A PETROGRAPHIC AND GEOCHEMICAL STUDY OF QUATERNARY VOLCANISM IN SOUTHERN OREGON

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Introduction: The purpose of this study is to better understand the complex history of the Cascade volcanic arc in Southern Oregon (Figure 1). Field work was performed by eleven participating Keck consortium students and encompassed a seventy-seven square mile area.

Geologic setting: Volcanic and associated tectonic events in the northwestern United States are believed to be the result of both subduction of the Juan de Fuca plate system beneath the continental United States and extension in the Basin and Range province (Guffanti and Weaver, 1988). The volcanic processes have evolved through time, probably due to changes in the rate and geometry of subduction (Hart and Carlson, 1987). The most recent volcanic events (<5 my) define the north-south trending Cascade volcanic arc from Mt. Garibaldi in the north to Mt. Lassen in the south. Within the state of Oregon, approximately 60% of the volcanic rocks are of andesitic composition and 30% are basalts (Guffanti and Weaver, 1988).

Field Observations: Thirteen discrete volcanic units were identified within a seven square mile area (Figure 2). Based on field observations and K-Ar dating, the oldest unit mapped was RK Kipuka (> 3.25 my) and the youngest was Crater Mountain (0.63 ± 0.05 my) (Mertzman, 1992-1993).

Analytical Techniques: 105 samples were collected in the field; thirty-three thin sections were cut and analyzed. Mineral assemblages, crystal sizes, and modal percentages together with distinctive petrographic textures were noted. Twenty eight rocks were selected for geochemical study. X-ray fluorescence, loss on ignition, iron titration and inductively coupled plasma methods were employed to ascertain major and trace element compositions.

Petrography:

Basalts : Burton Butte
Fine to medium grained holocrystalline rocks with anhedral grains of plagioclase (An 55) (55-65 modal % of minerals), olivine (15-20%, generally iddingsitized with poikilitic inclusions of spinel), magnetite (3-10%) and clinopyroxene (20-25%). The rocks are vesicular with strong diktytaxitic and seriate porphyritic textures. Crystals are up to 2 mm in size and infrequent glomeroporphyritic clumps are present.

Basaltic Andesite: Desolation Swamp, Esther Applegate
Fine to medium grained holocrystalline rocks with subhedral to anhedral phenocrysts (35-45 modal % of rock) of plagioclase (An 79 - An 66) (60-75 modal % of phenocrysts), clinopyroxene (15-20%), olivine (2-15%), magnetite (3-10%) and orthopyroxene (2-5%). Phenocrysts range from 0.1 mm to 0.8 mm in size. The rocks exhibit a seriate porphyritic texture with infrequent glomeroporphyritic clumps of the given minerals. Plagioclase dominates the felty groundmass with lesser amounts of clinopyroxene and magnetite.

Andesite: High Knob, Salt & Pepper, IDFC, Vulture Vesicular, Avalanche Lake, Esther Applegate, Winema, RK Kipuka, Crater Mountain
Fine to medium grained holocrystalline rocks with corroded anhedral to euhedral phenocrysts (30-50 modal % of rock) of plagioclase (An 63 - An 50) (50-70 modal % of phenocrysts), orthopyroxene (2-20%), clinopyroxene (5-15%), magnetite (5-10%), olivine (0-4%), iddingsitized olivine (0-3%) and scattered hornblende (Crater Mountain, Vulture Vesicular, Avalanche Lake and Winema, specifically). Phenocrysts (0.05 mm to 1.5 mm in size) are found as discrete crystals or in glomeroporphyritic clumps with a general hiatal porphyritic texture. The pilotaxitic matrix consists predominantly of plagioclase and lesser amounts of magnetite. Diktytaxitic textures are noticed in some of the more mafic samples.

Dacite: Hub Hill, Muddy Spring
Primarily cryptocrystalline rocks with anhedral to euhedral phenocrysts (15-20 modal % of rock) of plagioclase (An 62 to An 54) (60-70 modal % of phenocrysts), clinopyroxene (10-25%), orthopyroxene (5-15%) and magnetite (3-5%) in a plagioclase rich matrix. Phenocrysts range from 0.1mm to 2 mm in size with infrequent glomeroporphyritic clumps of plagioclase and clinopyroxene. Some plagioclase and clinopyroxene crystals have corroded exteriors and interiors. The groundmass displays a trachytic texture.

Geochemical Data: Rock compositions range from basalt to dacite based on wt. % SiO_2. Burton Butte is the sole basaltic unit and is classified as a high-alumina olivine tholeiite. The basaltic andesites and andesites generally have intermediate K_2O compositions with High Knob and Avalanche Lake and certain Esther Applegate and Salt and Pepper rocks having low concentrations of potassium. All samples analyzed are of subalkaline composition; an AFM diagram indicates the lavas are calcalkaline with the exception of Burton Butte and Muddy Spring which are tholeiitic (Irvine and Baragar, 1971). Possible parallel trends depicted in plots of K and Rb versus SiO_2 (Figures 3A and 3B, respectively) might indicate two distinct primary magma compositions that have undergone similar differentiation processes (Wilson, 1989).

Discussion: The varied whole rock compositions can be possibly explained by differing degrees of fractional crystallization of primary basaltic magma. Evidence for crystal fractionation can be found in figure 3C. Zr behaves incompatibly with all major phenocryst phases in the rocks studied and therefore its concentration should increase with increasing amounts of crystal fractionation. Wilson (1989) also suggests that low concentrations of MgO in rocks indicate more evolved and fractionated magma (Figure 3D). Furthermore, decreasing amounts of Ni (K_d(magnesian olivine) = 14) provide evidence for olivine fractionation (Figure 3D) (Henderson, 1982).

The tholeiitic composition of Burton Butte and Muddy Spring may result from early crystal fractionation under more reducing conditions than other rocks studied, thus promoting iron enrichment. However, the chemistry of Burton Butte suggests rather primitive compositions which limits fractionation. Iron enrichment is proposed to occur under conditions where the crust is generally less than 25 km.(Gill, 1981).

High silica contents can result from extensive low pressure fractionation of magnetite, plagioclase, pyroxene ± olivine in sub-volcanic magma chambers within or at the base of the crust (Figure 3A) (Gill, 1981). SiO_2 enrichment can also occur through fractionation of hornblende from hydrous magmas. The growth of hornblende in subduction environments is related to dehydration of subducted crust at depths of 80-125 km. Released hydrous fluids move into the mantle wedge and the base of the continental crust, potentially inducing growth of metasomatic amphibole (Wilson, 1989). As hornblende bearing magmas rise through the crust and are subject to lower pressures, hornblende is resorbed and replaced by magnetite, plagioclase, clinopyroxene ± orthopyroxene (Gill, 1981). This process of hornblende growth and resorption is probably recorded in Crater Mountain, Avalanche lake and Vulture Vesicular lavas, of which Crater Mountain is a likely source vent.

SiO_2 enrichment may also be a consequence of crustal assimilation. As magmas ascend through somewhat more silica rich crustal rocks and stagnate in reservoirs, wall rocks can be partially melted and assimilated into the magma body, increasing the SiO_2 content. The amount of assimilation under such conditions is dependent on the temperature of the magma, the composition of crustal rocks and duration of contact between the two. Gill (1981) points out that yttrium contents of less than 15 ppm are restricted to andesites erupted through crust greater than 30 km thick. Therefore, the higher silica of certain samples with <15 ppm Y (figure 3E) might indicate greater amounts of crustal assimilation due to magma moving through thicker crust. Also, high concentrations of LIL's (K, Ba, and Rb) (Figures 3A, 3B and 3C, respectively) further suggests passage of andesitic magmas through thicker crust (Gill, 1981). It must be noted that geothermal properties limit the amount of assimilated crust to 10-20% of the total magma volume (Wilson, 1989).

Arguments also have been made for compositional variations in rocks due to magma mixing. The occurrence of corroded phenocrysts in many of the rocks studied may be interpreted as the reaction of unstable mineral phases in mixed magmas, however P-T changes may also induce the same reactions. Also, scatter found in many of the variation diagrams might result from mixing of magma (Gill, 1981).

Conclusions: The varied compositions of rocks analyzed are related to the differentiation of primary magmas formed from the subduction of oceanic crust beneath the North American plate. Principle processes associated with differentiation include crustal fractionation of magmas, assimilation of crustal rocks and possible magma mixing. Other important factors believed to take part in the development of magma types include the presence of hydrous fluids and variations in temperature and pressure regimes associated with magma genesis. Heterogeneities in the sources material may also influence the compositions of magmas produced in this segment of the Cascade volcanic arc.

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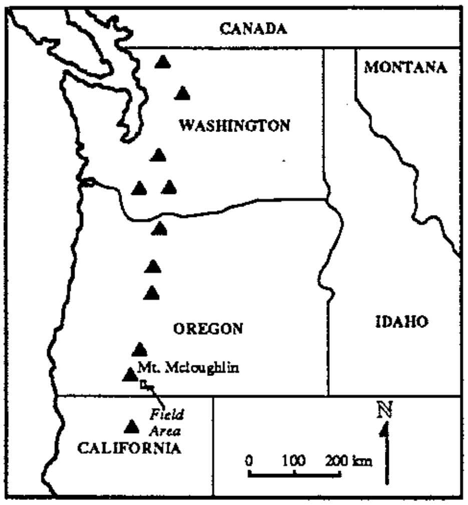
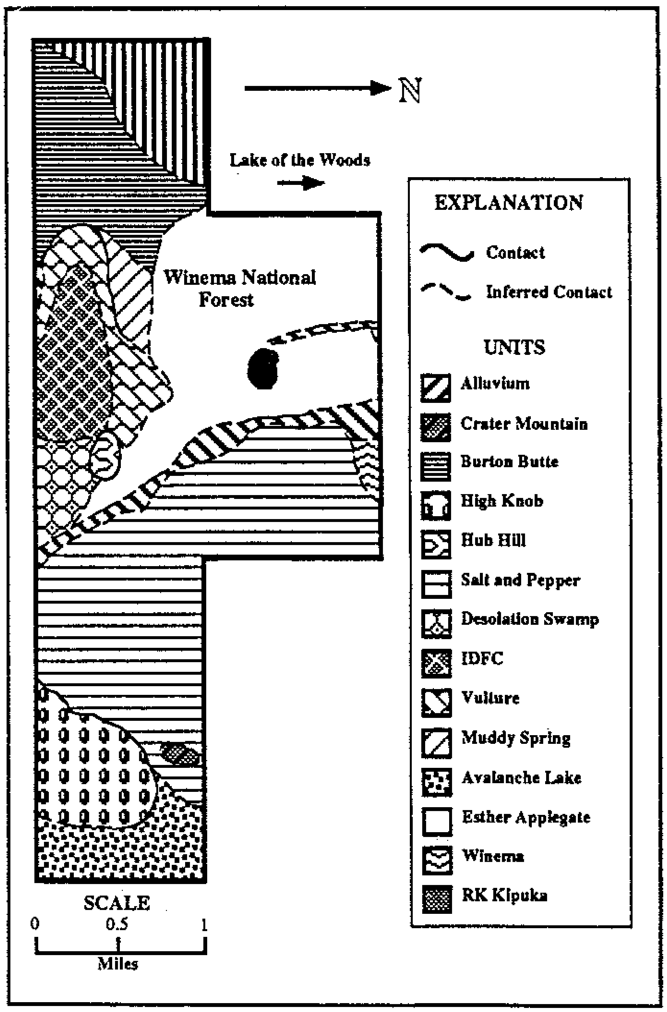


Figure 1 (*above*). Distribution of major volcanic vents in the present Cascade arc (Baily and Conrey, 1992).

Figure 2 (*right*). Simplified map of the seven square mile field area showing the distribution of rock types. (Units are listed from youngest (top) to oldest.)



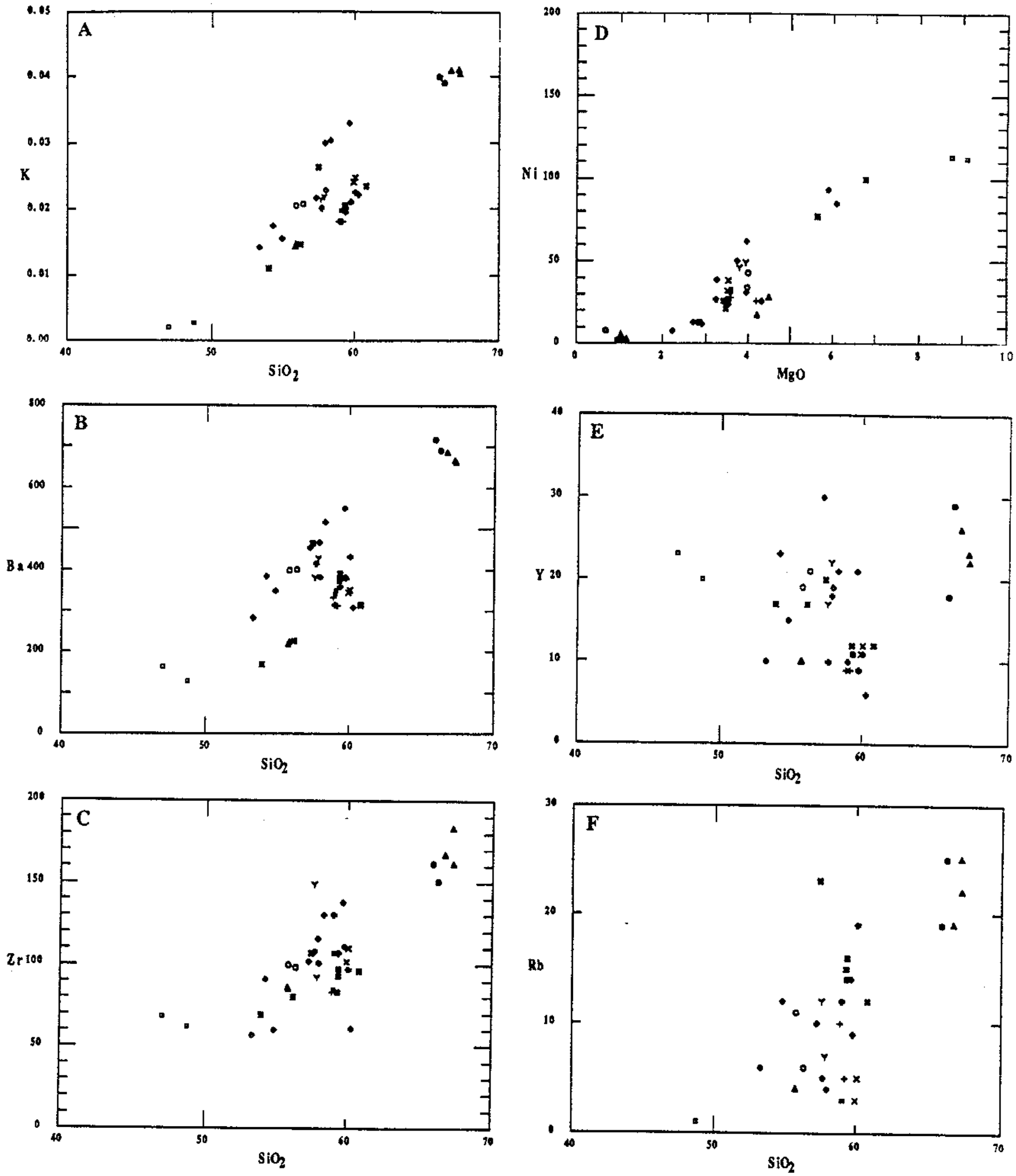


Figure 3. Variation diagrams of analyzed quaternary Cascade volcanic rocks from southern Oregon: A) K vs. SiO_2 plot; B) Ba vs. SiO_2 plot; C) Zr vs. SiO_2 plot; D) Ni vs. MgO plot; E) Y vs. SiO_2 plot; F) Rb vs. SiO_2 plot.