The geochemistry and petrogenesis of volcanic rocks near Keno, Oregon, in the southern Cascades Range

Myra Hill
Department of Geology Williams College, Williamstown, MA 01267
Faculty Sponsor: R.A. Wobus, Williams College

INTRODUCTION:

The formation of the southern part of the Cascades Range is the result of both subduction off the west coast of North America and the extensional regime of the Basin and Range province to the east. Understanding the regional tectonic processes is key for interpreting the petrology and geology of the Keno area. With geochemical and age data it is possible to determine the petrologic history of the magmas responsible for this volcanism. This study focuses on the stratigraphic, petrologic, and geochemical relationships of volcanic rocks in an eight-square mile area along the Klamath River, just west of the town of Keno in southern Oregon. There are no large stratovolcanoes in this area; Mt. Shasta is to the south and Mt. McLoughlin to the north.

GEOLOGIC SETTING:

The north-south trending Cascade Range, characterized by large and beautiful stratovolcanoes, is a subduction-related arc composed of two distinct assemblages based on the age and type of volcanics erupted. The western Cascades are mid-Tertiary, and were very active beginning about 30 Ma; they are typically calc-alkaline continental margin andesites. The eastern Cascades, known as the High Cascades, are Quaternary and are composed of both mafic and more silicic volcanics (Taylor, 1990). Basin and Range extension further east is thought to be a result of back arc rifting from the subduction of the Juan de Fuca Plate (Hart and Carlson, 1987). Basin and Range lavas are geochemically similar to low-potassium olivine tholeiites (LKOTs) and high-alumina olivine tholeiites (HAOTs) of modern Pacific back arc regions (Guffanti and Weaver, 1988).

FIELD OBSERVATIONS:

Sources for most units mapped are outside the area. Some are easily identified such as a small vent to the northwest, located on the southeast flank of Buck Mountain, and also Chase Mountain, which contributed flows from the south. Figure 1 shows the units as mapped.

Faulting has certainly occurred in this area, but clear indicators such as slickenlines or offset units were not visibly present. There are at least five NW-SE trending topographic ridges within or terminating in this area and these are interpreted as normal faults related to extensional tectonics.

Two small ash cones occur in a NW-SE trend as well, though no surface trace of a fault is visible. A large extent of cross section along the Klamath River exposes pyroclastic layers of fine ash, cinder/lapilli, and agglomerate layers with larger clasts. The layers average 8-30 cm thick. Blocks and bombs are also present and form a lag deposit on the surface where the finer material has weathered away. No lava flows were found here, but strike and dip measurements of the layers support quaquaversal dip from original-slope deposition.

The stratigraphic relation of these cones to adjacent units is unclear. and so a definite age relationship is hard to decipher. Stratigraphic relationships of all the units were generally difficult to determine; one contact is visible in a road cut exposing four stacked flows, and the river canyon exposes 300 feet of section comprising three or four flows, but these are not necessarily distinguishable in the field as different units. K/Ar dating has helped to clarify the ages of some of the units.

The Klamath River also appears to have been near its present location during the deposition of some of the flows because pipe vesicles and very fine-grained black alteration are present in the Chase flow exposed by the river, and in the Keno diktytaxitic unit as well. There is also a small Quaternary alluvium deposit comprised mostly of reworked pyroclastic material near the present location of the river (Fig. 1).

LITHOLOGY AND PETROGRAPHY:

Twenty-nine samples were studied in greater detail petrographically. Four units represented by these samples are basaltic andesites and one is basaltic. Extinction angles were often difficult to obtain on plagioclase laths, so anorthite compositions are given as a range. General characteristics of each flow are noted below, in order of decreasing age. Most units also contain very fine-grained opaque minerals scattered throughout the groundmass, sometimes also occurring within olivine crystals. These are interpreted to be chrome spinel (Mertzman, 1995, personal communication).

Buck Mountain basaltic andesite: Flows from this unit came from Buck Mountain itself and from a small scoria cone on its SE flank. In hand sample this unit is dark grey and porphyritic with a fine-grained groundmass. Petrographically, plagioclase makes up 40-60% of the rock and has a composition of An35-55. Pyroxenes are mostly very fine-grained, clumped in the groundmass, and usually too small to distinguish. Medium to coarse-grained olivine phenocrysts form about 10% of the rock and often look "moth-eaten," though they were once clearly euhedral. The texture is dominantly intergranular with a few pyroxenes large enough to begin an ophitic look.

Hamaker Mountain basaltic trachy andesite: This unit appears slightly diktytaxitic and is mostly aphanitic. Petrographically it has >50% plagioclase phenocrysts of composition An45-55. Opx and Cpx occur only in the groundmass and together comprise 30-40% of the rock. Olivine comprises only 7-10% of the rock as fine to medium-grained phenocrysts. The texture is intergranular.

Chase Mountain basaltic andesite: In hand sample this unit has a fine-grained groundmass with some small glomeroporphyritic clumps of olivine and plagioclase phenocrysts. Opx is very fine-grained and seen only in some samples. Petrographically, Chase rocks contain about 50% plagioclase, usually lath shaped with a composition of An45-50 and but there are occasional zoned plagioclase phenocrysts as well. 20-25% of the rock is Opx, very fine-grained in the groundmass or sometimes fine-grained phenocrysts; 15-20% is Cpx and this has the same character as Opx. The texture is generally intergranular.

Little Chase composite cone: This feature appears similar to the ash cones but larger and has some lava flows as well as pyroclastic layers. A lag deposit of blocks and bombs is also present on this cone. Some of this flow is exposed in a road-cut directly underlying the Keno diktytaxitic basalt. Petrographically the rock of this unit has >50% plagioclase occurring mostly in laths and often clumped together; the plagioclase composition is An45-60. Opx and Cpx are mostly very fine-grained anhedral crystals in the groundmass with only some Cpx as fine-grained phenocrysts. Together the pyroxenes make up about 40% of the rock. Olivine comprises about 5-10%, mostly as euhedral medium-grained phenocrysts. The general texture is porphyritic with olivine phenocrysts.

Keno diktytaxitic basalt: This unit is characterized by its diktytaxitic texture, visible in both hand sample and thin section. Petrographically, it contains 30-40% plagioclase mostly in laths, with a composition of An55-65. Opx and Cpx both range from being fine to coarser-grained and are about 20-25% each. Olivine makes up 5-10%, is generally very fine-grained and anhedral. The overall texture is very ophitic.

GEOCHEMISTRY:

Geochemical analysis by XRF was done at Franklin and Marshall College for both major and trace elements on 29 samples. The data points separate clearly into the categories of tholeiitic and calc-alkaline on an AFM triangle (Fig. 2). The tholeiitic samples were mapped as Keno diktytaxitic basalt, the youngest unit by K/Ar dating at 2.0 +/- 0.3 Ma (Mertzman, 1996, personal communication). The LeBas classification diagram (Fig. 3) also supports this separation by plotting the samples into the categories of basalt and basaltic andesite. The Keno basalts are characteristically low in alkalis while the rest of the data points plot primarily as basaltic andesite, or very near the geochemical boundary between basalts and basaltic andesites at 52% SiO2. This diagram also shows two samples with relatively higher K2O values. When these are compared with data for samples to the south of this area, they correlate closely with lavas from Hamaker Mountain to the south (Mertzman, 1996, personal communication).

INAA data were obtained for four samples and plotted on a REE plot normalized to chondrite. The plot is relatively flat for the basaltic data, averaging about 10 times chondrite. The basaltic andesite samples plot at about 70 times chondrite for light REEs to 10 times chondrite for heavy REEs, showing a weakly fractionated pattern.

A spider diagram of representative samples from each unit (Fig. 4) shows the basaltic andesites to be slightly enriched in the less compatible LIL elements, while all of the units show MORB-like concentrations of more compatible elements. This is consistent with a theory of contamination which would have added these LIL crustal elements to a rising basaltic magma. The Nb trough, most pronounced in the tholeiitic unit, has been hypothesized to be caused by a retention of Nb in the mantle source during partial melting (Wilson, 1989).

K/Ar age dating was done by Stan Mertzman on other selected samples in this and nearby areas. Buck Mountain basaltic andesite is the oldest unit mapped here at 2.8 +/- 0.1 Ma, Hamaker sampled along the river in this section is 2.7 +/- 0.2, Chase is 2.51 +/- .07 Ma, and Keno Diktytaxitic basalt is 2.0 +/- 0.3 Ma (Mertzman, 1996, personal communication).

DISCUSSION:

The geochemical and age data help to place these units within the larger framework of Cascade volcanism. The five basaltic andesite units are all calc-alkaline; geochemically and chronologically, they relate to the lavas of the subduction-related Cascades. The positive sloping trend of the Chase samples, when plotted on an SiO2 vs. total alkalis diagram (Fig. 3), shows a possible fractional crystallization trend in the magma chamber. Buck Mountain basaltic andesite samples plot towards the mafic end of Chase samples, and are older as well. Within this small area, it is likely that each of these nearby vents may have tapped the same local magma chamber, and if so, it follows that older lavas produced would be relatively more "primitive" than most of the younger Chase flows. This is also reflected in the higher LILs of the Chase unit relative to Buck Mountain samples. The samples which plot as tholeiitic all come from the Keno diktytaxitic basalt unit. The HAOT chemistry of this unit matches the characteristic chemistry of the extensional Basin and Range province. Thus, the general trend of the Cascades volcanics towards more "evolved" calc-alkaline lavas is seen here in the basaltic andesite units, prior to the overprinting by tholeiitic basaltic lavas from the westward migrating Basin and Range province. This area thus marks the overlap between Cascade and Basin and Range volcanism.

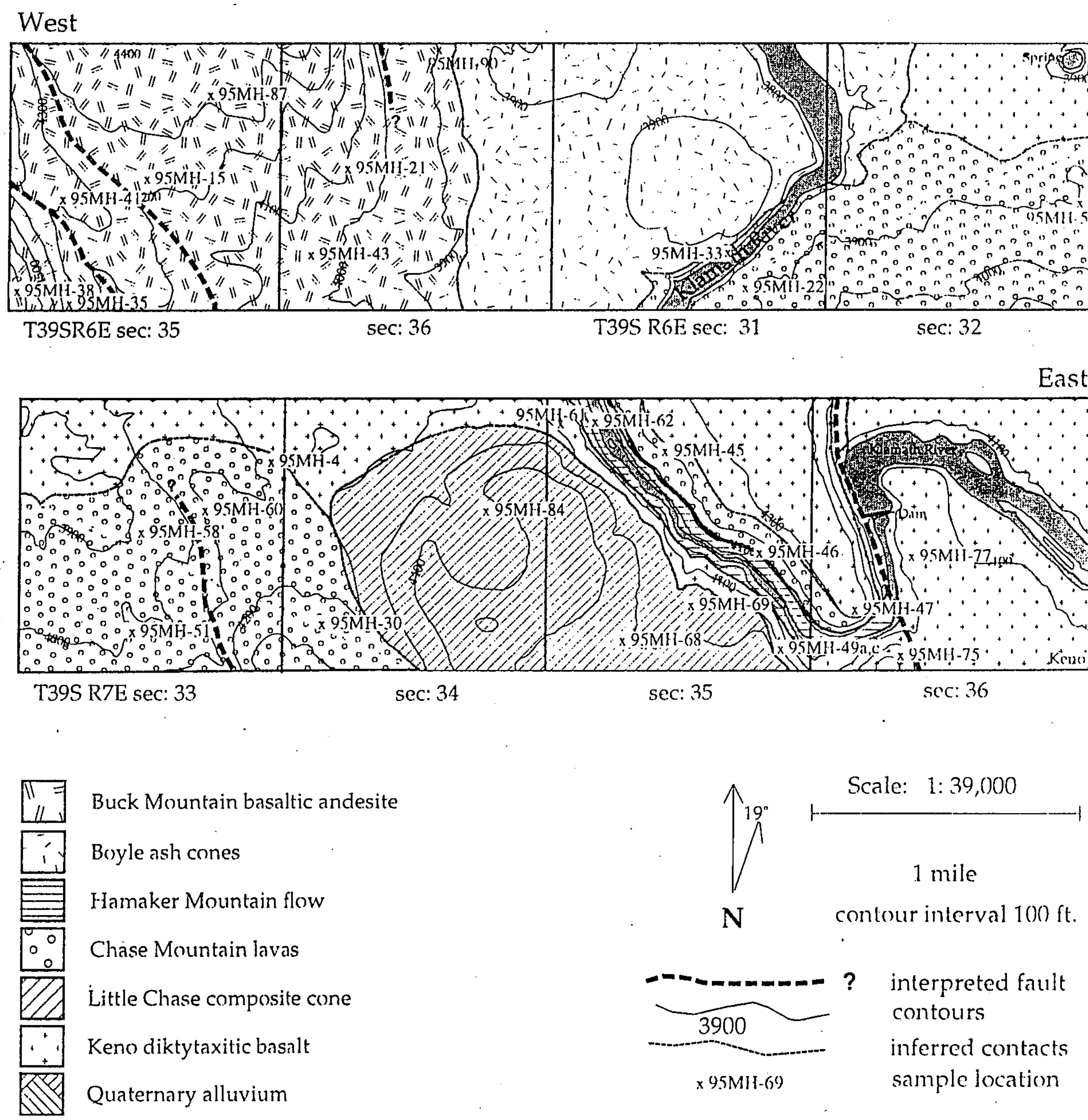

Figure 1: Geologic map and sample locations of study area

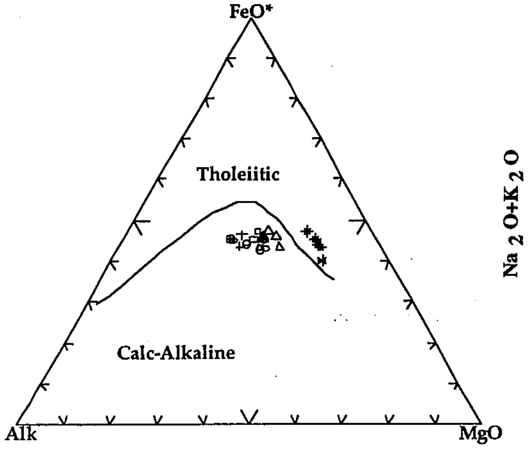

Figure 2: AFM tholeiitic vs. calc-alkaline diagram.

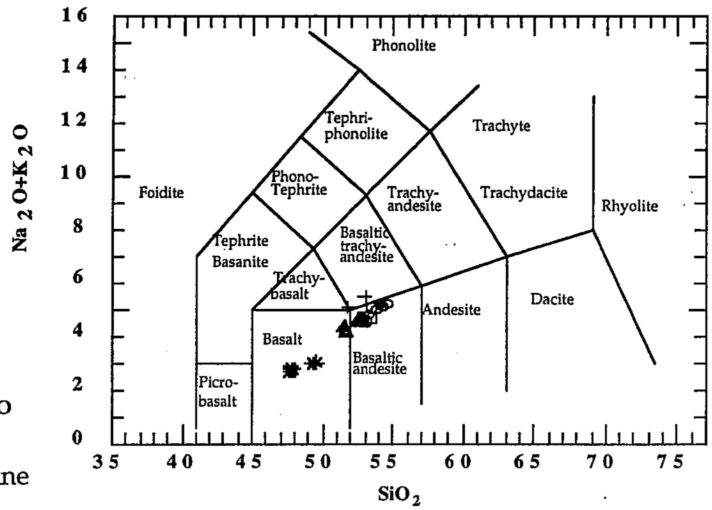

Figure 3: SiO2 vs. total alkalis classification diagram after LeBas.

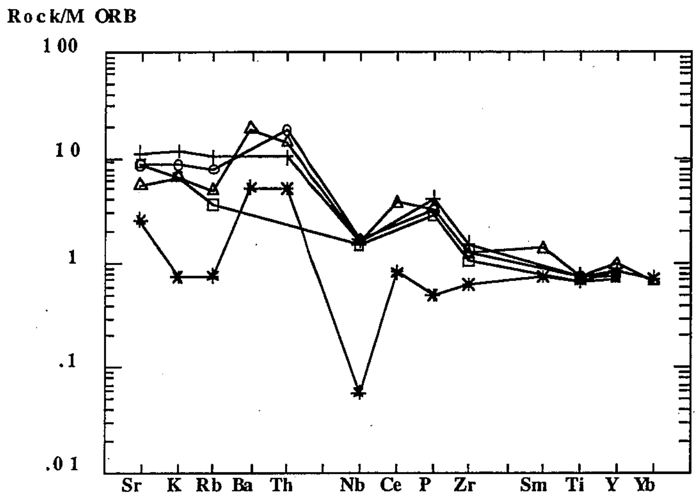

Figure 4: Spider plot of representative samples for each unit. Plot normalized to MORB.

<u>Symbol Legend Figures 2-4</u>

- △ Buck Mountain basaltic andesite
- + Hamaker Mountain lavas
- ○ Chase Mountain basaltic andesite
- □ Little Chase composite cone
- ✱ Keno diktytaxitic basalt

REFERENCES CITED

Hart, W. K., and Carlson, R. W., 1987, Tectonic controls on magma genesis and evolution in the northwestern United States: Journal of Volcanology and Geothermal Research, v. 32, p. 119-135.

Guffanti, M., and Weaver, C. S., 1988, Distribution of Late Cenozoic volcanic vents in the Cascade Range: Volcanic arc segmentation and regional tectonic considerations: Journal of Geophysical Research, v. 93, no. B6, p. 6513-6529.

Mertzman, 1995, unpublished K/Ar data.

Mertzman, 1996, unpublished K/AR data.

Taylor, E. M., 1990, Volcanic history and tectonic development of the central High Cascades Range, Oregon: Journal of Geophysical Research, v. 95, no. B12, p. 19,611-19,622.

Wilson, M., 1989, <u>Igneous Petrogenesis</u>, Unwin Hyman, London, 466 p.