# Geology, Petrology and Geochemistry of the Southeast Flanks of Mt. McLoughlin Volcano, Southern Oregon.

**Lindley F. Hall**
**Williams College**
**Williamstown, Mass. 01267**

## Purpose

This study of an area near Mt. McLoughlin volcano in the Cascades is a continuation of past research by two Keck Consortium groups in the summers of 1991 and 1992, under the direction of Prof. Stan Mertzman. The present study uses field relations, petrography, and geochemistry to determine if the diverse flows are a result of subduction or extensional Basin and Range tectonics.

## Geologic Setting

Oregon's High Cascade stratovolcanoes, including Mt. McLoughlin, have formed in response to the subduction of the Juan de Fuca plate beneath the North American plate. Formed during the Pliocene to the Pleistocene, they follow a geochemical trend of tholeiitic to more calc-alkaline rocks over time (White and McBirney,1978). The role of fractional crystallization, crystal settling and contamination will be discussed in relation to the formation of the diverse magma types on the flanks of Mt. McLoughlin.

## Field Description

I mapped a seven square mile zone southeast of Mt. McLoughlin and east of Brown Mountain. The northern boundary of my mapping area passes through Pierce Point. The western side of the map area borders Lake of the Woods, continues into the Winema National Forest to the east, and abutts West Varney Peak and Greylock Mountain on the east. Ten flow units were identified in the field and named by the percent of olivine phenocrysts present: for example, 1-3% olivine equals andesite, 3-5% olivine was labeled basaltic-andesite, and >5% olivine was called basalt. Samples were also collected for thin section analysis, chemical analysis, and radiometric dating. Rocks were placed in stratigraphic order based on contact relationships, relative degree of weathering, and percentage of exposed contacts. Outcrops could not be found below 6,000 feet and in many places flows had been disrupted by Quaternary glacial or modern fluvial activity.

## Petrography

The ten unit descriptions are listed from oldest to youngest. Two to three thin sections for each unit were studied. Modes were determined by point counting, and the Michel-Levy method was used to determine the plagioclase compositions.

1.) Pierce Point Basalt: This basalt is 1.42± .05 my (Mertzman, personal communication, 1993). In hand specimen its 1-2mm phenocrysts of olivine are distinctive. In thin section it is holocrystalline with an aphantic groundmass and inequigranular phenocrysts. The rock contains 17% phenocrysts, which are as follows: 10% large plagioclase (andesine) crystals in glomoroporphyritic aggregates with the clinopyroxene(cpx) and orthopyroxene(opx) crystals, 3-5% olivine with shrinkage cracks, and 2% very fine grained, tabular opx (hypersthene), as well as 2% cpx (diopside).

2.) Sunset Basalt: Adjacent to Lake of the Woods, it has a dark, fine grained groundmass with 30% medium to fine grained, sub-euhedral, inequigranular phenocrysts. There is a big contrast between the groundmass and phenocryst size. The phenocrysts are: 20% large, lath-like opx(hypersthene), 7% medium-grained, zoned plagioclase (andesine), and 3% cpx (augite). There is also 3-5% olivine and iddingsitized olivine present. The source is unknown, but from the amount of weathering and its chemical analysis it appears to have formed simultaneously with the Pierce Point magma.

3.) Camel's Hump Andesite: The source for this andesite is Pierce Point to the west. Megascopically Camel's Hump lavas have a dark groundmass with a slightly vesicular, and dictytaxitic texture. Under the microscope it is holocrystalline with an aphantic groundmass and 25% phenocrysts. 15% of the plagioclase grains are in <1mm microphenocrysts and 3% plagioclase(andesine) are in 2mm sized phenocrysts. There are also 3-5% opx (hypersthene) in clusters with 1-3%cpx (diopside) grains. 1% olivine is also present.

4.) Seldom Butte Andesite: This undated unit forms a small hill in the north of my mapping area. The high amount of weathering and vegetation places it stratigraphically below the Greylock Andesite and subsequent flows in the southeast of my map. Megascopically it is dark and vesicular. Microscopically it has 1% fine grained, zoned plagioclase(andesine), 80% very fine grained, tabular plagioclase, and two pyroxenes. The most likely source is Rye Spur to the northwest.

5.) Rainbow Bay Andesite: This unit occurs in the field in massive, vesicular, spheroidally weathered boulders northeast of Lake of the Woods and underlies the flows to the east. Microscopically it is not very distinguished. It includes 16% phenocrysts: 10% fine grained, tabular plagioclase(andesine), and two pyroxenes. The source is unknown.
6.) Greylock Mountain Andesite: It forms the 7500 peak to the east of my field area and has been dated at 0.92±0.02my(Mertzman, personal communication, 1993) Megascopically the groundmass is medium grey with plagioclase phenocrysts evenly distributed. Microscopically Greylock andesite has an aphantic groundmass with 20% phenocrysts that are fine grained and inequigranular.. 10-15% of the phenocrysts are elongated, prismatic plagioclase (andesine). There is 2-3% opx(hypersthene) and 2% cpx (diopside) sometimes in clusters with each other. Greylock is more seriate than the Salt and Pepper andesite.
7.) West Varney Peak Andesite: This unit is 0.80±0.03my (Mertzman, personal communication, 1993). It forms a 7324 foot peak off the northeast corner of my map area. The rock is distinguished megascopically by large snowflake-like phenocrysts of deep brown opx. Also unique is the high (90%) phenocryst content. 70% of the phenocrysts are very fine grained plagioclase crystals. 10% of the plagioclase(andesine) is fine to medium grained with zoning. There are: 3-5% large, euhedral opx(hypersthene) grains, and 1-3% subhedral olivine(forsterite) grains. The groundmass consist mostly of dark opaques with minor plagioclase and pyroxenes.
8.) Low Echo Basaltic-Andesite: This has been dated at 0.68±0.09my (Mertzman, personal communication, 1993). Its source is Crater Mountain to the east. Low Echo in hand specimen has a dark, slightly shiny, fine grained groundmass, with distinctive iddingsitized olivine phenocrysts. The phenocrysts are as follows: 3% fine grained plagioclase(andesine) in elongate and tabular grains, with 90% very fine grained plagioclase composing the groundmass, along with 3% olivine(forsterite) and 2%opx(hypersthene).
9.) Salt and Pepper Andesite: Referred to as "plagioclase- rich material" in hand specimen, this unit also originates from Crater Mountain. There is an abundance of plagioclase in both the groundmass and the phenocrysts. Microscopically there is 20%plagioclase(andesine) in laths that are less than 1mm to greater than 1mm. Some of the two pyroxenes are in clusters.
10.) Winema Andesite: Its source is also Crater Mountain, and it has been dated at 0.63±0.05my (Mertzman, personal communication, 1993). (In the field I referred to this as the "fine grained material".) Winema has a very fine grained, light grey goundmass with a low phenocryst content. Microscopically the groundmass is made up of 97% very fine, aligned plagioclase needles (andesine), with 3% very fine phenocrysts of opx(hypersthen) and cpx(augite).

## Geochemistry

Fifteen samples were analysed at Franklin and Marshal College in Lancaster, Pennsylvania. X-ray fluorescence (XRF) analysis provided major element data, and trace elements were found with ICP (inductively coupled plasma). K-Ar dating was also done on six samples at Case Western Reserve University by S.A. Mertzman.

On a total alkalies versus silica (TAS) diagram, seven of the ten units plot as andesite, with SiO2 values from 58.7 to 60 percent. Low Echo Basaltic-Andesite is on the andesite and basaltic-andesite boundary with SiO2 value of 57%. Pierce Point Basalt and Sunset Basalt (%SiO2 49.7 and 49.5) plot in the basalt field (figure 1). All rocks are calc-alkaline, except for the Pierce Point Basalt and Sunset basalt, as shown in Gill's Ni vs. MgO diagram (Gill, 1981). In a triangular Pearce and Cann Ti-Y-Zr diagram, the majority of the rocks are calc-alkaline with some on the edge of the within-plate basalt zone (figure 2).

On a rock vs. MORB Pearce plot all samples follow a trend of extremely high peaks at Ba and Sr, and low to no Rb. All are enriched in the LREE's and depleted in the HREE's. Compared to the andesites, Sunset and Pierce Point basalts are depleted in Sr, K, and Ba, enriched in Ti, Y, Yb, and Sc, and unusually high in Cr and Ni (figure 3).

Variation diagrams for MgO vs. K2O, CaO, and SiO2 show slight SiO2 enrichment with age, possibly a result of olivine and pyroxene fractionation. Because of pyroxene fractionation CaO depletes with time and finally there is K2O enrichment in time, also a residual result of olivine and pyroxene fractionation (figure 4).

## Discussion

Trace element data provide the best information about the source and differentiation history of the magmas. Crustal assimilation or contamination during subduction may be important in explaining the enrichment in LREE's and depletion in HREE's. Subduction related magmas have strong spikes at Sr, K, and Ba as a result of crustal components added to the mantle basalts by subduction zone fluids. Other

distinctive signs of volcanics contaminated by continental crust include Rb, Zr, and Cr troughs on a spider diagram and enrichment in Ba, Sr and K (Wilson, 1989). The Y levels present, <15ppm, are restricted to andesites erupted through crust >30 cm thick (Gill, 1981).

With the exception of Low Echo Basaltic-Andesite, another process responsible for the geochemical signatures today is crystal fractionation or settling. Figure 4 shows that through time the magmas became more silica and potash-rich, and CaO, Cr, Ni, and Sc depleted due to olivine and pyroxene fractionation. Some rocks also plagioclase zoning which suggests disequilibrium cooling.

## Conclusions

The andesite, basaltic-andesite, and basalt flows on the southeast flanks of Mt. McLoughlin show evidence especially of crustal contamination and crystal fractionation. Because of the changing SiO2, CaO, and K2O over time, an argument can be made that all are genetically related. Except for Pierce Point Basalt and Sunset Basalt, all of the rocks are calc-alkaline and can be tied to generation from the eastwardly subducting Juan de Fuca plate beneath the North American plate. The tholeiitic nature of the other two units suggests they have had no contact with the continental crust and could possibly be related to Basin and Range extensional tectonism.

## References Cited


Gill, J., 1981. Orogenic Andesites and Plate Tectonics: Springer Verlag, New York, 336pp.

LeBas, M.J., Le Maitre, R.W. and Zanettin, B., 1986, A Chemical Classification of Volcanic Rocks Based on the Total Alkali Silica diagram: Journal of Petrology v.27, p.745-750.

Mertzman, S.A., unpublished K-Ar data, 1992 and 1993.

White,C. and McBirney,A.R.,1978. Some Quantitative Aspects of Orogenic Volcanism in the Oregon Cascades: Geol. Soc. America Memoir: v.152, p.369-388.

Wilson, M., 1989. Igneous Petrogenesis: Unwin Hyman, London, 466pp.


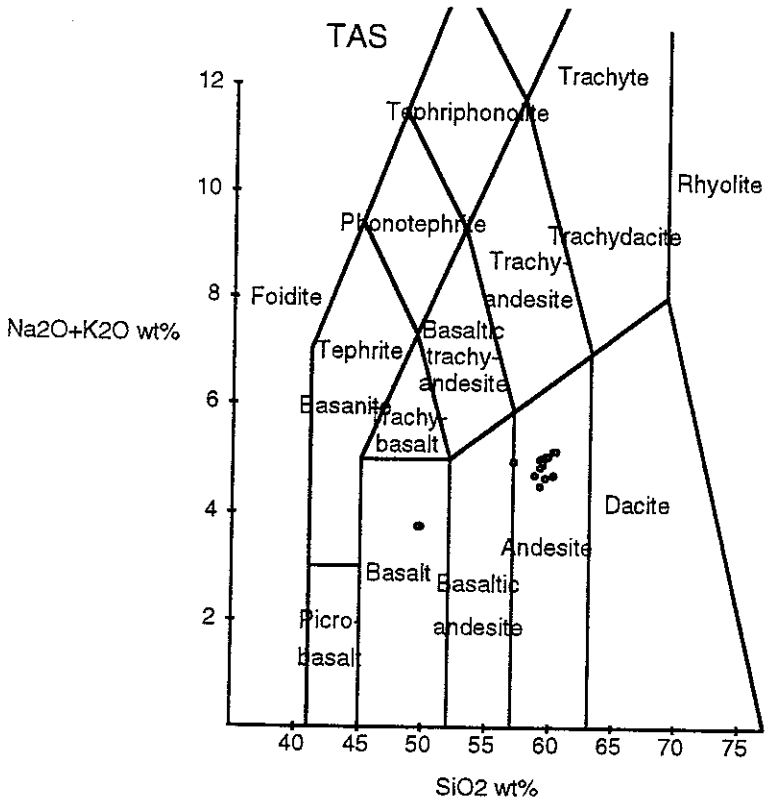


Figure 1. Samples plotted on a Total Alkali vs.Silica diagram (after LeBas, et al. 1986). Basalt=Pierce Point, Sunset units, Basaltic-Andesite=Low Echo unit, Andesite=others.

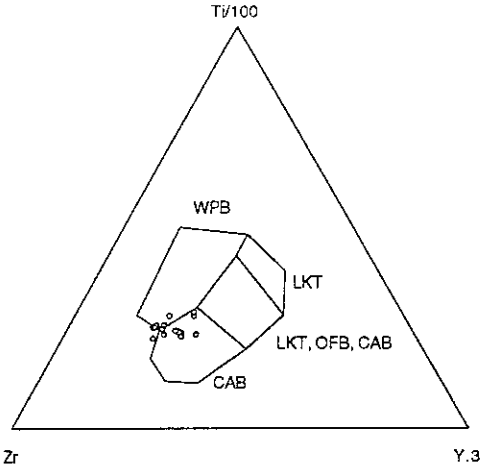


Figure 2. CAB=calc-alkaline basalt, WPB=within plate basalt, LKT=low potash tholeiite.

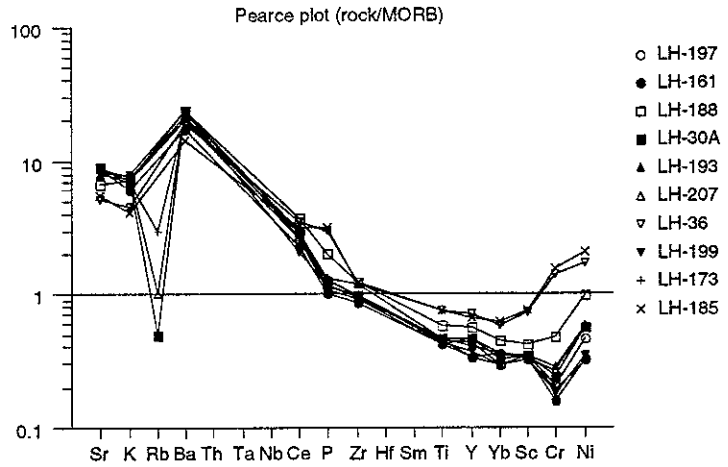


Figure 3. This spider plot displays trace element levels for the ten units. Note that most samples had negative Rb so were plotted as having no Rb. The rocks are enriched in LREE's and depleted in HREE's.

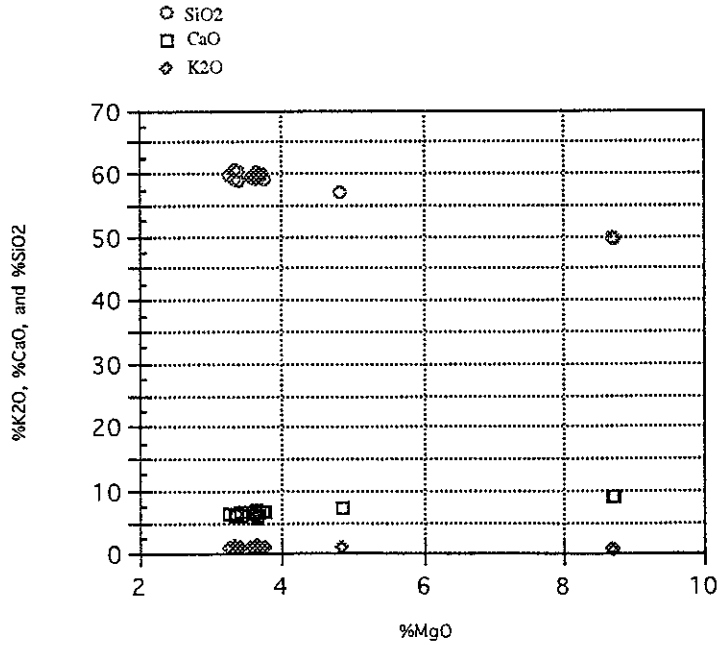


Figure 4. %K20, %CaO, %SiO2 vs. MgO shows SiO2 enrichment, CaO depletion and K2O enrichment with time. The oldest units are to the right and the youngest to the left.