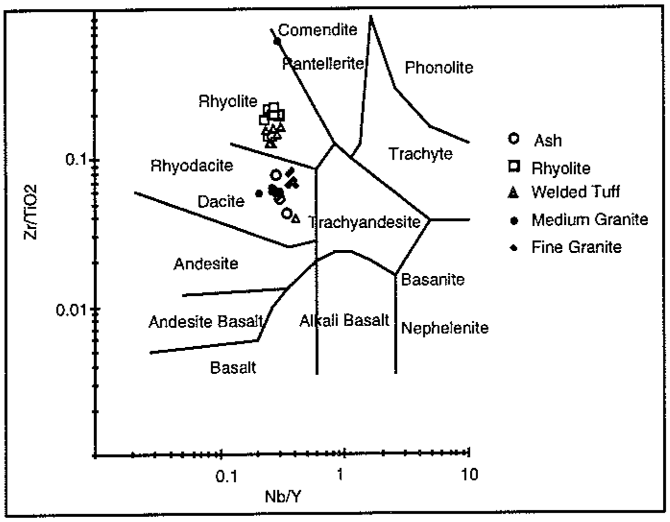

Fig. 3 Classification diagram for Vinalhaven felsic volcanic rocks and granites from Winchester and Floyd (1984).

and granites (Fig. 4 and 5) show similar patterns, with those of the granites most closely resembling the ash layers of the volcanic units. Both groups of rocks show relative enrichment in large ion lithophile elements (LILEs) and moderately high concentrations of high field strength elements (HFSE). The primary difference in these signatures is the enhanced Ba trough in the granite samples, although both sets of rocks show a reasonably tight and correlative data set. A chondrite-normalized rare-earth element (REE) plot (not shown) also shows a tight clustering for most of the felsic samples, with modest fractionation between light and heavy REEs (from approximately 100 to 30x chondrite) and a distinct negative europium anomaly.

TECTONIC SETTING

The tectonic discriminant diagram after Pearce (1984) in Figure 6 shows that both the Vinalhaven Rhyolite and the medium and fine-grained granites in the southern portion of the island plot primarily as "within-plate," though several of the granite samples cross the boundary into the "volcanic arc" field. The straddling of data points across that particular tectonic boundary is consistent with similar plots for the Silurian granitic rocks at Mt. Desert Island, further east along the Maine coast (Wiebe et al., 1997).

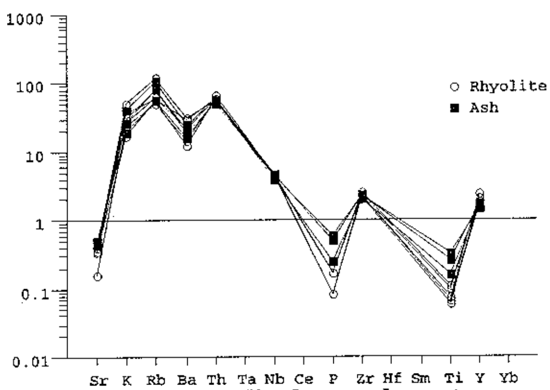

Fig. 4 MORB-normalized trace element abundances in Vinalhaven Rhyolite. Normalizing values are from Pearce (1983).

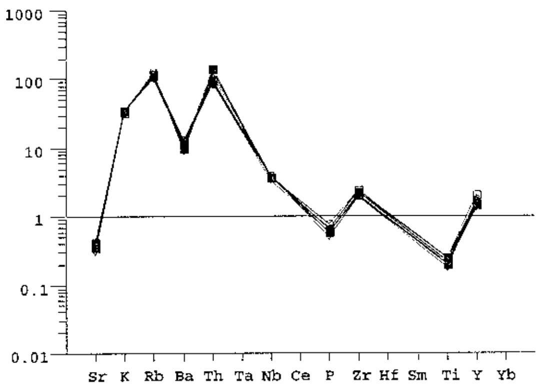

Fig. 5. MORB-normalized trace element abundances in medium-grained Vinalhaven Granite. Normalizing values are from Pearce (1983).

DISCUSSION AND CONCLUSIONS

The stratigraphic spacing between successive ash, welded tuff, and flow horizons indicates that several pulses of explosive volcanism produced the Vinalhaven Rhyolite and the volcaniclastic rocks of the Perry Creek Formation. Geochemical data such as the clumping of the ash and granite samples apart from the effusive rhyolites in Figure 3 exclude the use of traditional magma chamber models for explaining a relationship between these units. The ash units sampled are stratigraphically below the rhyolite; if a genetic relationship between the volcanics and the granites exists, we would expect that these early vent-clearing deposits should yield higher silica values than those of a related pluton of the same magmatic origin.

The trace fossil *Chondrites* and the emplacement of small carbonate clasts up-section from the base of the Perry Creek are evidence for a disconformity. If the fossiliferous rocks are basal Perry Creek this implies a period of

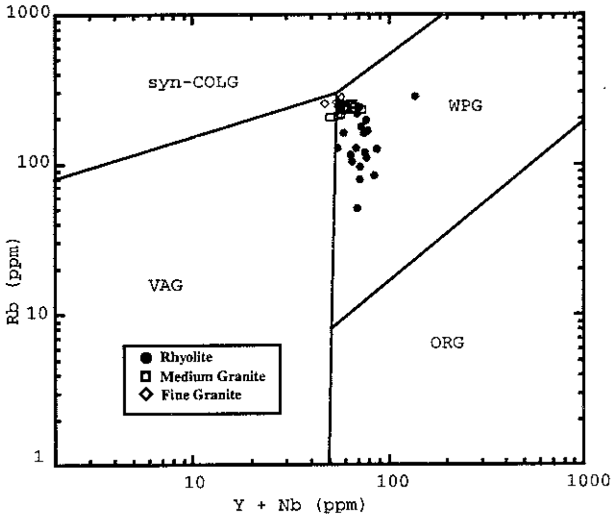

Fig. 6. Discrimination diagram for Vinalhaven rhyolites and granites after Pearce et al. 1984.

quiescence of volcanism extensive enough for carbonate deposition. It is also possible that the fossiliferous rocks discovered at Site 3, currently mapped as part of the "Perry Creek Formation" (Gates, in preparation), are actually a portion of the Seal Cove Formation. This would imply that the Seal Cove and the Perry Creek are in stratigraphic contact here and that there was a time gap between the mafic-intermediate volcanism of the Vinalhaven Diabase and the onset of the felsic phase. It is as yet undetermined whether the rhyolites and the Vinalhaven Diabase (see Klemetti, this volume) are roughly contemporaneous.

Tectonic discriminant diagrams of the felsic rocks of northern Vinalhaven and those further east along the coast at Mt. Desert Island and the Cranberry Islands (Wiebe, et al., 1997) show similar patterns, as portrayed in Figure 6. This borderline value skewed toward the "within-plate" field may indicate that the series of volcanic arcs composing the Coastal Volcanic Belt had already been amalgamated by the time of felsic volcanism; perhaps a back-arc environment had developed at this stage of the closure of the Iapetus Ocean.

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