Igneous and Metamorphic Geology of Vinalhaven Island, Maine

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INTRODUCTION

The coastal plutonic rocks of Maine were originally named and described by Chapman (1962, 1968) as the Bays-of-Maine igneous complex. He recognized the bimodal character of the complex, the widespread evidence for mixing between highly contrasted magmas, and described the mafic plutons as large, sheet-like masses with overlying granitic material that collected beneath a country rock roof. Some of these mafic bodies are well layered and fractionated. Granitic bodies occur both as sheet-like masses and as subequant plutons with steep contacts. These plutonic rocks intrude a wide range of metasedimentary and metavolcanic rocks that belong to different fault-bounded, northeast-trending terranes with different stratigraphies and structural and metamorphic histories (Williams and Hatcher, 1982). The field relations of these plutons suggest that they post-date the main assembly of these lithotectonic terranes (Ludman, 1986). Hogan and Sinha (1989) emphasized the bimodal character of these plutons and suggested that at least some of the magmatism was related to rifting within a region of transtension in a transcurrent fault system.

This project examined the geology of Vinalhaven Island (Gates, in press) (Fig. 1). The igneous rocks on Vinalhaven belong to the Coastal Maine Magmatic Province (Hogan and Sinha, 1989), and represent the roots of a Silurian (?) bimodal volcanic system that apparently developed in an extensional tectonic setting, possibly in a back-arc environment. Two previous Keck projects in Maine have studied similar systems along the Maine coast (Cadillac Mountain and Gouldsboro complexes) and led to the publication of several papers (Wiebe et al., 1997a, 1997b; Wiebe and Adams, 1997). The Vinalhaven plutonic complex appears to be perhaps the best exposed of these bimodal intrusions. The coastal outcrops are superb and show complex commingling and mixing relations between gabbroic, dioritic and granitic rocks near the base of the intrusion. Huge inclusions of metamorphosed country rock also occur near the base the pluton. Two main varieties of granite, both with mafic enclaves, are widely exposed and were easily sampled in coastal sections, vast quarries, and glaciated exposures inland. The highest levels of the intrusion cut into fresh, weakly deformed basaltic and rhyolitic volcanics that may be cogenetic with the plutonic rocks.

The northwestern part of Vinalhaven (Fig. 1) is underlain by a remarkably well preserved sequence of Siluro-Devonian(?) volcanic, subvolcanic, and volcaniclastic rocks ranging in composition from basalt to rhyolite. The entire sequence has been gently folded into a basin-like structure, but regional metamorphic and other deformational effects are minimal so that primary structures and textures are still obvious.

STUDENT PROJECTS

The first few days were spent in getting an overview of the island geology and in giving the students an opportunity to see the variety of problems that were available. The resulting projects fall into three broad groups: problems that focus either on plutonic, volcanic or metamophic rocks. Six students took up projects that addressed significant problems in the plutonic rocks.

Four of these (Holli Frey, Megan Mandernach, Michael Rhodes, and Blair Schoene) focused on different coastal sections which displayed complex interactions between resident granitic magma and episodic replenishments of basaltic magma. These projects form a coherent group that covers

nearly the entire base of the chamber. Several exciting relationships were discovered. (1) The granitic, hybrid and mafic rocks at the base of the chamber are cumulates with a stratigraphic record not unlike sedimentary rocks. Depositional map units can be traced long distances and the sequence of units records specific events that occurred in the magma chamber (e.g., replenishment, fractional crystallization, mixing). (2) Unlike other Maine plutons, substantial thicknesses of mixed hybrid rocks occur and must have been generated by processes acting within the chamber. (3) Several spectacular examples of huge concentrations of densely packed mafic pillows occur at many points in the basal rocks. These closely resemble "pillow mounds" that are often produced when basaltic magma has erupted on the ocean floor.

Mary Beth Cheversia studied dikes that occur throughout the island. They have a wide compositional range, variable attitudes and occur in all units. This study will provide important constraints on the nature of magmatic liquids that were injected into the Vinalhaven crust at different times. These dikes should provide both insights into the tectonic setting as well as possible links between the various plutonic and volcanic units on the island.

Carrie Bruno studied the mafic, intermediate and felsic inclusions (enclaves) which occur in both varieties of the Vinalhaven granite. These enclaves appear to represent quenched samples of hybrid magmas that formed within the magma chamber. Understanding the petrography and chemistry of these enclaves will provide important insights into the processes of mixing within the chamber. We also believe that their compositions may be equivalent to the magmas which produced the layers of hybrid cumulates at the base of the granite.

Jennifer Newton and Erik Klemetti concentrated on the Vinalhaven volcanic rocks located along the northwestern margin (roof?) of the Vinalhaven granite. These volcanic rocks exhibit unusually well preserved structures; they appear to be bimodal in composition with substantial areas of rhyolite and a major unit of basaltic (?) composition. Jennifer Newton focused on the felsic volcanic rocks which contain excellent examples of pyroclastic flow and fall deposits, debris flows, lahars and volcanic breccias as well as a major rhyolite dome. This appears to be an exceptional opportunity to study volcanic processes in Silurian rocks. Geochemical study is of further interest because these rhyolitic rocks might be the extrusive products of the Vinalhaven granitic magma chamber. Erik Klemetti studied a unit mapped as the Vinalhaven Diabase, finding that it's field expression varied from vesicular flows and breccias to massive sill-like exposures . He sampled the unit around its crudely elliptical outcrop on the island and also took samples vertically through sections that were well enough exposed.

All of these plutonic and volcanic studies involved careful petrographic and geochemical work (XRF for major and trace elements and INAA for REEs).

Brian Porter worked on the geology of the little-known Calderwood Formation and some contact metamophosed blocks of country rock within the Vinalhaven granite. The Calderwood Formation is a well stratified series of multiply deformed metavolcanic and metasedimentary rocks affected by regional greenschist facies metamorphism. His is a broad study, involving stratigraphy, structure and metamorphism. A major goal is to be able to correlate this unit with better known units in the area. This should be an important contribution to the regional geology of coastal Maine.

Martha Wilson focused her project on extensive and large blocks of country rock that occur in parts of the cumulate plutonic rocks at the base of the granitic body. These appear to have been stoped from the chamber roof and settled to the floor of the chamber. They include rocks which resemble the Calderwood Formation and younger, less deformed volcanic and sedimentary units on the northern margin of the Vinalhaven granite. These blocks have been strongly affected by contact metamorphism and still preserve delicate sedimentary and metamorphic structures that formed prior to the metamorphism. Some of the metasedimentary rocks contain cordierite, andalusite and possibly hypersthene. A study of these rocks should provide valuable insights into the thermal history of the pluton. A major goal to try to correlate the blocks with specific country rock units.

CONCLUSIONS

The ten projects described above should provide a superb basis for detailed understanding of the evolution of the igneous geology of Vinalhaven as well as important contributions to understanding of the regional stratigraphy of coastal Maine. Over the next two years, we anticipate several different groupings of faculty, students and visitors will write papers that can be published in national or international journals. More immediately, several students will present papers on their individual research projects at regional GSA meetings.

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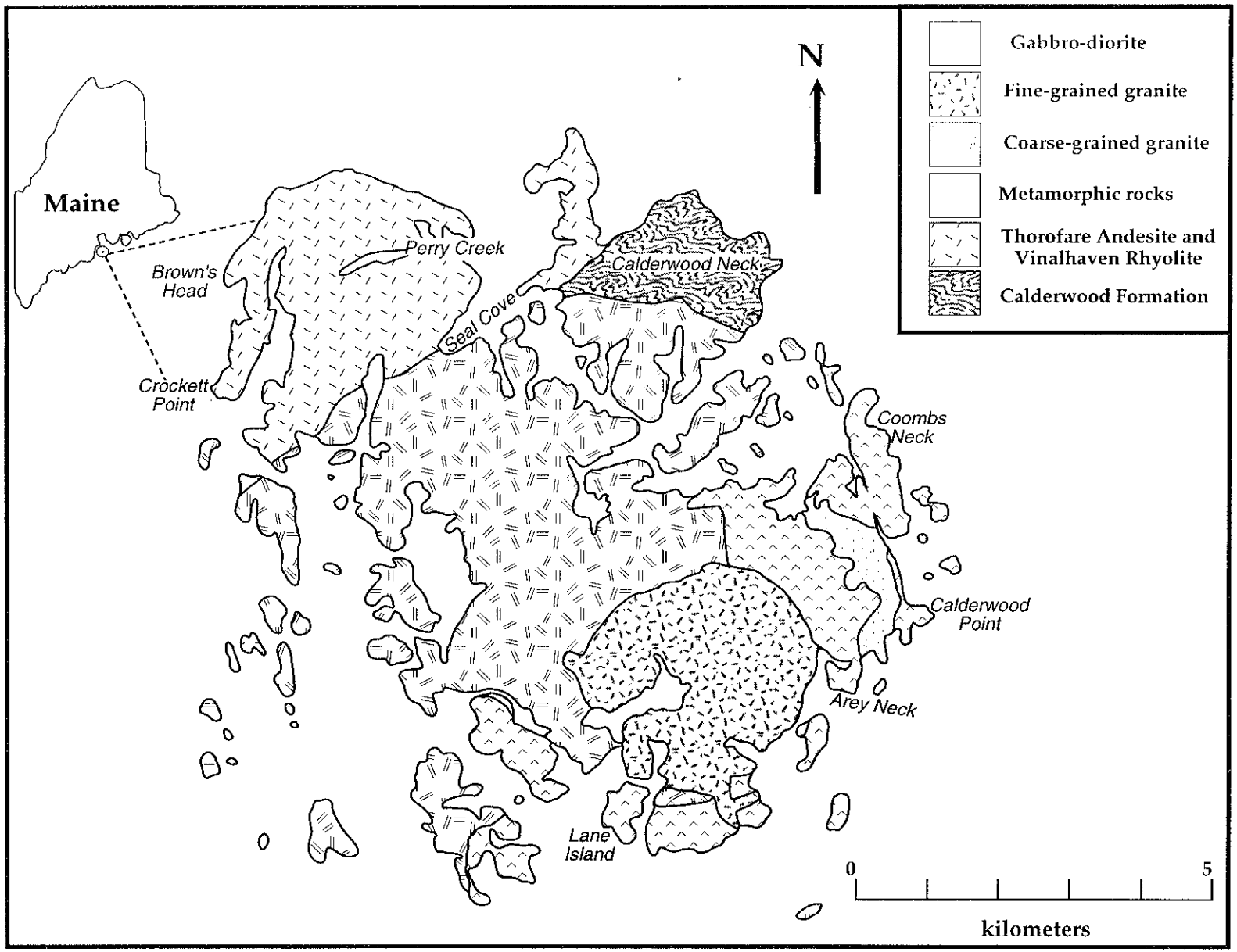

Fig. 1. Geologic map of Vinalhaven Island modified from O. Gates (in press) by R. Blaire Schoene.