

# Geochemistry and Petrology of Neogene Volcanics of the Southern High Cascades near Keno, Oregon

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## INTRODUCTION

The Cenozoic evolution of the Cascades been marked by a northwestern migration of volcanism coincident with subduction of the East Pacific rise spreading center under the North American Plate beginning approximately 30 Ma. In more recent times (Late Miocene to Holocene), active calc-alkaline volcanism of the Cascades has been focused in the High Cascades which extends from Lassen Peak in California to Mount Meager in British Columbia. This young volcanic arc is primarily a result of oblique subduction of the Juan de Fuca, Gorda, and Explorer plates under the North American plate. Structurally, the region is characterized by numerous NW-SE trending normal faults due to the recent impingement of Basin and Range extension on the High Cascades (Blakely et al., 1997). Because of its proximity to Basin and Range extension and volcanism, it is possible that two different mantle source regimes are involved in the latest magmatism which has sporadically occurred in this region. This study focuses on a suite of subalkaline Cascade rocks collected immediately north of the California-Oregon border. Geochemical and petrographic analysis of these rocks may yield a clearer picture of the complicated magmatic processes ongoing in this region.

## FIELD AND ANALYTICAL METHODS

The study section consists of a ten square mile area (from north to south on the Mule Hill Quadrangle: R5E, T40S, Sections 2, 11, 14, 23, 26, 35; and R5E, T41S, Sections 2, 11, 14) located just north of the Klamath River. Lithologic units, as well as individual flows within units, were delineated in the field based on hand sample mineralogies and textures. Relative ages were difficult to interpret due to poor exposure of contacts between many of the units.

A suite of 38 rocks representative of the various lithologic units was chosen for geochemical and petrographic thin section analysis. Various procedures including rock crushing, X-ray fluorescence analysis, loss on ignition, and iron titration were performed at Franklin & Marshall College.

## PETROGRAPHY AND STRATIGRAPHY

A 1000-point count of each thin section was performed to provide an accurate measure of the modal abundance of phenocryst and groundmass phases. On the basis of field relationships, petrography, and geochemistry of the 38 rock specimens, eight distinct lithologic units ranging in composition from basalt to basaltic trachyandesite have been defined:

**Andesite Kipuka (A) (15.0 +/- 0.4 Ma)** (All K/Ar dates from Mertzman, 1998): This unit is the oldest in the study section and is found only in the southern portion as a topographic high point. In hand sample, the rock is a flow laminated, medium-gray, aphanitic andesite, with a very fine-grained groundmass. In thin section, trachytic plagioclase laths dominate the rock. Clinopyroxene is the dominant ferromagnesian phenocryst phase, and both clinopyroxene and orthopyroxene exist as intergranular phases. An abundance of fine grained (<.01 mm) apatite needles is characteristic of this rock. The modal mineralogy ranges from 60-65% plagioclase, 10-15% clinopyroxene, 10% orthopyroxene, and 5-11% opaque oxides. Using the Le Bas and others, 1986 classification, reveals this rock to be a basaltic trachy-andesite, quite anomalous in the context of the surrounding lavas.

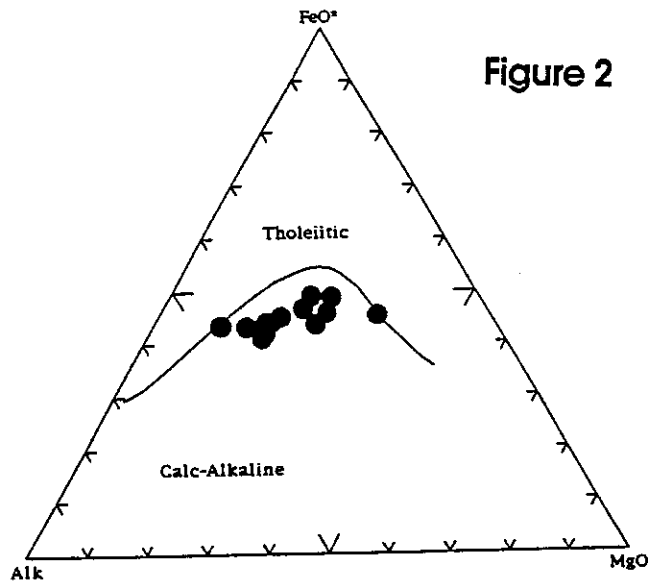
**Northern Equigranular HAOT (Neh) (3.66 +/- 0.24 Ma)**: This unit consists of a NW-SE trending flow front situated about one mile south of Oregon State Rt. 66. In hand sample, the unit appears as a light-gray, diktytaxitic, high alumina olivine tholeiite (HAOT) basalt. In thin section, the subophitic texture of this unit is revealed. Olivine is the dominant ferromagnesian phenocryst phase containing numerous poikilolitically enclosed euhedral picotites. The unit is comprised of 48-50% plagioclase, 20-23% clinopyroxene, 15-20% olivine, 4-5% vesicles, and 3-4% opaque oxides.

**66 Basaltic Andesite (66Pba) (3.4 +/- 0.1 Ma)**: This unit is located directly south of Oregon State Rt. 66, and in outcrop exhibits flow jointing and spheroidal weathering. A hand sample reveals a medium grained, dark-gray, porphyritic basaltic andesite. In thin section, plagioclase occurs as both small laths in the groundmass and larger tabular phenocrysts. Small resorbed zones are present within the plagioclase phenocrysts giving them a "moth eaten" texture. Olivine, clinopyroxene, and plagioclase often occur in glomeroporphyritic

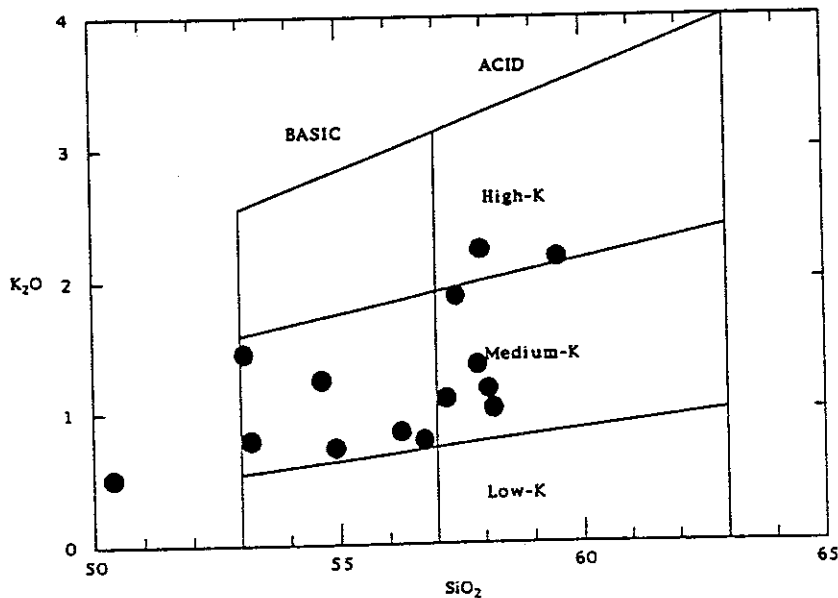
The least understood areas are the Shovel Creek "cones" which appear superimposed on lavas that are approximately 10 million years older. These cones are in a linear array, with the cone nearest the river the highest topographically. It appears that the structures are fault related, especially in light of the age discrepancy. They may be linked to the unit south of the creek as a cross-creek unit appears exactly where the cones stop north of the creek. Continued research would be required to fully understand the volcanological history of the Secret Springs area.

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**Figure 2**



**Figure 3**

clumps. The modal mineralogy ranges from 55-60% plagioclase, 25% clinopyroxene, 5-9% opaque oxides, and 5-7% olivine phenocrysts.

**Mud Spring Mountain Basaltic Andesite (Msm) (2.6 +/- 0.2 Ma):** This unit is the most voluminous basaltic andesite unit in the study section. It is composed of at least seven distinct flow sub-units, all classified as Msm. In hand sample, this unit occurs as a medium-gray, fine grained basaltic andesite. In thin section, olivine characteristically is iddingsitized and occurs in glomeroporphyritic clumps with plagioclase and clinopyroxene. The rock is comprised of 40-55% plagioclase, 35-39% clinopyroxene, 5% olivine, and 2-5% opaque oxides.

**Long Prairie Creek Fissure Basalt (Lpc-g) (2.4 +/- 0.2 Ma):** This unit originates from a fissure eruption north of the study section (located in the NW 1/4 of Section 3, T40S, R5E) and blankets the northwestern-most portion of the field area. A flow lobe of the unit also exists between the Msm and Mfba units. Hand specimens appear as medium-gray, glomeroporphyritic to porphyritic basalts. In thin section, the very fine grained intergranular texture dominated by granular clinopyroxene is the most distinctive feature. Samples in closest proximity to the source exhibit large (0.5-1 cm) glomeroporphyritic clumps of plagioclase and olivine, while samples from the distal flow end contain mainly olivine phenocrysts. The modal mineralogy consists of 45-47% plagioclase, 26-28% clinopyroxene, 14-15% olivine, and 6-9% opaque oxides.

**Mud Spring Mountain Fissure Basalt (Mfba):** This unit has not been radiometrically dated; however, strong field evidence that suggests Mfba stratigraphically overlies both Lpc-g and Msm. The upper age boundary is not as well constrained, and it is hoped that future study of the area will yield a K/Ar date for this unit. Mfba occurs as a NW-SE trending series of three hills just north of Mud Spring Mountain Basaltic Andesite. Hand samples occur as both vesicular scoriaceous basalts and porphyritic basalts. In thin section, large tabular zoned plagioclase exhibits the "moth eaten" texture, a characteristic this unit has in common with 66Pba. Complete post-crystallization alteration of olivine to opaque oxide is another distinctive petrographic feature. The rock consists of 40-47% plagioclase, 16-20% clinopyroxene, 10-14% olivine, 5-10% opaque oxides.

**Southern Equigranular HAOT (Seh) (2.1 +/- 0.3 Ma):** This unit lies just south of Mud Spring Mountain and is laterally extensive both east and west of the study area. Hand samples of this unit appear as light-grey, fine-grained, diktytaxitic HAOT basalts, with subhedral phenocrysts of olivine. In thin section, this unit is distinguishable from its northern relative (Neh) by its lack of subophitic texture and more pronounced diktytaxitic texture. The rock is comprised of 50-54% plagioclase, 17-18% clinopyroxene, 17-18% olivine, 8-10% vesicles, and 1-3% opaque oxides.

**Olivine-"rich" HAOT (Orh) (1.9 +/- 0.4 Ma):** This unit is the youngest and volumetrically most abundant in the area. Its source, though still undefined, is believed to lie west of the study section. Flows from this unit extend to the Klamath River canyon where it is observed to be at least 75 ft thick and composed of at least three distinct flow sub-units. In hand sample, this unit is a dark-grey, vesicular HAOT basalt. Thin section reveals that the diktytaxitic texture is strikingly similar to the Seh unit, the main difference being a slightly subophitic component to the groundmass. The unit is comprised of, 45-47% plagioclase, 29-30% clinopyroxene, 11-14% olivine, 8% vesicles, and 0.5-1% opaque oxides.

## GEOCHEMISTRY

A Total Alkalis vs. Silica (TAS) plot of the analytical data indicates several important trends. All of the lithologic units plot as subalkaline, fall within a fairly narrow range of SiO<sub>2</sub> content (~48-57 wgt%), and are classified as basalt, basaltic andesite, and basaltic trachy-andesite. On the TAS plot, the data form two distinct sub-parallel linear trends labeled "Trend 1" and "Trend 2" (Figure 1). The subalkaline nature of these units is further subdivided on an AFM plot (Figure 2, after Irvine and Baragar, 1971). The Msm, Lpc-g, Mfba, and 66Pba follow a calc-alkaline trend while the Orh, Neh, Seh units follow a more tholeiitic trend.

The two TAS sub-parallel trends were plotted separately on a chondrite normalized spider diagram to illustrate some interesting similarities and differences (Figures 3 and 4, after Sun, 1980). Both trends display a distinct Nb depletion in addition to high Ba/Rb ratios. The main difference between trends is the degree of enrichment of large ion lithophile elements (LILE), with Trend 1 indicating a lesser degree of enrichment than Trend 2. With the exception of La, differences between the two trends in the concentrations of high field strength elements (HFS) and light rare earth elements (LREE) are minimal.

Bivariate major and trace element plots indicate interesting trends as well. In general, as a function of decreasing MgO; Ni, Cr, Fe<sub>2</sub>O<sub>3</sub>T, and CaO behave compatibly, while Al<sub>2</sub>O<sub>3</sub>, K<sub>2</sub>O, TiO<sub>2</sub>, P<sub>2</sub>O<sub>5</sub>, Rb, Zr, and Ba behave incompatibly. As a function of decreasing CaO; Al<sub>2</sub>O<sub>3</sub>, P<sub>2</sub>O<sub>5</sub>, Rb, and Sr generally behave incompatibly. Additional bivariate plots of CaO vs. Y show that Y is nearly constant as a function of decreasing CaO, except in unit A where a strong incompatible trend is observed.



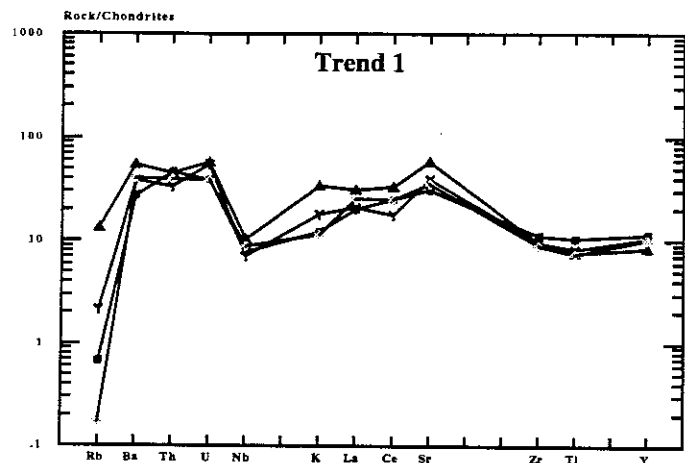


Fig. 3. Chondrite normalized spider diagram of Trend 1 showing Nb trough and high Ba/Rb ratio (after Sun, 1980).

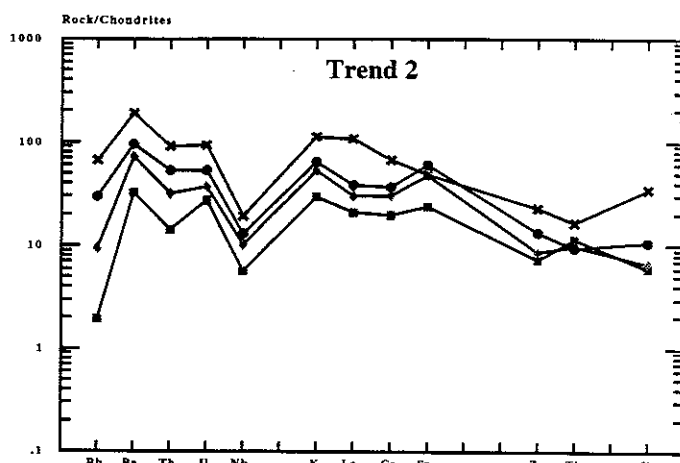


Fig. 4. Chondrite normalized spider diagram of Trend 2 showing Nb trough and high Ba/Rb ratio (after Sun, 1980).

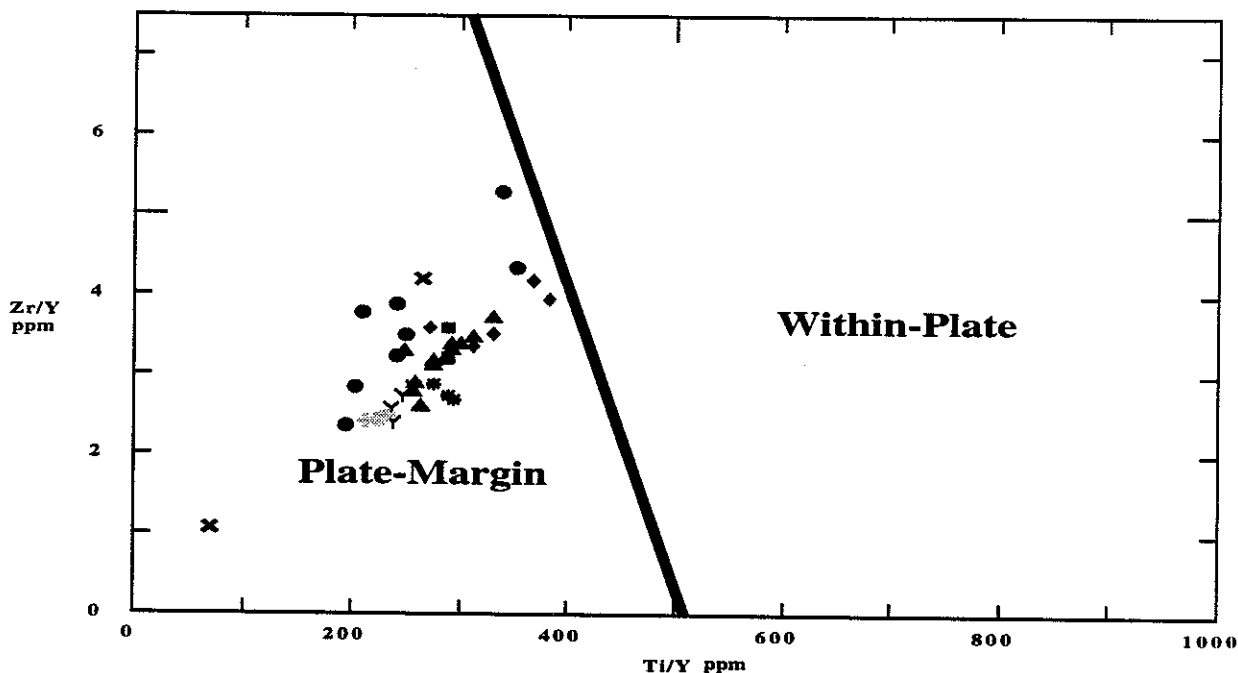


Fig. 5. Zr/Y-Ti/Y discrimination diagram indicating plate-margin nature of rocks of the study area (after Pearce and Gale, 1977).

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