

A Chronological, Petrological, and Geochemical Study of Pliocene and Quaternary Volcanics Near Mt. McLoughlin, southcentral Oregon

Benjamin E. Surpless
Carleton College
Northfield, MN 55057

Introduction

A 7 mi² field area is located several miles southeast of Mt. McLoughlin, a High Cascades composite volcano (Fig. 1). The area contains nine lithologic units distinguished on the basis of topography, field relationships, hand sample analysis, major and trace element geochemistry, and thin section petrography. These porphyritic, calc-alkaline and tholeiitic units (Fig. 2) range from basalt to andesite, with most units falling in the basalt to basaltic andesite range (Fig. 3a). The erupted lavas in the Mt. McLoughlin area are dry, lacking hydrous mineral assemblages (i.e. hornblende), and K₂O contents range from 0.1% to 1.3%, common for subduction-related melts generated by hornblende-rich sources at 80-100 km depth (Mertzman, pers. comm., 1992).

The roles that extension and subduction-related compression play in the southern High Cascades is debatable. The Cascade Range is a subduction-related arc, but Bailey and Conrey (1992) hypothesize that much of the basaltic volcanism in the central and southern Cascades displays characteristics of an extensional tectonic regime related to Basin and Range extension. Constancy in eruptive compositions of HAOT's (high-alumina olivine tholeiites) from 16 Ma to the present indicates the presence of an homogeneous oceanic mantle source beneath the northwestern U.S.

Mineralogy/Petrography

The nine lithologies listed stratigraphically in Figure 1 have several mineralogical characteristics in common. The units have a groundmass with well-defined grain boundaries (visible on thin section scale) that is mostly holocrystalline and dark to medium grey in color. In some units (i.e. Long Creek), brown glass is present, obscuring grain boundaries and relationships. The visible phenocryst assemblage (with crystals ranging up to 3.0 mm in diameter) consists of plagioclase, +/- olivine, +/- clinopyroxene, +/- orthopyroxene, and +/- magnetite. Microphenocrysts of apatite are present but only identified in thin section.

Plagioclase makes up 65% to 75% of each unit (all percentages listed are modal) and ranges compositionally from 45% to 55% albite (andesine to labradorite). Phenocrysts of plagioclase are typically lath-like, but equant phenocrysts are also common (especially in the Fourmile andesite). Complex crystal growth patterns and oscillatory zoning are widespread, a characteristic of High Cascades volcanics (McBirney, 1984). Trachytic flow texture in the lath-like plagioclase crystals is common.

Olivine phenocrysts are present in most samples, ranging from 1-2% in the andesite to 8-10% in several basalts. They are subhedral and highly fractured in thin section, with a tendency toward euhedral crystal form in the basalts and anhedral crystal form in the higher silica basaltic andesites and andesites. Many larger phenocrysts of olivine exhibit red-brown iddingsite rims in thin section which indicate post-crystallization oxidation at 200-300 degrees C (Mertzman, pers. comm., 1992).

Pyroxene (<1% to 15%) is present as *orthopyroxene* and *clinopyroxene*. In the basaltic andesite and andesite units, the pyroxenes (especially orthopyroxene) display subophitic texture and are euhedral to subhedral as microphenocrysts (up to 0.4 mm in diameter). In basalts, clinopyroxene and orthopyroxene are limited to the groundmass and are typically subhedral to anhedral. In many cases, pyroxenes are closely associated with olivine phenocrysts. Tabular crystals appear to nucleate around the borders of the larger olivine crystals, forming a rim of pyroxene around an olivine core. This might indicate a compositionally evolving source where pyroxenes are more stable than the phenocrysts of olivine just before the time of extrusion.

Magnetite (2%-5%) occurs as minute inclusions in plagioclase, pyroxenes, and olivine and as a microphenocryst. In many cases, the crystals are visible in hand sample, giving the groundmass a "peppered" appearance. Grain size ranges from about 0.023 mm in the groundmass to 0.2 mm in microphenocrysts.

Apatite (<1%) is euhedral to subhedral. Elongate crystals (<0.2 mm in length) are the dominant crystal form.

Glomeroporphyritic clumps are present in several units. Garcia and Jacobsen (1979) theorize that these crystal clots and their mineral assemblages are the result of the breakdown of amphibole crystallized at high pressure. Amphiboles react with the magma at lower pressures, forming an assemblage of plagioclase, augite (clinopyroxene), hypersthene (orthopyroxene), and magnetite. The clots are typical calc-alkaline crystal clots composed of plagioclase, olivine, +/- orthopyroxene, +/- clinopyroxene and magnetite.

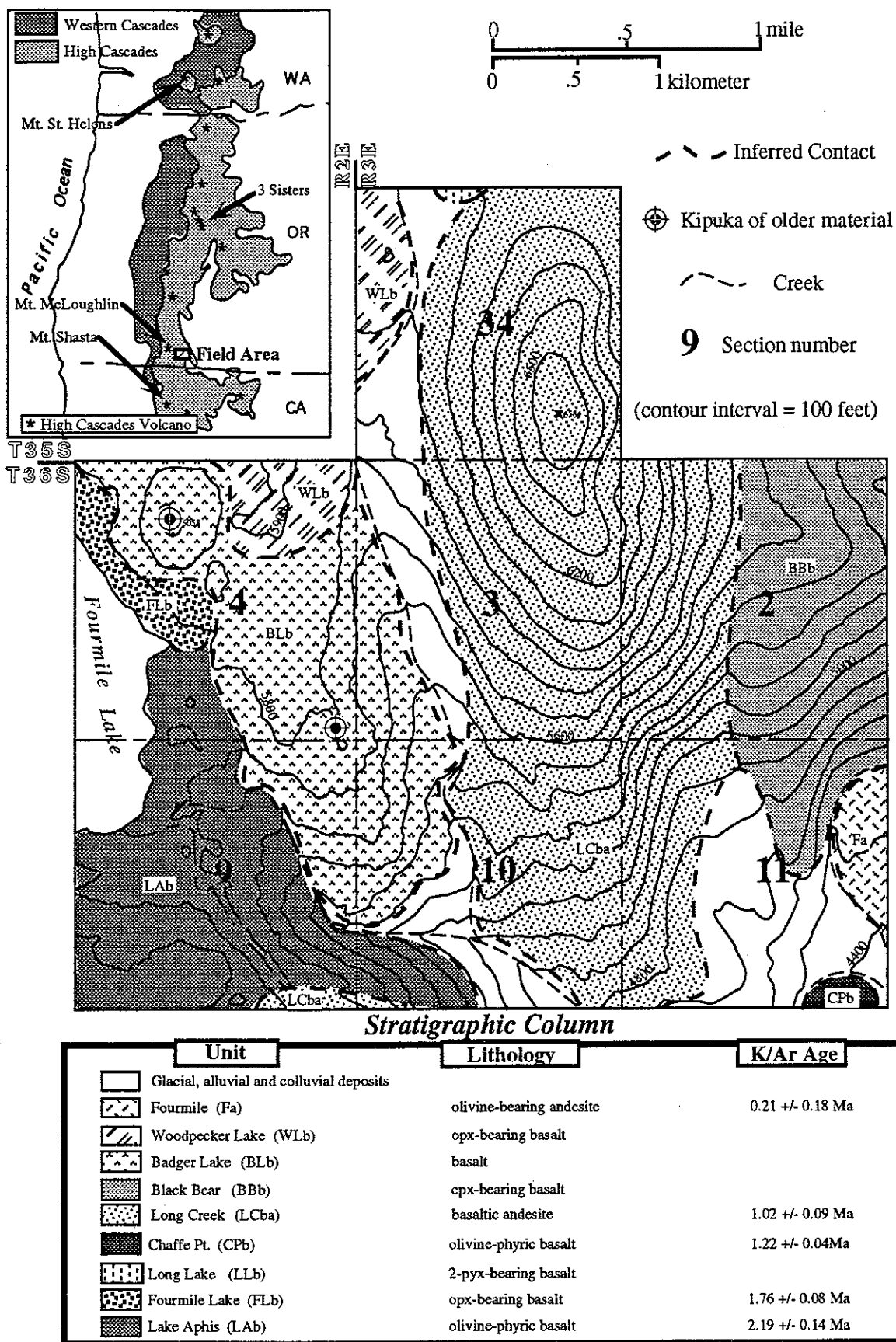


Figure 1. Stratigraphic column and geologic map displaying the distribution of distinct lithologies in the field area.

Unit Symbols

- Fourmile Δ
- Woodpecker Lk. \square
- Badger Lake \blacksquare
- Black Bear \bullet
- Long Creek $+$
- Chaffe Pt. \otimes
- Long Lake \circ
- Fourmile Lk. \boxplus
- Lake Aphis \blacktriangle

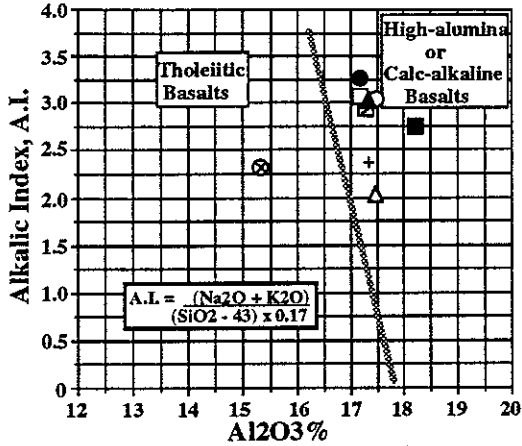


Figure 2. The Alkali Index vs. Al_2O_3 diagram. Each symbol indicates average unit composition. The grey line divides the subalkalic field into tholeiitic and calc-alkaline compositions (after Wilson, 1989).

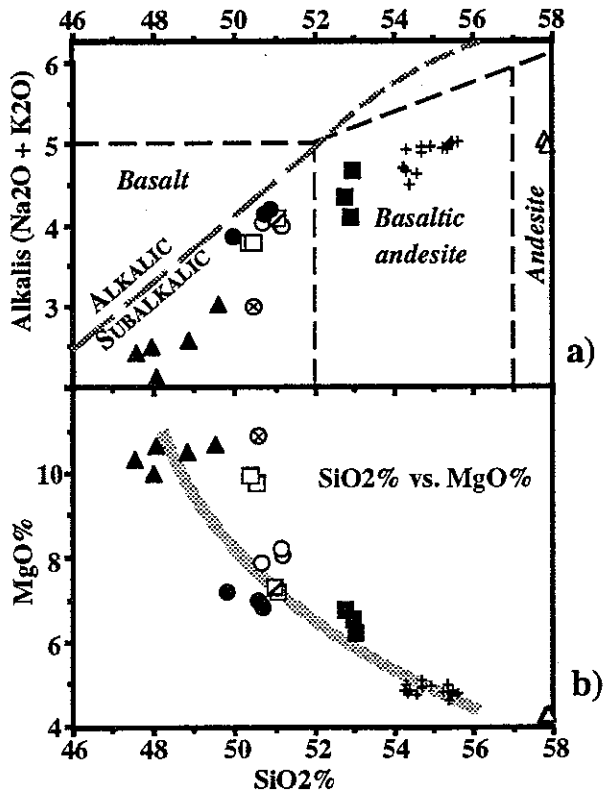


Figure 3a. Harker diagram vs. Alkalis. The lithologies of the area display subalkaline character and range from basalt to andesite. (basalt-andesite plot after Le Bas, et al., 1986; alkalic/subalkalic dividing line after Miyashiro, 1974)
 Figure 3b. Harker diagram vs. MgO. The trend indicated by the grey line displays a liquid line of descent expected in a magma chamber undergoing simple, closed-system fractional crystallization.

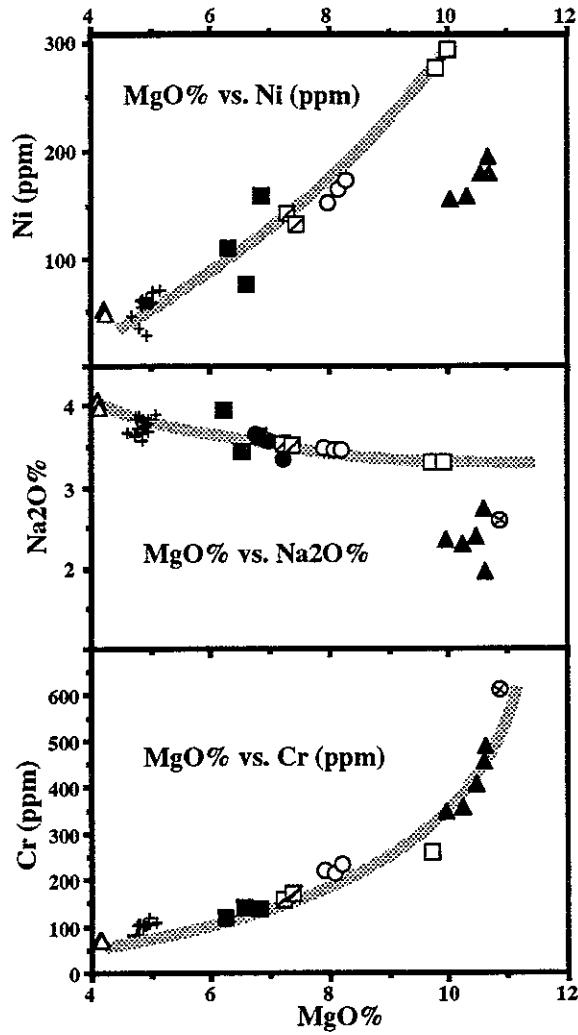


Figure 4. Ni, Na₂O, and Cr plotted vs. MgO. Liquid lines of descent indicate compositional evolution, but the Lake Aphis unit (\blacktriangle) and Chaffe Pt. unit (\circ) display deviations from the fractionation trend on the Na₂O plot. The Lake Aphis unit also displays marked deviation on the Ni plot. (Chaffe Pt. Ni data is unavailable.)

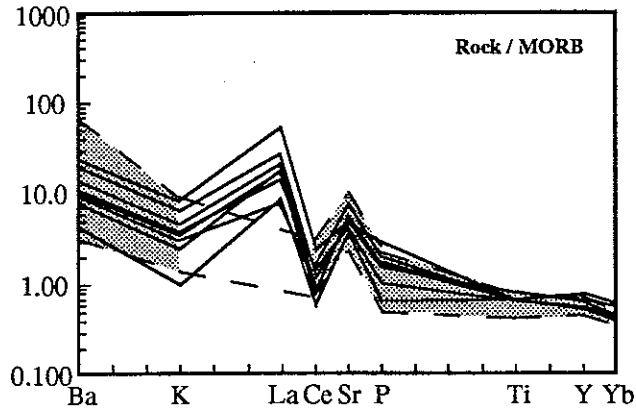


Figure 5. Spiderdiagram normalized to MORB composition. Each lithology is shown as a single line. The shaded section is from Pearce (1983). It displays common trace element abundances in rocks with significant subduction components. (La data wasn't available)

Magmatic Evolution and Fractional Crystallization

Fractional crystallization is one of several processes that play an important role in the compositional evolution of magmas. Chemical variation diagrams, useful tools in examining trends indicative of differentiation processes, show that fractional crystallization has probably taken place in the genesis of distinct lithologic units in the area (Figs. 3b and 4).

A likely fractional crystallization trend is shown in figure 3b, where SiO₂% and MgO% are plotted against each other. The trend is not well-defined, but much of the scatter in chemical variation diagrams is the result of analyses of porphyritic samples (Wilson, 1989). A stronger trend can be seen in the MgO vs. Na₂O variation diagram (Fig. 4). The diagram displays a fractional crystallization liquid line of descent, but the Chaffe Pt. and Lake Aphis basalt units do not follow the trend. The compositional differences do not completely disassociate the units from other lithologies in the area, but these elemental deviations eliminate the possibility of closed-system fractional crystallization.

Fractional crystallization of individual minerals is observed on trace element variation diagrams. Minerals present in many units of the study area (olivine, clinopyroxene, and magnetite) contain trace elements that indicate the mineral's abundance in that unit. Ni is highly compatible in the crystal structure of olivine, so trends in Ni abundance will correspond positively with the crystallization of olivine. Cr is compatible with both clinopyroxene and magnetite.

Figure 4 displays trends in the plots of MgO vs. Cr and MgO vs. Ni. The more basaltic end members show higher abundances of Cr and Ni than the basaltic andesite and andesitic end members. The extent of crystallization of olivine is traced by the abundance of Ni. The trend in Cr values shows a positive correlation with magnetite (present in greater abundances in less siliceous units) indicating higher compatibility with magnetite at the crystallization environment.

What might be expected is that a stratigraphy could be taken directly from a chemical variation diagram (i.e. SiO₂% vs. MgO%), but this is not the case. Examination of the unit stratigraphy (Fig.1) shows that the individual units were erupted in a random time sequence, *unrelated to their order on the liquid lines of descent* (Figs. 3b and 4). Trends shown on these diagrams indicate evolutionary trends of several batches of parental magma of approximately similar composition (Wilson, 1989).

Discussion

Geochemical analyses of lithologic compositions in the area have delineated three unit types. The Chaffe Pt. olivine-phyric basalt is tholeiitic (Fig. 2) and displays Cr abundances characteristic of mantle composition (Cr in abundances of 500-600 ppm (Fig. 4) indicate a mantle source (Wilson, 1989)). The Chaffe Pt. unit's tholeiitic composition might relate it compositionally to HAOT, which is common in the area. The Lake Aphis olivine-phyric basalt appears closely related to the Chaffe Pt. unit, but its calc-alkalic composition makes a true compositional relationship impossible. The Lake Aphis basalt is more likely related to the other units in the area despite the unit's deviation from liquid lines of descent on variation diagrams.

The trace element signatures of every unit are shown in the spiderdiagram in Figure 5. The unit's signatures show little similarity with that of mid-ocean ridge basalt. Spiked spiderdiagrams like Figure 5 indicate a major subduction component in magma generation (Wilson, 1989). Pearce (1983) used several well-established, subduction-related calc-alkaline basalts in developing a spiderdiagram that typified calc-alkaline basalts produced by the subduction of a lithospheric plate. The range in compositions of those lavas is shown in Figure 5 (shaded). This produces strong evidence for subduction-related magma generation without a strong MORB component or significant crustal contamination. A possible source for the extrusives in the area is a large, shallow-level magma chamber periodically recharged by pulses of magma produced by partial melting of mantle material above the subducting oceanic plate. This might explain why the area's volcanic stratigraphy does not follow a simple, unidirectional fractional crystallization trend.

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