Geochemical and petrological analysis of Miocene to Pleistocene volcanism in the southern Oregonian Cascades

Matthew S. Hall
Department of Geosciences, Franklin and Marshall College, P.O. Box 3003, Lancaster, PA 17604-3003
Faculty Sponsor: Stanley A. Mertzman, Franklin and Marshall College

INTRODUCTION

The Cascade Volcanic arc, located in the Pacific Northwest of the United States, extends from British Columbia to Lassen Peak in northern California. Volcanism within this area is due to the oblique subduction of the Juan de Fuca plate beneath the North American plate. The area of study is an eight square mile region located along the Klamath River, in a section of the southern Oregonian Cascade Mountains, to the west of the Basin and Range Province. Volcanism in this area ranges from late Miocene to late Pleistocene. The purpose of this study is to describe the geology, petrology, and geochemistry of a suite of mafic volcanic rocks, and integrate this data to formulate a better understanding of the volcanic history of the region.

FIELD OBSERVATIONS

The eight square mile field area (Figure 1) is located 22 km southwest of Klamath Falls, Oregon. Within this area six different volcanic units were distinguished. Distinctions between units were based on hand sample petrography, outcrop characteristics, and their stratagraphic relationship to each other. The field area is bisected (north/south) by the Klamath River, thus creating approximately 300 m canyon walls on the east and west side of the river.

In the east (section 32) a fault scarp is recognized trending in a northwest-southeast direction; similar trends (N15W to N20W) are observed throughout the entire field area. The Chicken Hills (section 32) and Grenada Butte (section 4; in the field area to the south) are in line with the above mentioned scarp. In the western portion of the field area, small hillocks (possible vents) are aligned parallel to this direction also. Alignment of vents over these faults suggests fault controlled volcanism. After faulting takes place, the magma will likely ascend along the path of least resistance. Thus, the faults are instrumental in the location of the vents.

ANALYTICAL TECHNIQUES

Thin section petrography and whole rock geochemistry were performed on 29 samples from the field area. Petrographic reports for each of these samples included modal mineralogy, texture, and other distinguishing characteristics. The geochemical analysis called for several sample preparation techniques to be utilized. After crushing each sample into a whole rock powder which is finer than an 80 mesh, a fusion technique was utilized to make a glass disk for each sample for major element analysis. A pressed powder technique was used to make a briquette for each sample for trace element analysis. Utilizing a Philips 2400 x-ray fluorescence spectrometer, the discs and pellets were analyzed to determine the geochemistry of the individual samples. Further analysis of each sample included a measurement of loss on ignition and a determination of its FeO concentration using a dissolution and titration technique. K-Ar dating was utilized to establish ages for most of the different units within the field area (Mertzman, unpublished data). Further trace element analyses were determined through INAA and ICP techniques.

LITHOLOGIC UNITS AND PETROGRAPHY

A petrographic analysis revealed similar mineralogies between units within the field area. Olivine either partially or totally altered to iddingsite, plagioclase, clinopyroxene, and magnetite are present in all of the units, although each mineral differs in size and abundance between units and within some units. A small amount of orthopyroxene is present within one unit, but minerals such as hornblende, quartz, k-feldspar, and biotite were never detected.

Klamath Canyon Olivine Basalt (6.0 ± 0.2 Ma): This unit encompasses most of the western half of the field area and the eastern canyon wall. Small hillocks in section 33 (west side) and/or a cinder deposit in section 26 to the north, are possible sources for this unit. In hand sample, this unit possesses a medium to dark gray groundmass with 5-8% olivine phenocrysts. Thin section analysis reveals that both mineral sizes and abundances fluctuate drastically. Altered olivine (20-30%) is the most abundant phenocryst. Olivine is sometimes found in glomeroporphyritic clumps and occasionally plagioclase phenocrysts are observed in the clumps also. Clinopyroxene and plagioclase (except for some infrequent larger plagioclase phenocrysts in some samples) are mostly restricted to the groundmass. The textures of the unit range from ophitic to intergranular.

Klamath Canyon Andesite (4.4 ± 0.2): This two pyroxene basaltic andesite is located near the bottom of the western canyon wall in the southern part of section 34. A poor outcrop of this unit provides a weathered hand sample, exhibiting clinopyroxene and olivine phenocrysts in a light tan groundmass. In thin section, clinopyroxene (40%) and plagioclase (40%) are the dominant phenocryst phases. Twinned clinopyroxene phenocrysts are found in glomeroporphyritic clumps. Small resorbed zones are observed within the plagioclase crystals, thus giving the phenocrysts a "moth-eaten" texture. Altered olivine (15%), orthopyroxene (3%), and magnetite (2%) comprise the rest of the mineralogy in the often pilotaxitic textured rock.

West Wall Basaltic Andesite: This unit crops out on the western canyon wall in the northern part of the field area. This granular, olivine phyric unit provides an outcrop with platy vertically oriented jointing. Surrounded by the Klamath Canyon Olivine Phyric Basalt, the unit may be a kipuka, dike or a shallow intrusive pluton. In thin section, altered olivine (10%) is the dominant phenocrystic phase. Plagioclase and clinopyroxene comprise most of the subophitic groundmass. Spinel (2%) is found poikilitically enclosed in olivine, and magnetite (12%) accounts for the remainder of the unit.

Hamaker Basaltic Andesite (3.0 ± 0.2 Ma): This unit is located in the far east portion of the field area. The source for this unit is Hamaker Mountain, which is located farther to the east. A hand sample reveals a dark massive rock. In thin section, 1-2 mm plagioclase phenocrysts (45%) are dominant. Olivine phenocrysts (8%) which have been partially altered to iddingsite can be found in glomeroporphyritic clumps with plagioclase. Clinopyroxene and plagioclase comprise the intergranular groundmass, while magnetite is found as a microphenocryst phase.

Chicken Hills' Rim Basalt (1.1 ± 0.2 Ma): The Chicken Hills are three separate scoria cones approximately 150 m high and aligned along a strike of approximately N15W in the eastern portion of the field area. In hand sample, plagioclase (15%) resides in a gray groundmass. In thin section, both clinopyroxene and plagioclase (except for a few 0.5-1 mm plagioclase crystals) are restricted to the subophitic to ophitic textured groundmass. Partially altered olivine (10%) is the most dominant phenocrystic phase and is often found in glomeroporphyritic clumps. Spinel is poikilitically enclosed in the olivines and microphenocrysts of magnetite are present as a second phenocryst phase. This unit also possesses a pervasive diktytaxitic texture.

Chicken Hills' Plagioclase Porphyry Basalt (1.1 ± 0.3 Ma): This unit is less abundant and more viscous than its Chicken Hills counterpart. This unit outcrops in large bulky flows and weathers into large ellipsoidal boulders. It is easily identified in hand sample by the abundance of plagioclase phenocrysts and the olivine and plagioclase glomeroporphyritic clumps. In thin section, plagioclase (60%) is the most abundant phenocryst phase. Partially altered olivines (15%), clinopyroxene (15%), and magnetite (4%) comprise the remainder of the phenocryst phases. In several olivine phenocrysts, spinel is poikilitically enclosed. Some samples from this unit are very granular and have a subophitic to ophitic texture. Other samples that are less granular exhibit intergranular texture. Diktytaxitic texture is abundant throughout the unit.

GEOCHEMISTRY

Geochemical analyses were made to help distinguish between units and to further classify the rocks. Utilizing the CIPW norm and plotting the data on an AFM diagram derived from Irving and Baragar 1971, all of the units were classified as sub-alkaline and tholeiitic.

Figure 2 plots MgO vs. CaO. This plot depicts the cohesive enrichment trends of the Klamath Canyon Olivine Basalt, the Chicken Hills' Rim Lava, and the Chicken Hills' Plagioclase Porphyry Basalt, the three major units in the field area.

Rare earth element geochemistry is displayed in Figure 3. All the units are equally enriched in HREEs, however it is noted that the Chicken Hills units plot differently, for they are less enriched in LREEs as compared to the other units. A spider diagram (Figure 4), using trace element geochemistry of the two Chicken Hills units, is also provided.

DISCUSSION

The Chicken Hills vent complex underwent two different stages of volcanism. First, all three Chicken Hill vents erupted Chicken Hills' Rim Basalt (CHRB). Subsequently, the central Chicken Hill erupted the Chicken Hills' Plagioclase Porphyry Basalt (CHPPB). Due to their close proximity in age, extrusion from the same vent complex, and similarity in geochemistry, it is easy to suggest that these units are likely to be genetically related. The MgO vs. CaO plot reveals possible information about the crystallization history of the CHRB and the CHPPB. These two units consistently plot in close proximity of one another. This plot displays MgO decreasing as CaO increases. One interpretation is CaO enrichment as olivine fractionates. Petrographic analyses of these units reveal plagioclase, clinopyroxene, and olivine as phenocryst phases, suggesting the interpretation of the geochemical data is plausible. Two trends concerning the Chicken Hills units are developed in Figure 3. The first trend has the Chicken Hills units possessing a flatter REE distribution in comparison to the other units. This flatter distribution maybe due to less fractionation and/or more partial melting within both the Chicken Hills magmas (Wilson, 1989). The second is the flat trend between lanthanum (La) and cerium (Ce). This flat trend is unusual and suggests a genetic link between these two basaltic units which are virtually identical in age. The spider diagram (Figure 4) further compares the Chicken Hills units. Here, the CHRB is more enriched in almost all the trace elements as compared to the CHPPB, except for strontium (Sr). The increased amount of Sr could result from plagioclase accumulation in the CHPPB. In comparison to CHRB, CHPPB is less enriched in the other trace elements which are incompatible in the plagioclase structure. This depletion in other trace elements is possibly due to plagioclase accumulation. However, a parallel distribution between the two units is retained.

Klamath Canyon Olivine Phyric Basalt is an extensive unit which is hard to petrographically divide into smaller sub-groups. The mineralogy is the same, but the minerals within individual samples vary widely in both abundance and size. Geochemically, this unit is more distinct. Figure 2 displays MgO decreasing as CaO decreases. This trend could possibly be interpreted as olivine fractionation, coupled with clinopyroxene and plagioclase fractionation. When plotted on an Al2O3 vs. MgO diagram (Figure 5), Al2O3 increases as MgO decreases. This trend reflects olivine fractionation, and suggests plagioclase fractionation was minor at best.

REFERENCES

Guffanti, M. and Weaver, C.S., 1988. Distribution of Later Cenozoic Volcanic Vents in the Cascades Range: Volcanic Arc Segmentation and Regional Tectonic Considerations: *Journal of Geophysical Research.* v. 93, p. 6513-6529.

Irvine, T.N., and Baragar, W.R.A., 1971, A guide to the chemical classification of the common volcanic rocks: *Canadian Journal of Earth Sciences*, v. 8. p. 523-548.

Mertzman, S.A.., 1996, Unpublished Data of K-Ar dates.

Wilison, M., 1989, Igneous Petrogenesis, London, Unwin Hyman, 466p.

Legend:

Klamath Canyon Olivine Basalt ▲ Chicken Hills' Plagioclase Porphyry Basalt ◈ Hamaker Basaltic Andesite ●
Chicken Hills' Rim Lava ◇ Klamath Canyon Andesite * West Wall Basaltic Andesite ■

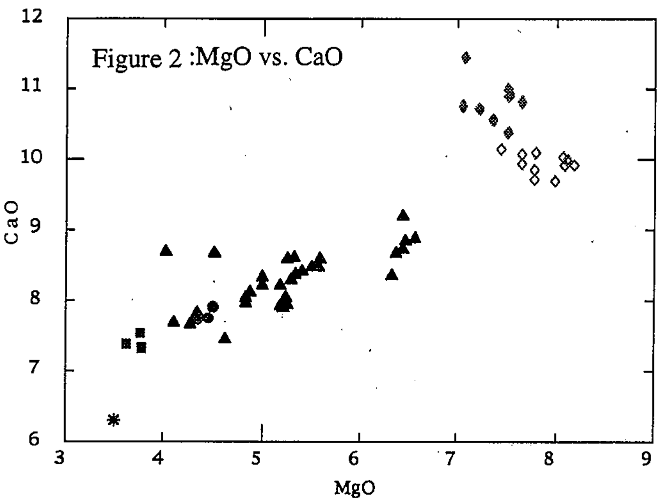

Figure 2 :MgO vs. CaO

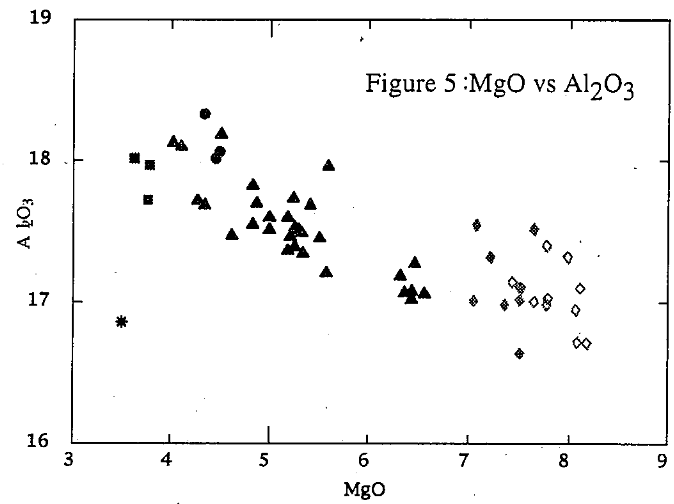

Figure 5 :MgO vs Al_2O_3

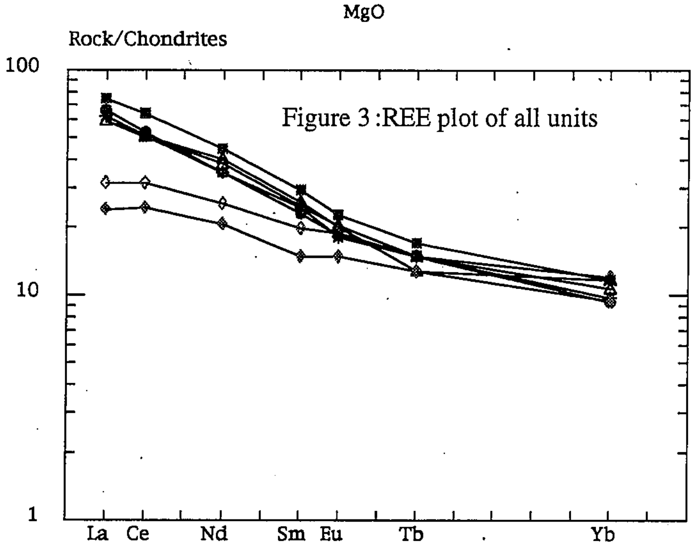

Figure 3 :REE plot of all units

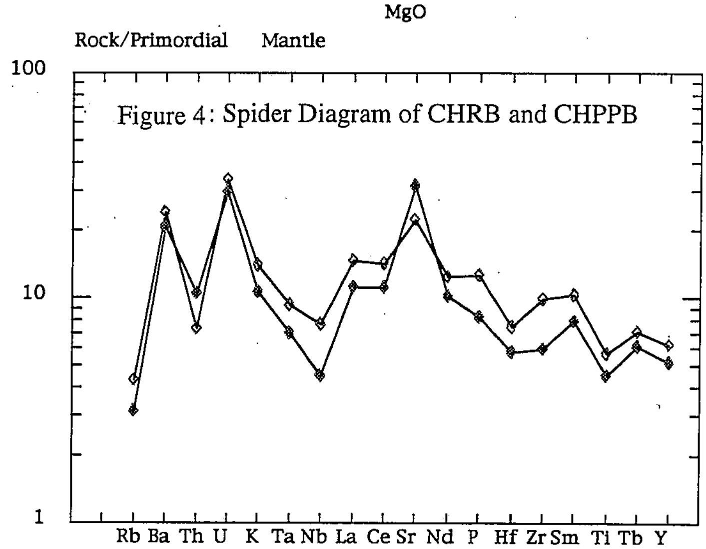

Figure 4: Spider Diagram of CHRB and CHPPB

Figure 1. Geologic map and sample location of the study area