A Petrological and Geochemical Study of the Rye Spur Area, Cascade Range, Southern Oregon

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The Cascade Mountain Range defines a linear trend of composite volcanoes that have been active from Miocene to the present. Calk-alkaline volcanics dominate this range at present, but changes in the subducting slab beneath the Cascades have also produced large outpourings of basalt interspersed with the volcanics. The Rye Spur area lies immediately to the southeast of Mt. McLoughlin, a volcano within the High Cascades province in southern Oregon. Less than twenty miles to the east of the area lies the Klamath Basin, a large water-filled graben that is thought to mark the beginning of the Basin and Range Province. This combination of compressional and extensional regimes may have yielded the variety of basalts and basaltic andesites (as defined by Le Bas et al., 1986) within the Rye Spur area

Rye Spur occupies the center of the six square mile field area and its andesitic lavas make up the most voluminous geological unit. Six other units are also present within the area: the southwest corner of the area is covered by Billie Creek andesite, the southeast corner by Pearce Point basalt, and the western edge by North Billie Creek andesite. The northern third of the field area contains the other three units, each of which have very limited extent (on the scale of hundreds of meters): the Rye Spur Quarry andesite, the high-alumina olivine tholeiites (HAOT), and a unit most easily identified by its sample number as Basalt 63. These latter units are surrounded partially or completely from colluvium predominately derived from Mt. McLoughlin. In the northeastern corner of the field area, this colluvium consists of fields of boulders of various lithologies that look very much like lava flows; at higher elevations the colluvium produced a hummocky terrain of laharic deposits that may have been modified by periglacial processes.

All of the units in the field area contain an anhydrous mineral assemblage dominated by plagioclase and include lesser amounts of olivine, clinopyroxene, orthopyroxene, magnetite/ilmenite, spinel and apatite. Rye Spur basaltic andesites have silica contents that range from 53 to 56 weight percent; the samples from the dome atop Rye Spur generally have a lower silica content and a higher percentage of mafic minerals than do the samples from lava flows. Textures are porphyritic to glomeroporphyritic; olivine is present only as a phenocryst phase whereas clinopyroxene and orthopyroxene are present as phenocrysts and are present in the groundmass. All phenocrysts range from 1 to 3 mm in length. Rye Spur lavas characteristically contain glomeroporphyritic clumps of plagioclase + pyroxene +/- olivine that are no more than 3 mm in diameter. The North Billie Creek andesites have similar mineralogy and texture to the Rye Spur samples and are distinguished primarily by the presence of glomeroporphyritic clumps of

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Figure 1.

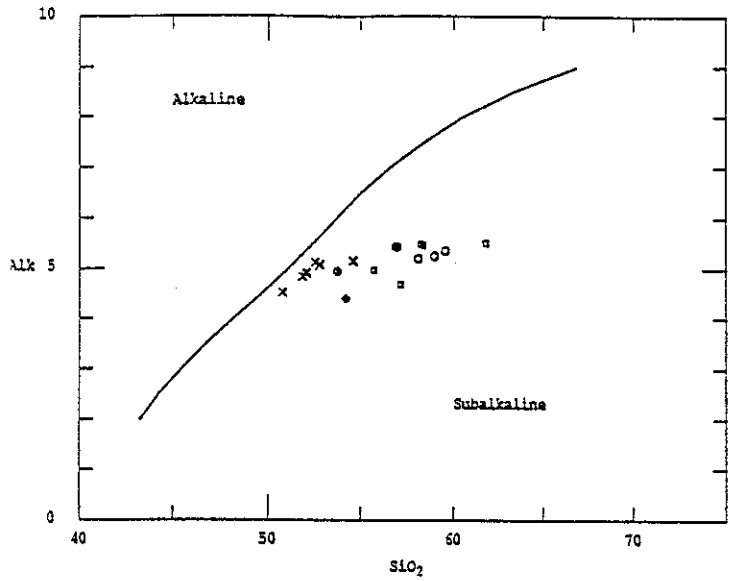


Figure 2.

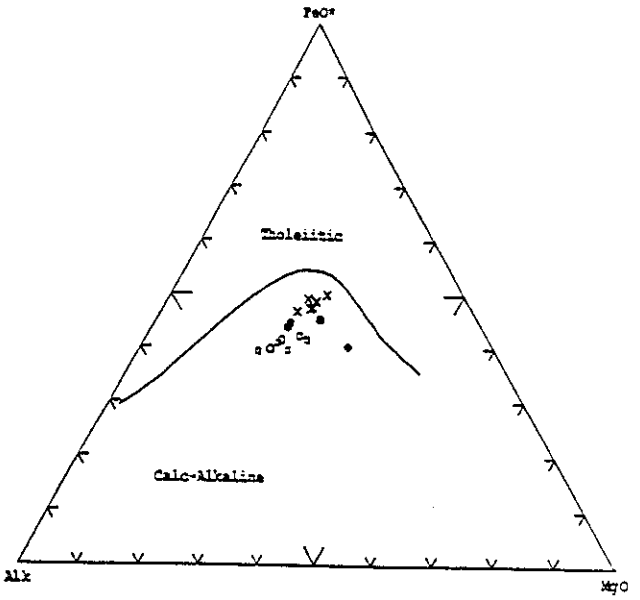


Figure 3.

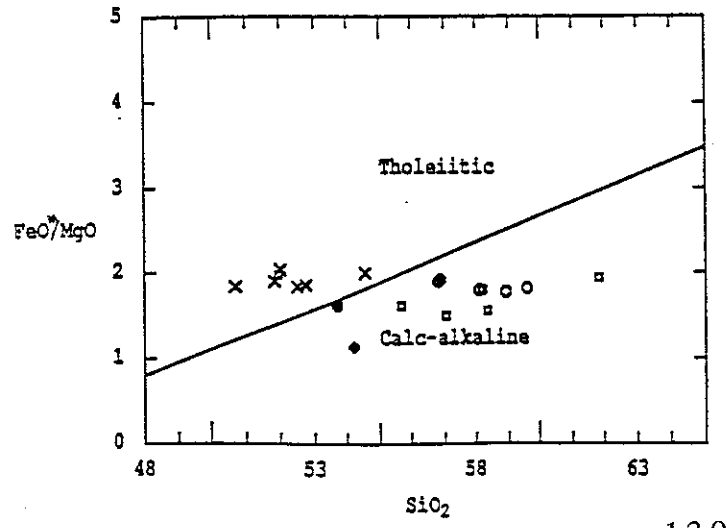
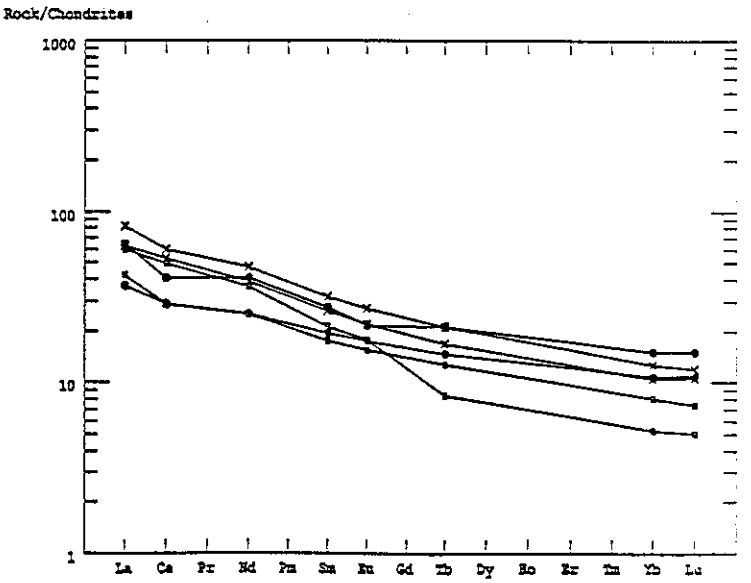


Figure 4.



plagioclase + pyroxene + olivine that are up to 5 mm in diameter. Additionally, plagioclase content is higher and phenocrysts are generally larger than those of the Rye Spur unit. The andesites of the Billie Creek unit also have similar texture and mineralogy to the Rye Spur samples; Billie Creek samples are distinguished by large (5 mm) plagioclase phenocrysts that are commonly resorbed (rims and cores). Most olivine crystals in this unit have thin rims of orthopyroxene. In each of these three units, pyroxene phenocrysts commonly display slight undulatory extinction when rotated under crossed polars. Also, olivine is iddingsitized and is present only as a phenocryst phase. Magnetite, apatite, and pyroxene comprise the groundmass constituents.

The basalt from Pearce Point has a glomeroporphyritic texture consisting of clumps of plagioclase, pyroxene, and olivine as large as 5 mm in diameter. Olivine crystals are heavily iddingsitized and are present only as phenocrysts. Magnetite has a high abundance (5%) in the groundmass. The HAOT samples have textures that range from trachytic to ophitic and diktytaxitic. Some of the olivine phenocrysts have suffered partial to complete high-temperature oxidation; in the samples with ophitic texture, olivine crystals are not surrounded by plagioclase as are the pyroxenes. Magnetite is present as a phenocryst phase in one of the samples. Basalt 63 has a pilotaxtic to subophitic texture; plagioclase occurs rarely as a phenocryst phase and olivine phenocrysts dominate the sample (15%). Magnetite is present as a phenocryst along with microcrystalline aggregates of pyroxene + olivine + magnetite +/- plagioclase. The Rye Spur Quarry yields a basaltic andesite with porphyritic texture. Olivine phenocrysts are subhedral to euhedral and display varying degrees of high-temperature oxidation. Pyroxene phenocrysts are rounded. Glomeroporphyritic clumps of pyroxene + Plagioclase + magnetite +/- olivine are also present along with clumps of very fine-grained dark material that is unidentifiable microscopically.

Major and trace element analyses were performed by X-ray fluorescence and additional trace and rare earth element data were obtained from inductively coupled plasma analysis. Six samples also underwent instrumental neutron activation analysis. Alkalies are lowest in the basalts and potassium content is especially low in the HAOT samples (0.8 wt % average). All of the samples except the HAOT samples and Basalt 63 plot within the calk-alkaline field of an AFM diagram as defined by Irvine and Baragar (1971); HAOT and Basalt 63 plot within the tholeiite field. The samples delineate an alkali-enrichment trend. All samples are alumina-rich (16-18%) except Basalt 63 which has an Al2O3 value of 15%. MgO and CaO decrease sympathetically when plotted in a variation diagram; alumina increases and iron decreases as these oxides decrease. P2O5 and TiO2 remain nearly constant with decreasing CaO or MgO although there is a slight enrichment in these oxides within the basalts.

Rb, Cr, and Sr are lowest in the basaltic samples; Sr is anomalously high in the Quarry sample and Cr has a high value in Basalt 63. Co, Sc, Yb, and Cr are highest in the samples with the highest mafic mineral contents. Sc displays a level trend with decreasing CaO and Sr and K2O decrease sympathetically with respect to each other. Cr and Ni both decrease substantially with decreasing MgO content.

Rare earth elements can be compared by utilizing a spider diagram (Figure 1). All samples are

enriched in REE and most show a LREE enrichment pattern, additionally, they lack any Eu anomaly. The samples also show a depletion in the high field strength element Ta which is consistent for lavas generated at an active continental margin (Hughes, 1990). The HAOT samples have nearly a flat pattern at 10X chondrite.

Within the variation diagrams the HAOT samples (hereafter the basalts) almost invariably plot together as do the Rye Spur, North Billie Creek, and Billie Creek samples (hereafter the andesites). The Quarry sample, Pearce Point, and Basalt 63 plot individually and cannot be said to associate within any grouping. Assuming a model of fractional crystallization for the production of the basalts and the andesites, variation diagrams show that plagioclase was not an early fractionating phenocryst phase. Sr and Al2O3 both increase with decreasing MgO, as theses elements remained in the liquid instead of being incorporated into the plagioclase lattice. The lack of a Eu anomaly also supports this conclusion (Hanson, 1980). Clinopyroxene fractionation is supported by a decrease in Sc with decreasing CaO, as Sc has a high distribution coefficient for clinopyroxene. The steady decrease in Ni and Cr with decreasing MgO points to fractionation of olivine and Cr-spinel (Figure 2). Ni is very strongly partitioned into the structure of olivine and the Ni-Mgo trend should be very steep if olivine is the only fractionating phase. The gentleness of the slope of this trend may reflect fractionation of other phases, such as orthopyroxene, which have smaller distribution coefficients for nickel.

The variation diagrams show a relationship between the Rye Spur, North Billie Creek, and Billie Creek units as they tend to plot in clusters. The Billie Creek Unit in all cases is most primitive, followed by the Rye Spur lavas and the North Billie Creek unit as determined by Mg#, field relations, and K/Ar dating (Mertzman, unpublished data). The Pearce Point basalts have trace element affinities to these andesites. I propose that these four units are derived from the same magma body and vary with degree of fractional crystallization within the magma chamber. Many additional comparisons need be performed to determine whether such a magma chamber is associated with the Mt. McLoughlin magma system.

The HAOT basalts are described in Kuno (1960). They are probably related to a shift in tectonic regime from compressional to extensional that occurred between 10 and 2 Ma, related to a change in the velocity of the subducting slab under the Cascade province (Alt and Hyndman, 1978). The HAOT samples at 2.2 Ma and Basalt 63 at 2.8 Ma may both have been produced during this extensional event although the difference in their REE patterns makes them difficult to relate to each other and to the other units in the area.

The Rye Spur Quarry rock cannot be compared to any other samples by chemistry. The two populations of plagioclase, two types of glomeroporphyritic clumps, and euhedral olivine phenocrysts together with rounded pyroxene crystals suggest that magma mixing was an important process in the formation of this andesite.

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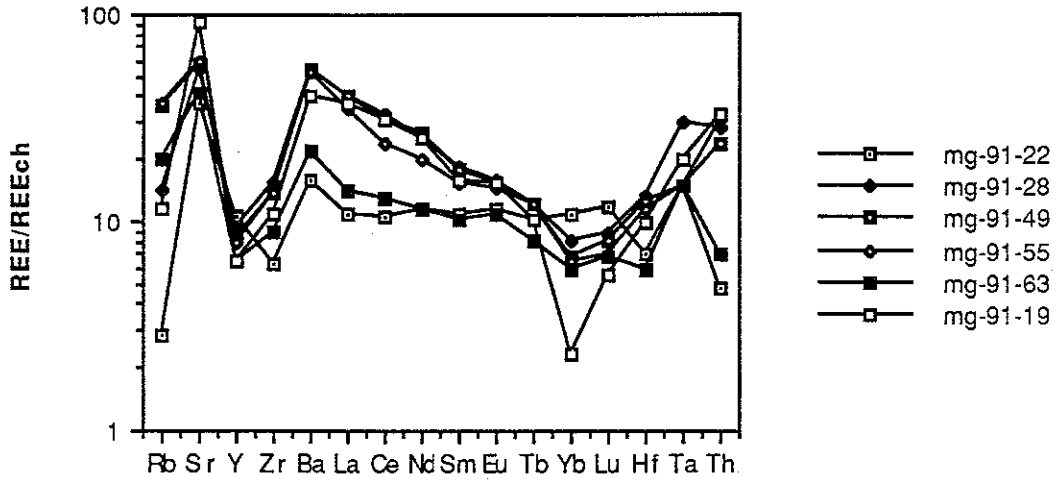
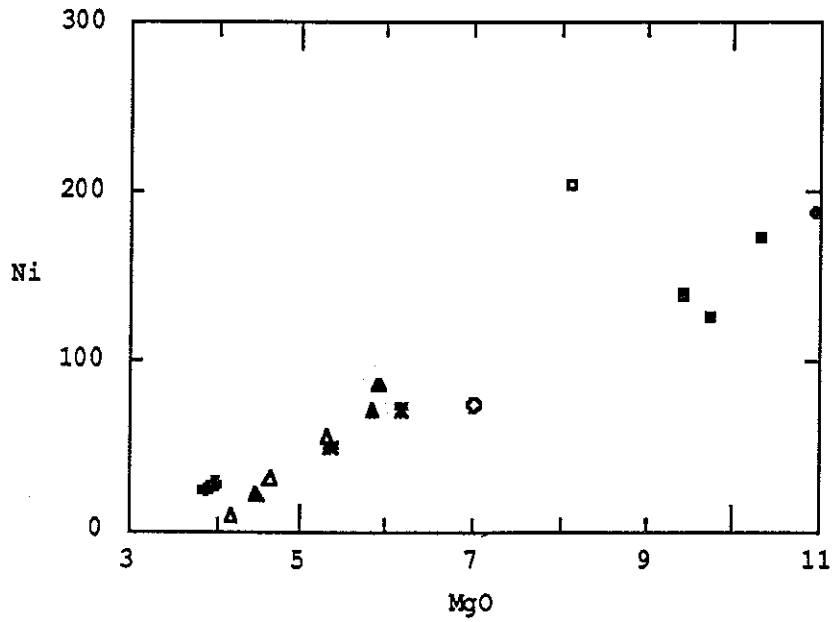
Figure 1: Spider Diagram for Samples Using INAA Data. Chondrite Values from Thompson, (1982).



Explanation: MG-91-22 = HAOT, 28 = Rye Spur Dome, 49 = North Billie Creek, 55 = Rye Spur, 63 = Basalt 63, 19 = Rye Spur Quarry.

Figure 2. Plot of Nickel versus Magnesium.



Explanation: Rye Spur -open triangle, Rye Spur Dome - solid triagle, North Billie Creek - solid cross, Rye Spur Quarry - open square, Basalt 63 - solid diamond, HAOT - solid square, Pearce Point - open circle, South Billie Creek - asterisk. Plot is normalized to 100 percent.