A Petrological and Geochemical Investigation of Teritary to Quaternary Magma Evolution in the Mount Hood Region, Cascade Range, North America

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Abstract

Over the last 700,000 years, Mount Hood, Oregon has erupted chemically consistent andesitic lavas and pyroclastic flow deposits. Lavas generally fall into the calc-alkaline range with a restricted composition of approximately 50-65 wt% SiO_2. Major element geochemistry suggests Tertiary lavas have undergone more fractional crystallization and magmatic differentiation processes than those of the Quaternary. Evidence of magma mixing is also found in thin section analyses with inclusions, sieve textures, and resorbed phenocrysts. Trace element analyses indicate the absence of HSFE depletion relative to LILE in Quaternary samples, indicating Tertiary samples exhibit a closer relationship to arc magmas than what is seen in Quaternary samples. The depletion in Tertiary samples implies a modification of their upper-mantle source region by slab-derived fluids in the subduction zone to the west of the Cascades. The depletion also implies that Quaternary lavas underwent less interaction with subducted sediment or less magmatic differentiation than Tertiary samples.

Introduction

A geochemical and petrological analysis of lavas from Mount Hood, Oregon was executed in order to identify the magmatic processes that affect lava compositions in the Mount Hood area of the Cascade Range. The lavas generally exhibit a trend of increasing silica content from the Tertiary to the Quaternary. By analyzing petrographic characteristics, mineral compositions, and variations in major- and trace-element compositions of lavas, the role of fractional crystallization, magma mixing, and crustal assimilation can be explained in more depth.

Near the city of Portland, Mount Hood (see Figure 1 & 2) stands as Oregon's highest peak at 3425 meters above sea level [cone height of approximately 2300 meters] (Cameron and Pringle, 1987; Cribb and Barton, 1997; Hildreth, 2007). Mount Hood is one of fifteen composite volcanoes in the North American Cascade Range, which extends from British Columbia to northern California. It is the northernmost peak of the Cascades in Oregon (Cribb and Barton, 1997). The volcano has experienced a moderate amount of eruptive activity in recent geologic history, with initial eruptive activity in the Pleistocene and most recent activity occurring in the mid-1800s (Hildreth, 2007). The most recent substantial eruptive period is called the "Old Maid" eruptive period (Cameron and Pringle, 1987). The compositions of Mount Hood lavas have remained generally constant throughout the peak's >700,000 year existence, which makes Mt. Hood a desirable place to study the processes that affect lava composition (Darr, 2006; Cribb and Barton, 1997).

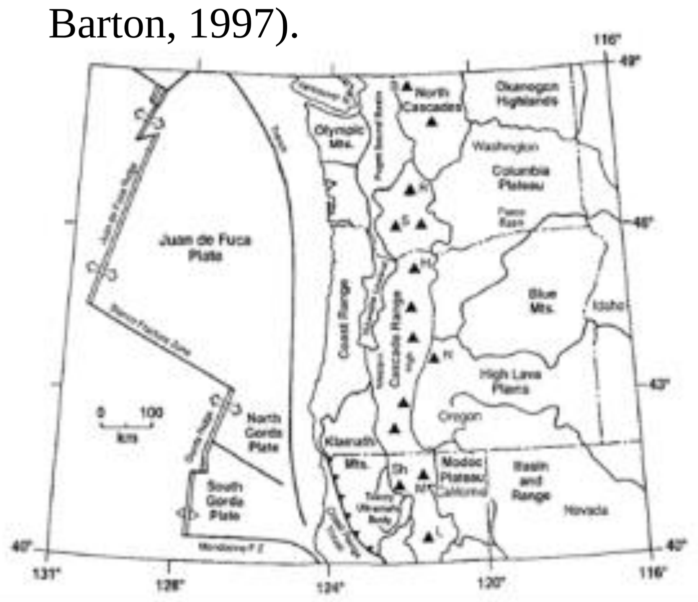

Figure 1. Map of the Cascade volcanic arc in relation to the Juan de Fuca subduction zone, slightly modified from Cribb and Barton (1997).

Figure 2. Mount Hood volcanic edifice, comprised of Quaternary period lava flows and pyroclastic deposits. Lower-lying hills comprise the Tertiary period volcanic base upon which the modern-day volcano is built. (Photo by Warner Cribb)

Purpose

This study identifies various evidence in lava samples from Mount Hood for magma mixing, fractional crystallization, and crustal assimilation in the magma chamber for Quaternary lavas.

Introduction Continued

The lava erupted from Mount Hood is derived from the Juan de Fuca subduction zone. As the Juan de Fuca plate is subducted under the North American plate, the overlying mantle wedge is partially melted and forms magma that ascends into the crust under Mount Hood. See Figure 3 for subduction zone diagram.

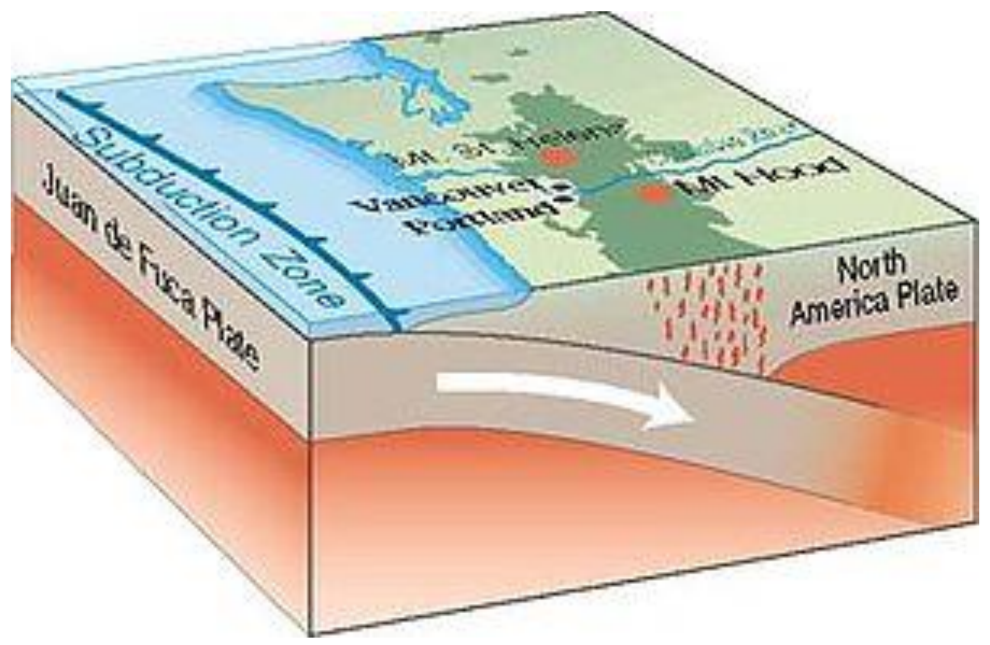

Figure 3. Depiction of the Juan de Fuca subduction west of the Cascade Range.

Methods

THIN SECTIONS

Mount Hood samples, collected by Dr. Warner Cribb, were taken from the research inventory of the Department of Geosciences at Middle Tennessee State University. Petrographic samples were analyzed in thin section (thickness – 28 microns) using a Leitz Wetzlar Polarized microscope. Figure 4 shows a sample thin section under microscope view.

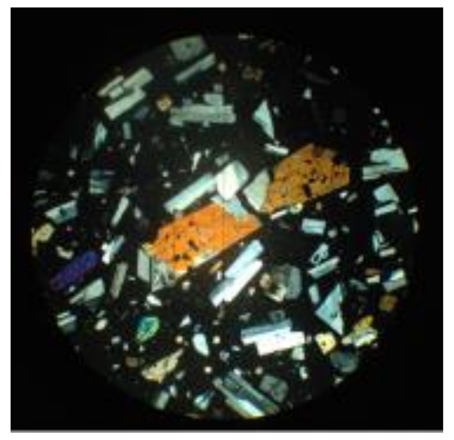

Figure 4. Typical petrographic assemblage of Tertiary lavas. The large orange and smaller colored crystals are pyroxene. Light-colored crystals are plagioclase. Black material is volcanic glass. Note the crystal boundaries are straight and continuous, indicating that crystals were in equilibrium with the surrounding melt.

Methods Continued

XRF SAMPLES

Gochemical samples were crushed using a Rocklabs bench-top ring mill for approximately five minutes. For sample pellet formation, 7 g of the powder was pressed for 15-20 minutes in a Carver hydraulic unit (model #3912) at 11 tons of pressure. For glass fusions, 0.8 g of powder was mixed with 1.9 g Lithium Tetraborate, 4.3 g Lithium Metaborate, and 2 drops of Lithium Bromide, then inserted into a Claisse fluxer. Samples were fused in platinum crucibles for 12 minutes, and then poured into platinum molds. The glass molds were allowed to cool for approximately 10 minutes before removing. See Figure 5 for pellet and fusion examples.

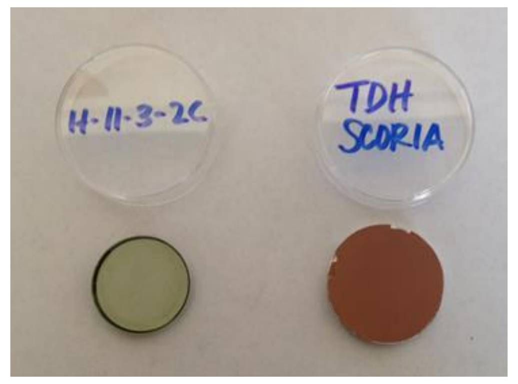

Figure 5. Examples of Glass Fusions and Pressed Pellets used in experimentation.

Sample fusions and pressed-powder pellets were chemically analyzed for major and trace elements in an Oxford MDX 1080+ x-ray fluorescence (XRF) spectrometer. Separate analytical methods were written for major element (SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O, P_2O_5) and trace elements (Ba, Nb, Rb, Sr, Y, Zr). Each method was calibrated using chemical reference standards certified by the U.S. Geological Survey and the National Institutes of Standards. The calibration data was then processed through linear regression algorithms, taking into consideration expected spectral interferences for each element. Next, select standards were analyzed as unknowns to check the known concentration of each element against its XRF calculated concentration. Regression curves were adjusted for any element whose calculated concentration fell outside the range of known concentrations specified for that element by the standard Certificate of Analysis.

Results

Petrographic and geochemical evidence for Mount Hood area lavas erupted in the Tertiary and Quaternary periods suggest especially different histories for these volcanic rocks. Tertiary lavas contain phenocryst and groundmass minerals which appear in chemical equilibrium with the groundmass, suggesting long-term periods of chemical equilibrium between the solid and melt phases. Quaternary lavas contain abundant phenocrysts containing disequilibrium textures, indicating the crystals were in disequilibrium with the surrounding melt. Geochemical characteristics of these lavas are equally distinct. Tertiary lavas exhibit major element oxide trends consistent with fractional crystallization as the dominant process controlling magma evolution. Quaternary lavas exhibit a restricted range of major element concentrations, indicating repeated periods of mixing between chemically distinct magmas. This can easily account for the disequilibrium textures observed in the Quaternary lavas. Furthermore, trace element characteristics of both Quaternary and Tertiary lavas are atypical of modern-day subduction zone melts in that they do not exhibit significant enrichment in LILE or depletion of HFSE. This suggests that only small amounts of sediment have been incorporated into the subduction zone source for the magmas, or that the subducted slab has undergone extremely limited dehydration beneath the mantle wedge, for as far back as the Tertiary period. However, significant differences in Sr concentrations between lavas erupted in these two periods strongly suggest unique magma source regions (Figure 6). Tertiary magmas appear to have a much stronger mantle signature, while Quaternary lavas appear to have a much stronger crustal signature. Higher concentrations of Rb in Quaternary lavas support this conclusion, in that Rb is likely to have been incorporated into the magmas as they traversed and chemically assimilated a pre-Quaternary Rb-rich crust.

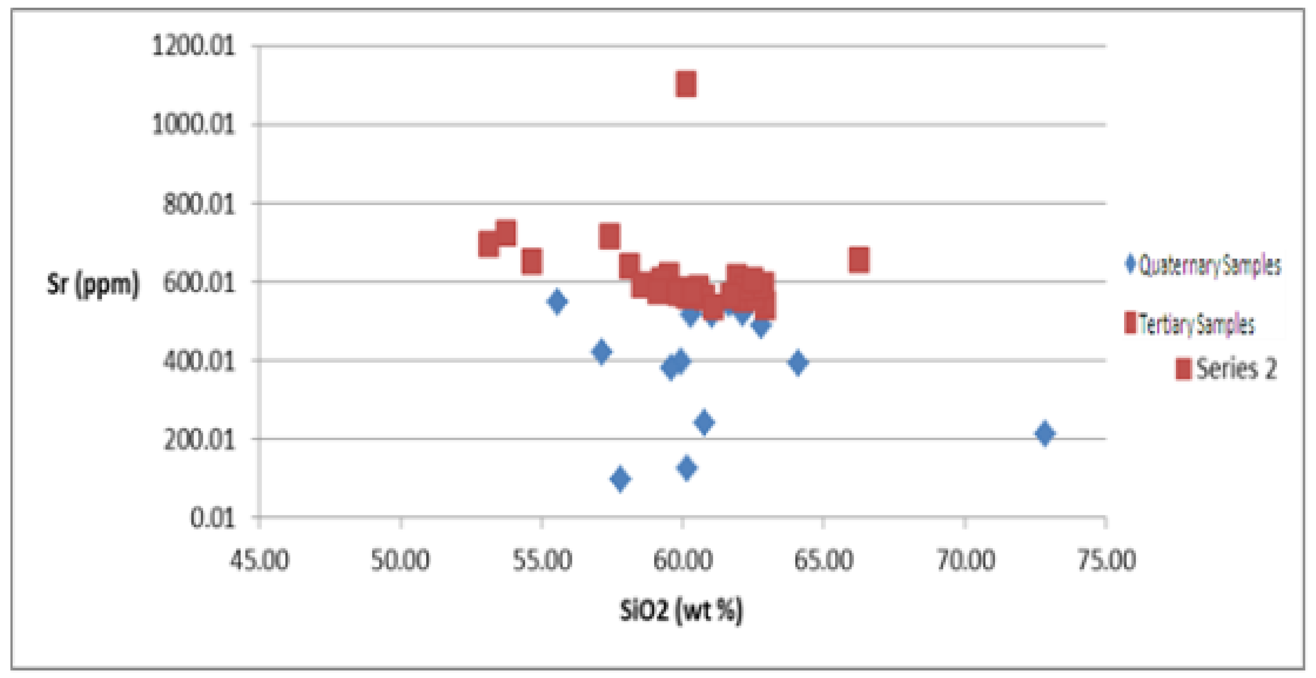

Figure 6. Comparison of Sr content in Quaternary and Tertiary samples

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References

Cameron, K. A. and Pringle, P.T., 1987, A detailed chronology of the most recent major eruptive period at Mount Hood, Oregon: Geological Society of America Bulletin, v. 6, p. 845-851.

Cribb, J.W., 1993, A petrologic and geochemical investigation of the evolutionary history of calc-alkaline magmas, Mt. Hood, Oregon [Doctoral dissertation]: Ann Arbor, Michigan, The Ohio State University, 399 p.

Cribb, J.W. and Barton, M., 1997, Significance of crustal and source region processes on the evolution of compositionally similar calc-alkaline lavas, Mt. Hood, Oregon: Journal of Volcanology and Geothermal Research, v. 76, issues 3-4, p. 229-249.

Darr, C.M., 2006, Magma chamber processes over the past 475,000 years at Mount Hood, Oregon: insights from crystal zoning and crystal size distribution studies [Master's thesis]: Corvallis, OR, Oregon State University, 154 p.

Hildreth, W., 2007, Quaternary magmatism in the Cascades: Geologic perspectives: U.S. Geological Survey Professional Paper 1744, 125 p.