A Petrographic and Geochemical Study of the Volcanics North of the Mountain Lakes Wilderness Area, Southern Oregon Cascades

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Introduction

Volcanism in the Cascade Range has largely been associated with the subduction of the Juan de Fuca plate beneath North America. However, the compositional variations within the volcanic chain appear to be linked to a more complex tectonic model. Basin and Range extensionalism and transverse fault zones have also been responsible for influencing volcanism (Guffanti and Weaver, 1988). Extrusives have varied from tholeiitic to calc-alkaline compositions over time, yielding basalts, andesites, and basaltic-andesites. The purpose of this study is to investigate the reasons for variations in volcanism within the study area.

The study area encompassed seven square mile blocks in the southeastern section of the project area; sections 3, 4, 5, of T37S R6E and sections 29, 32, 33, and 34 of T36S R6E. Two weeks in the field were devoted to making a superficial map of all exposed volcanic flows. Samples of each of these units were collected for petrographic and geochemical analysis. Within the study area, there were four separate volcanic vents responsible for yielding six distinct units.

Stratigraphy and Petrography

The oldest dated unit in the study area is the Harriman two-pyroxene andesite, at 1.36±.04 Ma (Mertzman, unpublished data). This heavily porphyritic unit contains phenocrysts of plagioclase (20%), orthopyroxene (5-7%), olivine (1-2%), and clinopyroxene (1%). In hand sample, the plagioclase phenocrysts are chalky, and their size ranges from 2 to 3 millimeters. The orthopyroxene were the most distinct, with sizes ranging up to 4 millimeters. In thin section, clumping of orthopyroxene and plagioclase is common. The olivine phenocrysts viewed in most sections are iddingsitized and highly fractured.

The Tomahawk Ridge units are located due north from the Harriman source vent, dated at 1.13±.09 Ma (Mertzman, unpublished data). These units actually originate from several different vents, but were lumped as one unit in the field based on their similar texture and phenocryst content. However, geochemical analysis of the samples revealed two distinct units. The age date was taken from the flow located at the source of the vent (TR-1), which overlies a much older flow (TR-2)[see figure 1]. Both were identified as aphyric basaltic-andesites containing less than 10% phenocrysts, 5 to 6% of which are plagioclase grains 1-2 millimeters in size. They also displayed well developed trachytic textures, with observable flow direction. However, TR-2 contained significantly greater amounts of plagioclase microphenocrysts and less ferromagnesium minerals than TR-1. Later geochemical work revealed TR-1 to be a tholeiitic andesite.

The Lone Hill basaltic-andesite (1.14±.10 Ma) is located due west of the Tomahawk Ridge unit, both are believed to be equal in age (Mertzman, unpublished data). The Lone Hill unit is fairly porphyritic, containing phenocrysts of plagioclase (15-20%), olivine (5-6%), orthopyroxene (2%), and clinopyroxene (<1%). The plagioclase and olivine commonly formed glomeroporphyritic clumps 2 to 3 millimeters in size. The texture observed in thin section revealed a slightly discernable flow pattern.

The Whistler basaltic-andesite is believed to be younger than the Lone Hill unit, judging from observations made in the field. It also lies stratigraphically below the West Varney Peak unit. This unit is fairly vesicular in hand sample, containing phenocrysts of plagioclase (25%), olivine (3-5%), and orthopyroxene (2%). Glomeroporphyritic clumping of the plagioclase and olivine is fairly common.

The youngest unit (.80±.03 Ma) in the study area is the West Varney Peak two-pyroxene andesite. This unit originated from the same vent as the Whistler unit. However, it was very distinct in hand sample. The unit contains phenocrysts of plagioclase (20%), orthopyroxene (5-7%), clinopyroxene (1-2%), and olivine (<1%). It greatly resembles the Harriman unit, only the orthopyroxene phenocrysts are much more distinct.

Geochemical Analysis

Twenty-one samples were analyzed for major and trace elements using both X-ray fluorescence (XRF) and inductively coupled plasma techniques (ICP). The data was used to observe geochemical trends present within the study area. Using Le Bas' classification for volcanics (1986), the samples ranged from basaltic-andesites to

andesites. The rocks all plotted within the calc-alkaline magma series using Irvine and Baragar's AFM diagram (1971), although some samples were close to tholeiitic.

The Harriman and West Varney Peak two-pyroxene andesites are by far the most acidic and calc-alkaline in composition. Using a number of Harker diagrams, these two units followed much of the same trends. Both andesites contain the lowest concentrations of TiO_2 and MnO, and display the greatest amount of iron depletion [see figure 2]. SiO_2 (60%), K_2O (1.2%) and Sr (996 ppm) concentrations are the highest in the West Varney Peak unit. However, the same unit also yields the lowest concentrations of CaO (5.3%) and Sc (13 ppm). The Harriman unit also contains a high percentage of silica (58%) and low concentrations of Sc (16 ppm). Out of all the units, the Harriman unit possesses the lowest P_2O_5, Y, and V concentrations .

The Whistler basaltic-andesite contained by far the highest concentrations of P_2O_5 (0.27%), Ba (540 ppm), Zr (140 ppm), Cr (121 ppm), La (29 ppm), and Ce (41 ppm). In the variation diagrams, the Whistler unit plots directly between the Lone Hill and West Varney Peak units [see figures 2, 3, and 4].

TR-1 andesite is the most tholeiitic unit within the study area, actually plotting just outside the calc-alkaline trend on a FeO/MgO vs. SiO_2 diagram. It possesses the highest amount of TiO_2 (1.14%), and the highest concentrations of Sc (25 ppm) and V (273 ppm). TR-2 basaltic-andesite differs from TR-1 in that it contains less total alkalis and FeO, yet is more enriched in CaO and MgO. The greatest variations between the two units can be observed in trace element concentrations. TR-1 contains greater amounts of Ba, Y, Sc, Yb, and significantly more V. On the other hand, TR-2 is more enriched in Sr, Ni, and Cr.

The Lone Hill unit was the most basaltic in nature. It possessed the lowest concentrations of SiO_2 (52.2%), K_2O (.70%), Na_2O (3.27%), and Sr (599 ppm). However, it also contained the greatest amounts of MgO (6.2%), CaO (8.4%), Ni (82 ppm), and Co (34 ppm). The Lone Hill unit is also one of the most iron enriched units in the study area, along with TR-1 [see figure 2].

Conclusions

Overall, the majority of the data supports the evidence that the subduction of the Juan de Fuca plate is the dominant influence on Cascade volcanism. All the major oxides and trace elements follow the predicted trends associated with continental arc volcanism. SiO_2 correlates negatively with FeO, MgO, CaO, and TiO_2, and positively with the two alkalis, typical for a subduction related model (Cox, 1979). However, the Tomahawk Ridge units may be linked to an extensional influence. Despite the variations, the units in the study area all appear to be genetically related. No evidence for magma mixing has been observed thus far, though it is still a possibility. The range of compositional variations between flows are believed to be the result of fractionation processes within crustal level magma chambers.

Based on the Mg content, the most primitive lava appears to be the Lone Hill basaltic-andesite. It is believed that this is the predecessor of the Whistler and West Varney Peak units. Olivine fractionation within the chamber could be associated with the Lone Hill unit's high concentrations of MgO and Ni (Cox, 1979)[see figures 3 and 4]. The increase in Sr from the Lone Hill to the West Varney Peak unit suggests increasing fractionation of plagioclase within the chamber. Plagioclase fractionation can also be linked to increases in SiO_2 content (Gill, 1981). The Whistler unit appears to be intermediate between the two, with the depletion of Fe indicating continued differentation within the chamber. All the trends follow a pattern of increased differentiation over time.

The differentiation process for the Harriman and Tomahawk Ridge units has proven to be much more complex, and is still unknown. The link between the two units has not yet been established, although they definitely appear to be related. The depletion in iron, MgO, and CaO from TR-2 to the Harriman unit appears to follow the same differentiation path as the West Varney Peak unit. However, the youngest flow, TR-1, shows quite a unique differentiation path. Since it is known to originate from the same vent as TR-2, TR-1 is thought to have been differentiated by convection of the magma within a crustal level chamber. The higher concentrations of Al_2O_3 and Sr in TR-2 suggests plagioclase accumulation at the top of the magma body, which was first erupted. This accumulation of plagioclase would cause the heavier ferromagnesium constituents to be circulated to the bottom of the chamber, later erupted as TR-1. This would explain TR-1's higher concentrations of total iron, V (273 ppm), and TiO_2 (1.14%). The differentiation of TR-1 from TR-2 would also be supported by the enrichment in total iron, indicating a shift to a tholeiitic composition (Grove and Kinzler, 1986)[see figure 2].

Basin and Range tectonism could possibly be the cause for this shift to tholeiitic volcanism. The fact that the Tomahawk Ridge forms a linear trend parallel to the Klamath Graben structure suggests a possible extensional influence. However, the study area is much too small for making any assessments about tectonic influences with respect to compositional variations.

Works Cited

Cox, K. G., J. D. Bell, and R. J. Pankhurst, 1979. The Interpretation of Igneous Rocks London: George Allen Unwin, 450p.

Gill, J.B., 1981. Orogenic Andesites and Plate Tectonics Berlin: Springer-Verlag, 336p.

Grove, T. L., and R. J. Kinzler, 1986. Petrogenesis of Andesites: *Annual Review of Earth and Planetary Sciences*, v. 14, p. 417-454.

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

Irvine, T. N., and W. R. Baragar, 1971. A Guide to the Chemical Classification of the Common Volcanic Rocks: *Canadian Journal of Earth Sciences*, v. 8, p. 523-548.

Le Bas, M. J., Le Maitre, R. W., Streckeisen, A., and B. Conettin, 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, 1993.

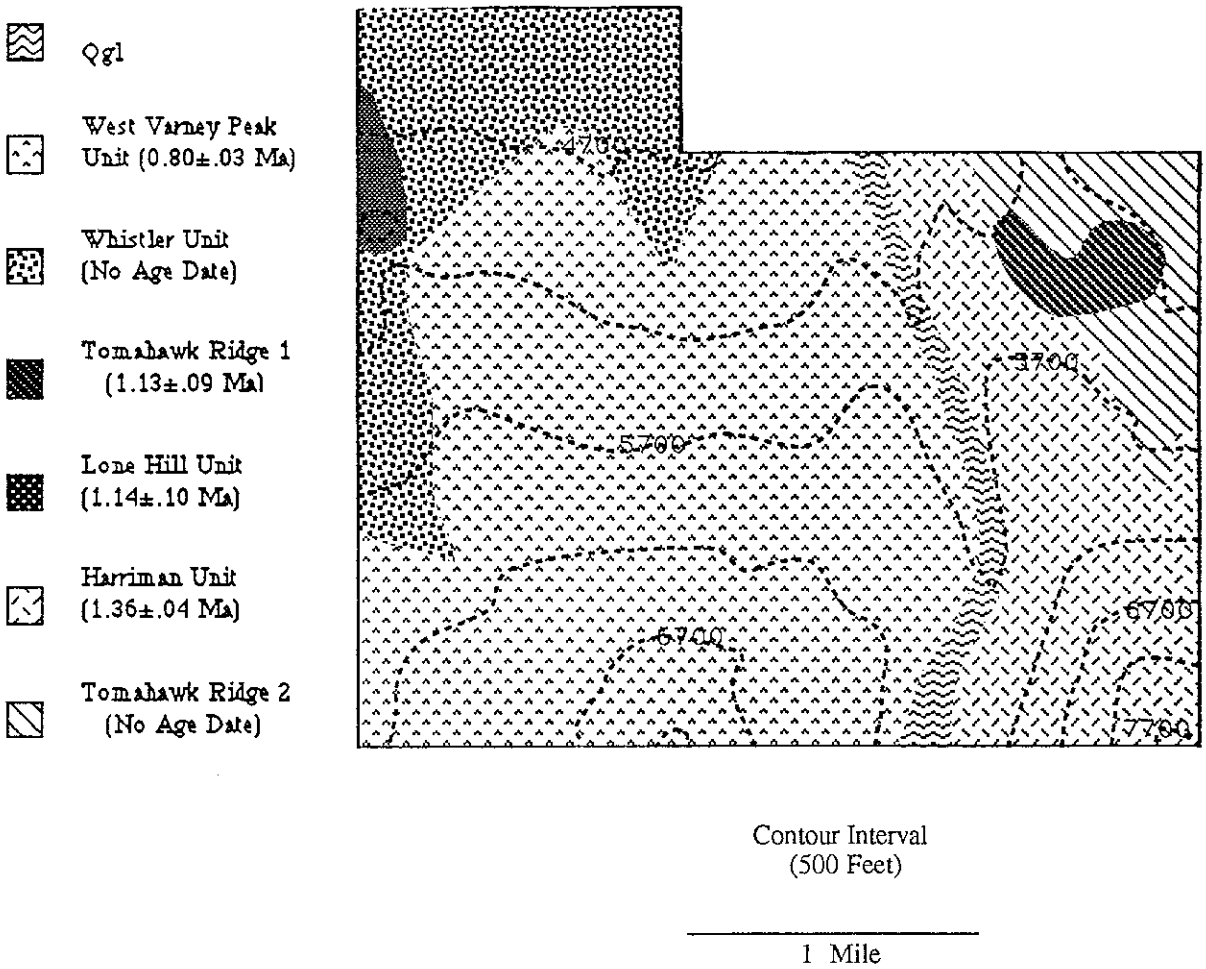
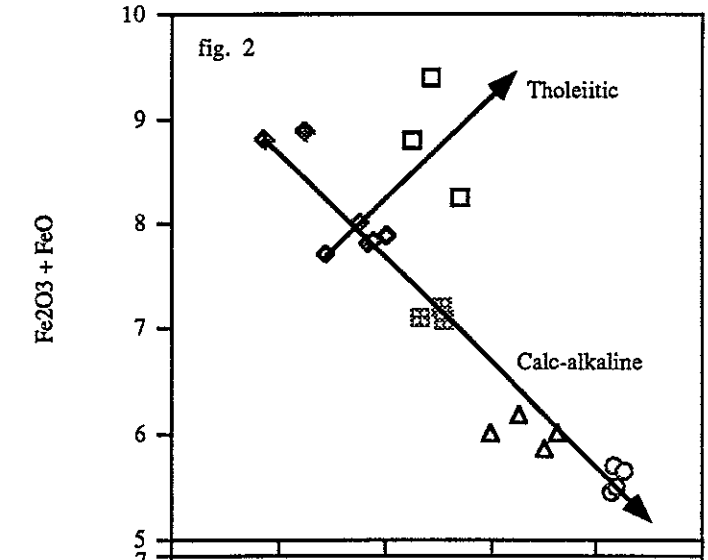
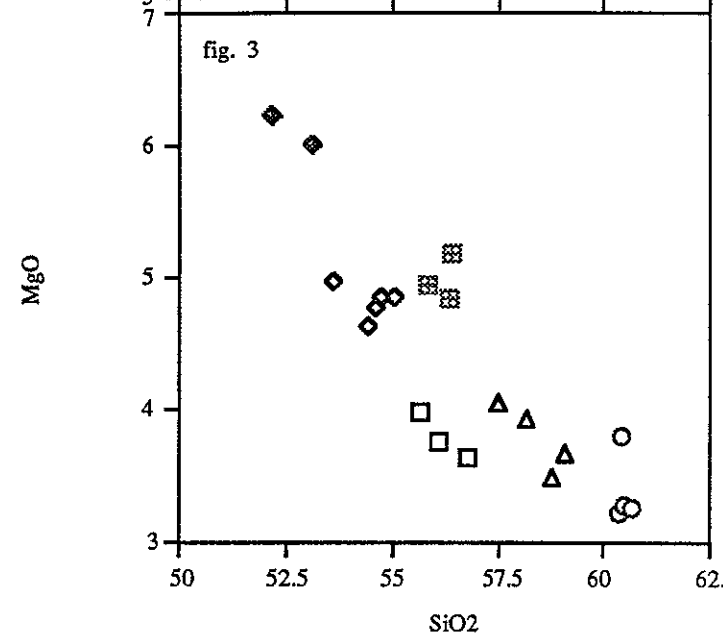


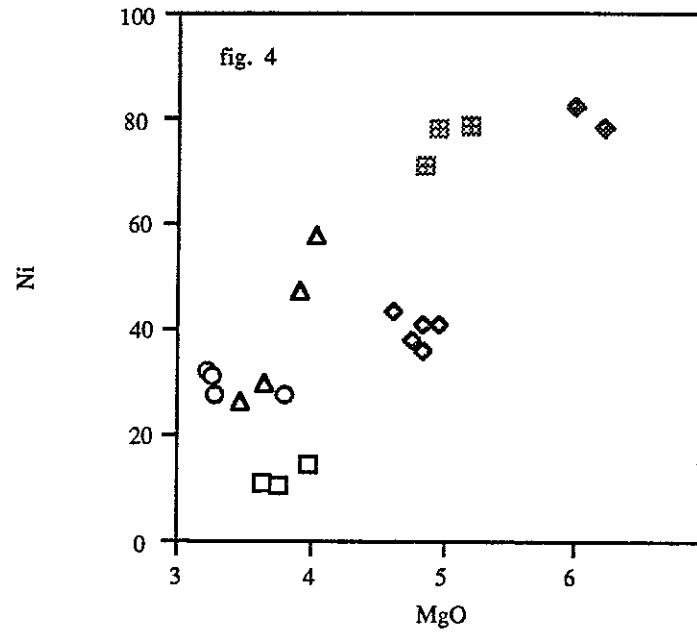
Figure 1. Geologic map of the study area, with K-Ar age dates.

Figure 2. The Fe2O3 vs. SiO2 graph shows the patterns of iron depletion or enrichment resulting from an increase in differentiation. The tholeiitic trend differs significantly from the calc-alkaline trend.



Figures 3-4. Both graphs show trends possibly related to olivine fractionation. Figure 3 shows MgO correlating negatively with SiO2, indicating olivine may be fractionating from the melt. The trend formed with Ni vs. MgO in figure 4 also supports a possible olivine fractionation process.





Legend

- TR-1
- TR-2
- West Varney Peak
- Harriman
- Whistler
- Lone Hill