PLIO-PLEISTOCENE CASCADE VOLCANISM IN SOUTHERN OREGON

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LATE TERTIARY VOLCANISM IN THE REGION SOUTH OF MT. McLOUGHLIN AND BROWN MOUNTAIN IN THE SOUTHERN OREGONIAN CASCADES

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INTRODUCTION

The Pacific Northwest has been a zone of convergence between North America and oceanic plates of the Pacific basin throughout most of Mesozoic and Cenozoic time. The Cascade Range of northern California, Oregon, and Washington include a broad belt of middle Tertiary volcanic centers known as the Western Cascades (McBirney, 1978) and another much narrower north-south alignment of Quaternary volcanoes known as the High Cascades. Both linear arrangements record arc magmatic events related to subduction of oceanic lithosphere as is evidenced by marine magnetic anomalies, (Engebretson and others, 1985), deep focus earthquakes (Ludwin and others, 1990), and geologic and tectonic constraints (Taylor, 1990). Most of the larger Quaternary volcanoes occur on a nearly north-south continuous line that is generally less than 75 kilometers wide from Lassen Peak in northern California to Mount Hood in Oregon, but numerous smaller vents and extensive lava flows comprise a significant part of the overall volume of Quaternary volcanic rocks. In the state of Washington, however, the pattern of volcanoes is complex and less linear; in addition, Quaternary lava flows are limited to the area near the main stratovolcanoes. Other volcanic centers associated with the High Cascades are located to the east of the main trend of volcanoes; for instance, Medicine Lake and Newberry volcanoes are located several tens of kilometers east of the main chain.

Various researchers have noted systematic geological and geophysical variations along the length of the Cascade Range that presumably are due to the interactions between the North American, Explorer, Juan de Fuca, and Gorda plates. Recently Guffanti and Weaver (1988) studied the spatial, temporal, and compositional distribution of volcanic vents, including monogenetic and minor volcanoes and proposed a five segment model of the Cascade Range (See Figure 1). The isostatic residual gravity data of Blakely and Jachens (1990), when contoured, define structural boundaries between crustal blocks of different densities. Their results are strikingly consistent with the segmentation model of Guffanti and Weaver. Apparently, since a significant proportion of the Pliocene to Quaternary volcanism is concentrated at or near these contacts between blocks of crust of different densities, these contact zones promote ascension of magma to the surface of the Earth.

OVERVIEW OF RESULTS

The most important general observations of this study to date are:

a) a relatively wide range in chemical compositions of basaltic lavas have been erupted within a relatively small region within the Cascade arc;
b) within the time span latest Miocene through the Quaternary the average SiO_2 of the lavas has decreased steadily; and
c) in the 200 square miles which have been mapped in some detail there is only one occurrence of an extrusive rock whose SiO_2 content is in excess of 62%.

Ten students mapped and sampled over 70 square miles in the Oregonian Cascades during the summer of 1994, working out of a base camp located in the campground at the Fish Lake Resort. The area of interest in 1994 is due south of those focused upon during the summers of 1991 and 1992. The volcanic rocks mapped this past summer have turned out to range in age from nearly 20 Ma to approximately 0.8 Ma as determined through whole rock K-Ar radiometric dating. Kipuka of early to middle Miocene aged Western Cascade volcanics have been outlined in the extreme western part of the area which have been unconformably surrounded by extrusives 6.5 to 5 million years old. These latest Miocene to early Pliocene volcanics represent the initial phase of High Cascade volcanism in southern Oregon.

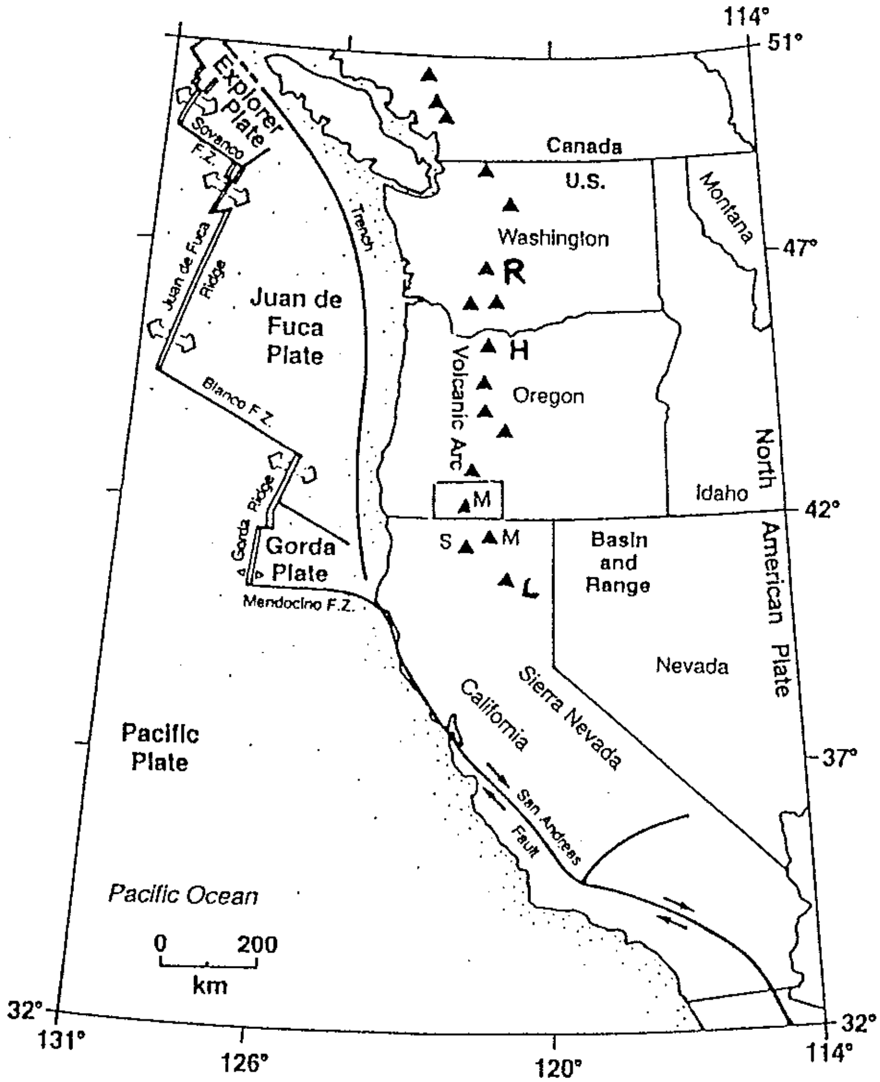

Figure 1. Plate tectonic setting of the Mt. McLoughlin volcanic region. Triangles represent major Quaternary volcanic centers of the Cascade Range. Small rectangle encloses the McLoughlin area. L = Mount Lassen; S = Mount Shasta; M = Medicine Lake; H = Mount Hood; R = Mount Rainier. With regard to segmentation models, segment 1 encompasses the volcanoes of northern Washington and southern British Columbia, segment 2 from Rainier to Hood, segment 3 from Hood to McLoughlin, segment 4 Shasta and Medicine Lake and Segment 5, Lassen.

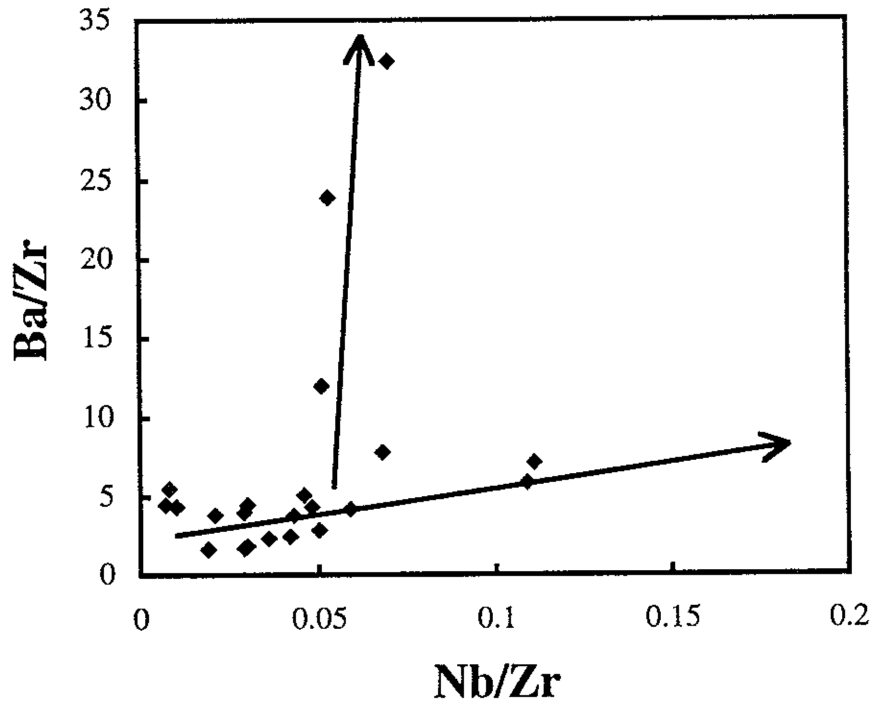

Figure 2. Ba/Zr versus Nb/Zr for a representative suite of McLoughlin region basalts and basaltic andesites (<55% SiO_2). The nearly vertical vector, which is constrained by the three data points whose Ba/Zr ratios are >10, points toward the approximate composition of pelagic sediment (Nb/Zr ~ 0.06 and Ba/Zr ~ 62) as reported by Hole and others (1984). The much more gently sloped vector defines a coupled enrichment in Ba and Zr and represents a "mantle array" trend similar to that for oceanic basalts.

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A synopsis of the mineralogy of these extrusives is as follows:

a) ferromagnesian minerals include olivine, clinopyroxene, orthopyroxene, Cr-spinel, titanomagnetite, and very rarely hornblende;
b) non-ferromagnesian minerals include plagioclase feldspar and rarely apatite;
c) no mica, no alkali feldspar, and no primary silica phases have been encountered to this point in time.

A synopsis of the chemistry of these extrusives is as follows:

a) utilizing the IUGS chemical classification of volcanic rocks the vast majority of the samples are basalt, basaltic andesite, and two-pyroxene andesite;
b) exceptions to #1 are several flows of 6 Ma trachybasalt are known from the extreme western margin of the area and one two-pyroxene dacite unit has been mapped in the area southwest of Lake of the Woods;
c) the basalts are a panoply of olivine tholeiites using the Yoder and Tilley (1962) classification with the exception of the trachybasalts which are nepheline normative;
d) a significant number of the basalts have mg#s that are in the range of 70 to 75; thus, suggesting they are primary melts generated in the upper mantle by partial melting a peridotite source. They have arrived at the Earth's surface having underwent little or no fractionation and/or assimilation enroute. An extensional tectonic regime is a likely prerequisite in terms of getting these unmodified primary basaltic liquids to the surface considering the frequency with which they are found in this geographic region.

An Interesting Detail

Examine the Ba/Zr versus Nb/Zr diagram (See Figure 2) for one petrogenetic "snapshot" into possible magma origins for the mafic rocks in this area. Ba and Nb contents have been normalized to Zr, a slightly more compatible trace element, in order to minimize as much as possible scatter which relates to variations in degree of crystallization or partial melting. Two distinct trends have been noted by vectors in Figure 2. One, the gently sloped vector, delineates the fairly typical behavior of increasing concentrations of both Ba and Nb; geochemists often refer to this vector as representing the "mantle array". The nearly vertically oriented vector is the one which causes a petrologist to pause; it trends toward a high Ba/Zr component. Ba enrichment in arc magmas commonly has been attributed to subduction of Ba-rich pelagic sediments (Hole and other, 1984). Another interpretation suggests these high LILE/HFSE ratios might reflect source enrichment by LILE-rich "emanations" released at depth by the subducted slab through dehydration-decarbonation chemical reactions. To date only three lavas with Ba/Zr >10 have been delineated, suggesting the last hypothesis might not be appropriate since it is rather difficult to imagine how such a large-scale process (at least as envisioned by me!) could selectively enrich the source regions, only three magma batches without similarly affecting rather enormous volumes of the hangingwall-forming upper mantle peridotite. Clearly Sr, Pb, Nd, and O isotopic data will help better constrain the nature of the source for these rather unusual Cascade arc basalts.

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Petrology of the Volcanic Rocks south of Cox Butte, Southern Cascade Range, Oregon

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Introduction

Volcanisim in the southern Cascades is a result of the subduction of the Juan de Fuca plate beneath the North American plate and of the crustal extension in the Basin and Range (Guffanti and Weaver, 1988). The tectonic complexities of this region are responisible for the compositional variations in lesser known eruptive vents. The third Keck Consortium research project to Oregon focused on the small volcanic vents south of Mt. McLoughlin in an attempt to differentiate subduction volcanism from extensional volcanism. Each student researcher was responsible for a seven square mile study area in which the field relationships and geochemical analyses were used to distinguish units from one another and to determine the magamtic source of each unit. The goal of my research is to study the petrology of the volcanic rocks that lie south of Cox Butte.

Field Observations

The study area is located within the Brown Mountain quadrangle in R4E T37S sections 33 - 36 and R4E T38S sections 2 - 4 (see figure 1). Outcrops were scarce and the contacts between flows were usually obscured. Determining unit boundaries was aided by lobate topographic lines and by stream valleys. Most units were intensely weathered and difficult to distinguish without a fresh sample. The rock samples brought back for petrography, ICP, and XRF anayses were taken from the freshest possible outcrops.

Lithology

During the four week study, eight different volcanic units were identified. Five of the units could be traced back to a volcanic vents, all of which were outside the study area. The units range in composition from basalt to basaltic andesite and range in age from late Miocene to middle Pleistocene. Unit descriptions are based on field and petrographic observation. All of the K-Ar dates were obtained from personal communication with Stan Mertzman (1994). The units are listed from oldest to youngest.

Lithic tuff is an unwelded tuff with numerous lithic fragments of varying compositions. There are no fragments within the rock that relate to any of the other units in the study area. It is possible that the unit is from the Western Cascade province and was extruded between late Eocene and Miocene time.
5385 T (Grungy Green) basalt (5.82 +/- 0.09 Ma) is porphyritic with a plagioclase microlites showing flow alignment. There are phenocrysts of olivine (10%), clinopyroxene (5%), and orthopyroxene (2%). This unit is highly weathered and has a greenish color.
Daley Creek basaltic andesite (5.09 +/- 0.13 Ma) is porphyritic with phenocrysts: 2 - 4 mm plagioclase (45%), 1 mm olivine (10%), and 1 - 2 mm clinopyroxene (10%). The clinopyroxene is usually elongate and the plagioclase shows resorbtion.
Big Draw Creek basalt (2.96 +/- 0.06) is porphyritic with plagioclase microlites. The units contains 15% olivine and 10% clinopyroxene phenocrysts. There is a sugary texture, but it is not diktytaxitic.
Cox Butte basalt (2.96 +/- 0.06 Ma) has an aphanitic groundmass with phenocrysts of <1mm plagioclase (40%), 2 - 4mm olivine (10%), 1mm clinopyroxene (10%), and <1mm orthopyroxene (4%). Glomeroporphyritic clumps and a sugary texture are characteristic features. The outcrop is commonly platy.
Cinder Pit olivine basalt (2.77 +/- 0.05 Ma) is porphyritic with phenocrysts of olivine 2 - 3 mm (15%). There is plagioclase in the groundmass. The unit has a sugary texture and is platy in outcrop form.
Four Corners olivine basalt (2.63 +/- 0.08 Ma) is porphyritic with phenocrysts 1 - 2 mm long of olivine (10%). Iddingsitized rims are common around olivine phenocrysts. There is some plagioclase in the groundmass.
Burton Butte basalt (0.82 +/- 0.08 Ma) is porphyritic with phenocrysts of clinopyroxene (5%), olivine (15%), and plagioclase (30%). Glomeroporphyritic clumps, diktytaxitic texture, and vesicles are distinctive characteristics of this unit.
Quaternary alluvium deposits are found in swamps in the low lying areas near Beaver Dam Creek. The area is completely vegatated.

Conclusions