PETROLOGY AND GEOCHEMISTRY OF BASALTIC ANDESITES, MOUNT MCLOUGHLIN, OREGON

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Purpose: Mount McLoughlin, located 30 miles east of Medford in southern Oregon, consists mainly of mafic blocky lava flows. This study characterizes the petrology of these volcanics from field relations, petrography, and geochemistry. These data are used to constrain the origin and evolution of the McLoughlin lavas and their relationship to the regional tectonics.

Geologic Setting: Mount McLoughlin, a 2900 meter high composite cone located between Mount Shasta and the Crater Lake Volcanics, belongs to the modern High Cascades province. The Early Cascades formed in the Late Miocene, although the formation of the large peaks occurred in the last million years (McBirney, 1978). Guffanti and Weaver (1988), among others, apply a subduction model of the Juan-de-Fuca and Gorda North plates below the leading edge of the North American continental plate as a source for the magma of the Cascades volcanics. Varying amounts of crustal and fluid contamination, and processes such as magma mixing and fractionation yield the calc-alkaline and tholeiitic lavas found in the continental arc setting of the High Cascades. This study will focus on the role of these processes in the development of the Mount McLoughlin and adjacent flows.

Field Descriptions: Field research included three weeks mapping and sampling of an area of six square miles (9.7 km2) on the southern flank of the volcano. Five distinct units were identified: Rye Spring - an older platform lava, three units from present-day Mount McLoughlin, and a flow from the nearby Brown Mountain vent. Outcrops range from extensive blocky lava flows to isolated, weathered boulders whose phenocrysts include pl ± ol ± cpx ± opx. Typical flows are 400 meters long, 150 meters wide, and 3 to 5 meters thick. Unique flow structures such as grooves or compression troughs resulted from the paleotopography.

Petrography: The following unit descriptions, based on twenty-eight thin sections, progress from oldest to youngest. Point counts of a representative thin section from each unit gave modes. The Michel-Levy technique was used to determine the plagioclase compositions.

1. Rye Spring: This basaltic andesite (defined by geochemistry) exhibits hypidiomorphic textures with mafic minerals having ragged edges. Mafic alteration, including iddingsite, indicates minor exposure to weathering. The plagioclase (An 60) displays a zoned tabular habit, slightly aligned with the flow direction. The orthopyroxene is probably bronzite due its non-pleochroic nature. Mode: pl- 64%, glass- 11%, ol- 5%, mt- 5%, cpx- 4%, bzt<1%, vesicles- 6%, alteration minerals- 2%, matrix mafics- 2%.

2. Mt. McLoughlin I: The olivine-phyric basaltic andesite also shows zoned, tabular plagioclase (An 62) crystals and trace alteration of the olivine. Plagioclase or olivine sometimes enclose the euhedral opaques. Mode: pl- 52%, cpx- 9%, mt- 6%, ol- 4%, hyp- 2%, glass- 14%, vesicles- 10%, m. mafics- 5%.

3. Mt. McLoughlin II: This two-pyroxene basaltic andesite has porphyritic and glomeroporphyritic textures in thin section and hand specimen. Phenocrysts of pl ± ol ± opx ± cpx often exhibit partially-melted cores. The groundmass plagioclase is generally subtrachytic. Olivine crystals are occasionally rimmed by pyroxene. One flow of this unit contained hypidiomorphic cognate inclusions containing higher amounts of glass, as well as one "xenolith" consisting of euhedral plagioclase (An 90) and magnetite with trace orthopyroxene and olivine. Mode: pl (An 60)- 73%, cpx- 7%, mt- 5%, hyp- 4%, opx- 3%, glass- 4%.

4. Mt. McLoughlin III: This unit is very similar to the McLoughlin II, with the glomeroporphyritic clots more evident. McLoughlin II and III are separated on the basis of their field relations and their petrographic textures although they have almost identical geochemistry. The plagioclase again appeared zoned and tabular with the large phenocrysts having partially-melted cores. A few of the clinopyroxene and orthopyroxene crystals had small anhedral olivine rims. Mode: pl (An 60)- 76%, mt- 4%, cpx- 4%, hyp- 3%, ol- 2%, glass- 6%.

5. Brown Mountain: This basaltic andesite is the most silicic of all the units. The laths (An 58) are subtrachytic with a few of the cores resorbed. Lath-like microphenocrysts of orthopyroxene show strong pleochroism. Mode: pl- 44%, glass- 38%, hyp- 13%, mt- 1%

Geochemistry: X-Ray Fluorescence and the ICP analysis provided the major, minor, and trace element data for twenty-one samples. Five samples were examined by Instrumental Neutron Activation Analysis for concentrations of Large Ion Lithophiles and Rare Earth Elements. Accuracy levels fell generally within 8% deviation for major and minor elements except phosphorus (15%), and 10% for trace elements except barium, ytterbium, and tantalum (26%, 11%, and 18%).

The geochemistry characterizes all units as basaltic andesites with silica concentrations ranging from 53 to 59 weight percent, although Rye Spring borders on being a high-alumina basalt. The range of silica concentrations varies too little to determine a calc-alkaline or tholeiitic trend; all samples plot within the calc-alkaline field of Irvine and Baragar (1971) and Miyashiro and Shido (1975). That the rocks plot as both calk-alkaline basalt/andesite and tholeiitic andesite on Jensen's cation plot (1976) suggests that the McLoughlin lavas may be transitional between the tholeiitic and calc-alkaline series (e.g. Green, 1980).

One of the Rye Spring samples had unusually high strontium concentrations compared to other members (figure 1) and on the basis of its petrography may be a sub-unit or a separate unit. The REE plot of the Rye Spring and McLoughlin units show slight LREE enrichment with a small positive europium anomaly (figure 2).

Discussion: Differentiation processes such as crustal assimilation, fluid transport, magma replenishment, and crystal fractionation vary in importance for the formation of the Mt. McLoughlin and adjacent magmas. Fluid transport is a minor constituent as shown by low LIL levels such as K, Rb, Ba, and Th, for calc-alkaline rocks (figure 1). However, higher Zr concentrations in the early units suggests slight crustal assimilation. Either assimilation or accumulated plagioclase may account for elevated strontium levels and the positive europium anomaly.

The size and variation within the study area are too limited to test magma mixing. The rimmed and partially-melted glomeroporphyritic crystals signal disequilibrium within the melt. The pyroxenes rimmed with olivine in McLoughlin III, however, could stem either from magma mixing or from an influx of more mafic or original parent magma into the fractionating chamber. (Similar pleochroism between these phenocrysts and groundmass hypersthene suggests that the phenocrysts originated in the melt, not merely as plucked xenocrysts.) A change in pressure/ temperature conditions, however, would account for a liquidus that could crystallize pyroxene before olivine. Microprobe data would allow further interpretation.

Crystal fractionation seems to account for most of the magma evolution. The phases indicating fractionation trends within the McLoughlin and Brown Mountain rocks include olivine (Ni vs. SiO2, figure 3a), pyroxene (Sc vs. SiO2, figure 3b), and magnetite (TiO2 vs. SiO2, V vs. SiO2). Plagioclase fractionation, on the contrary, does not figure importantly in melt differentiation (CaO vs. Al2O3, Sr vs. SiO2) The LIL and REEs do not confirm any fractionation trend. The LREE should become enriched while the HREE levels decrease, during fractionation of mafic minerals through time. Instead the Rye Spring and Mt. McLoughlin rocks show an overall depletion of REE through time (figure 2). Thus, the spectrum of REE patterns, the shapes of which show similarities between units, indicate the rocks have not solely evolved by fractionation.

The simplest model for the evolution of the melts, then, would involve two separate systems. Rye Spring at 6.06 + 0.1 m.a. (Mertzman, unpublished data) formed in a system geochemically distinct from that of the later rocks. Then, a separate crustal magma chamber formed, in which fractionation took place with some replenishment of parent magma. Intermittent eruptions led to the emplacement of the McLoughlin and the neighboring Brown Mountain flows. Partial melting of the subducted plate and interaction with the overlying mantle wedge could have supplied the parent magma (Green, 1980). However, extensive modeling of the parent melt has not yet been performed.

Aside from Mount McLoughlin's location in the High Cascades, the geochemical data support a subduction-related genesis for the volcano. All of the units plot within the subduction basalt region of Wood's (1979) Hf-Th-Ta diagram and within the continental arc/margin zones of diagrams by Bailey (1981), Pearce (1983), and Wood (1979). Also trace element spider plots follow the continental calc-alkaline parameters defined by Condie (written comm.).

Conclusions: The mafic to intermediate flows composing and surrounding Mount McLoughlin show evidence of crystal fractionation. Crustal and hydrous fluid contamination appear minimal. Although Mount McLoughlin is more mafic than the imposing peaks of the High Cascades, its genetic history is connected to the subducted oceanic plate beneath the edge of the North American plate. As a volcano composed primarily of basaltic andesites, Mount McLoughlin is perhaps a transitional eruptive feature between the intermediate-composition peaks, such as Mount Shasta and Mount Rainier, and the widespread intra-peak basalt flows.

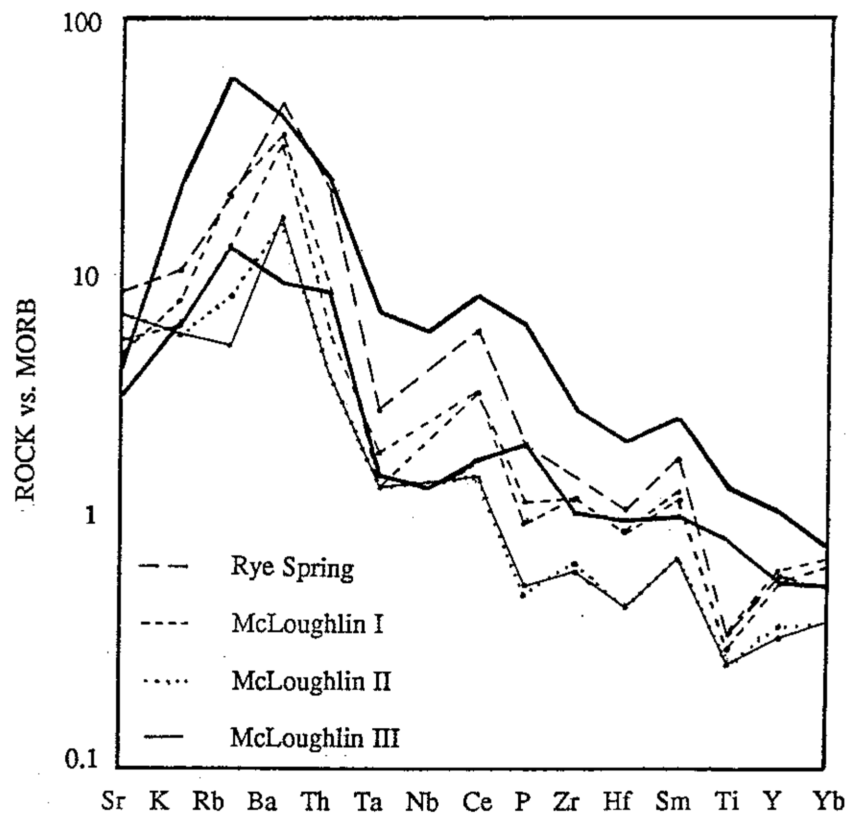

Figure 1: This spider plot displays trace element levels for the Rye Spring and McLoughlin units. The heavy lines represent the parameters for continental margin calc-alkaline basalts (Condie, written communication).

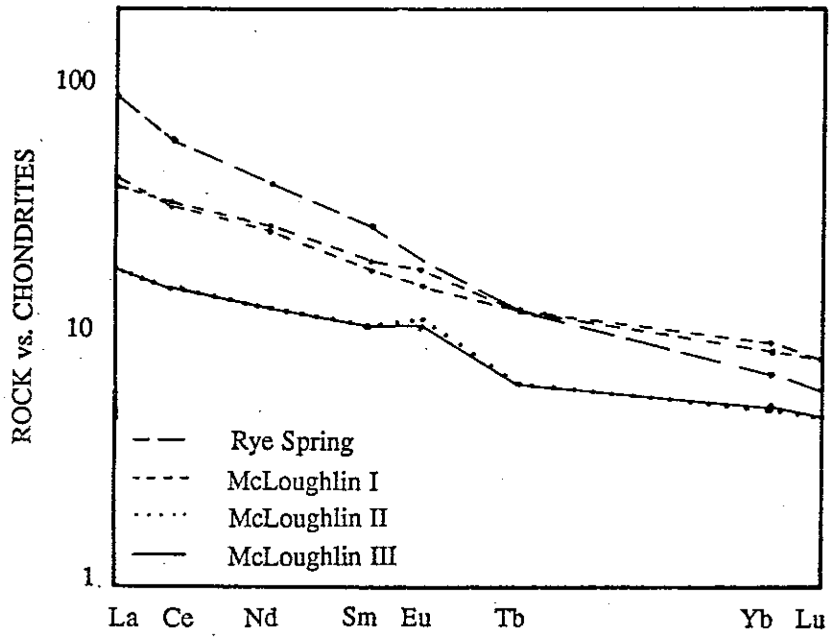

Figure 2: This diagram shows Rare Earth Element concentrations for Rye Spring and the McLoughlin units.

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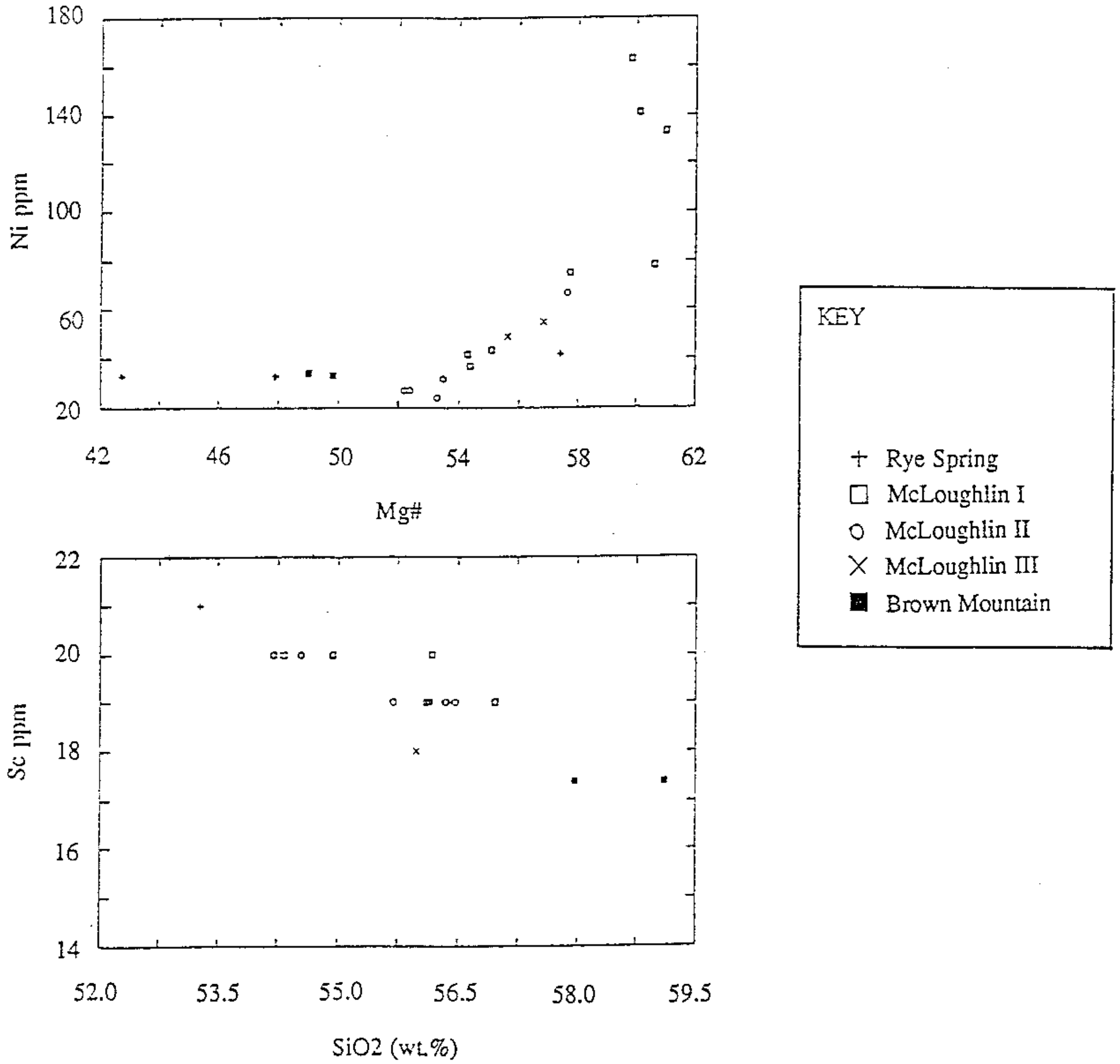

Figure 3: These variation diagrams show fractionation trends for all units. a) Decreasing nickel concentrations vs. the Mg# suggest olivine fractionation. Mg# = 100x molecular proportions of MgO / MgO + MnO + FeO*. b) Scandium concentrations decrease with respect to silica to indicate pyroxene fractionation.