Tectonic Controls on Magma Genesis in Southern Oregon

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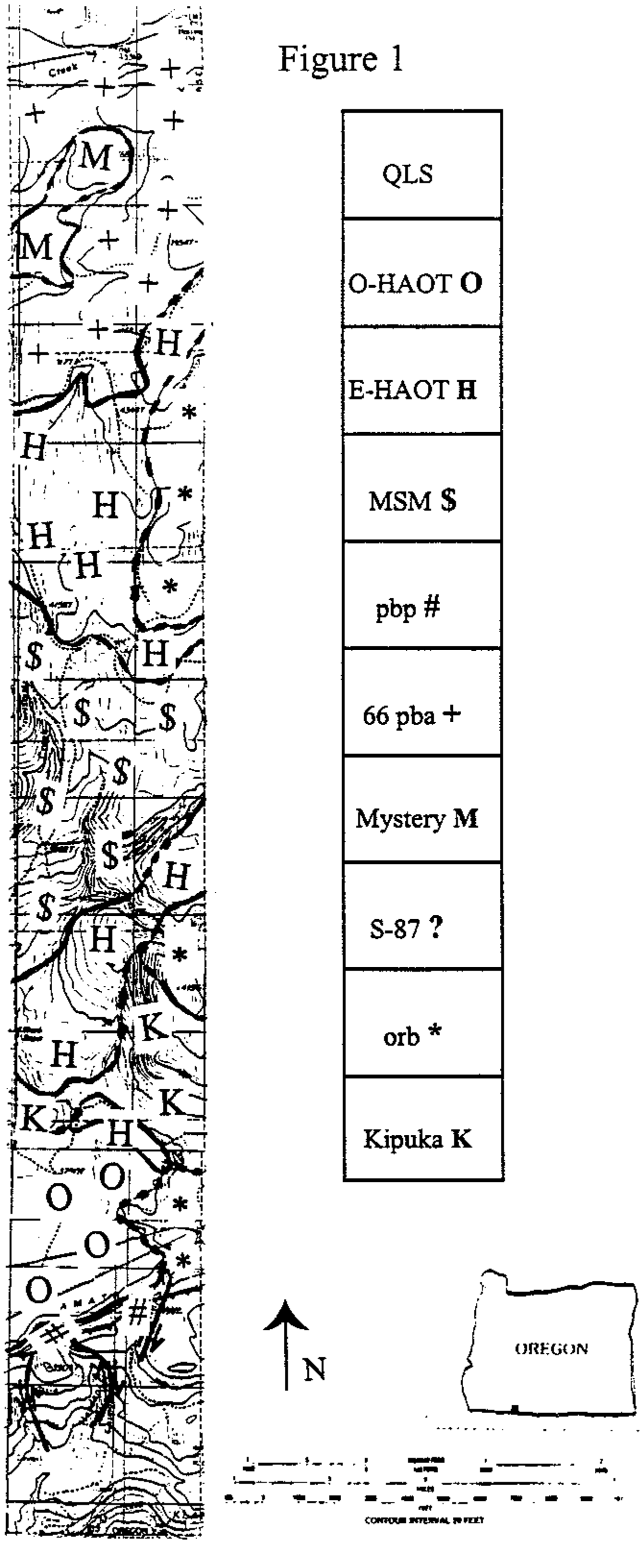
Introduction:

The Blanco Fracture zone between the Juan de Fuca and Gorda North plates comes ashore in the vicinity of Keno, Oregon, just north of the California/Oregon. The Blanco Fracture Zone began forming 4.9 Ma when the Explorer plate separated from the Juan de Fuca plate causing rotation of the Pacific/Juan de Fuca pole of rotation (Embley et al., 1984). Right lateral movement along the northwest-trending Blanco Fracture Zone is driven by the relative motions of the Gorda North and Juan de Fuca plates. Overall subduction rates in the Pacific Northwest have slowed 60% since 6.9 Ma and subduction of the young, buoyant Gorda Block has ceased altogether (Spence, 1987). The Juan de Fuca plate continues to be subducted at a rate of 40 mm/yr (Goldfinger et al., 1997). The Blanco Fracture Zone extends under the continent of North America where the right lateral shear generates east-west extension (Pease, 1969). It is hypothesized that this complex tectonic history has influenced magmatism in the northern California/southern Oregon region.

Methods:

The mapping area for this project was a strip one mile wide and seven miles long located just southwest of Keno, Oregon and extending south from Oregon Rte 66 to the Oregon/California border (T40 and 41S, R5E Sections, 1, 12, 13, 24, 25, 36, and 1 on the Mud Spring Mtn 7 ½ minute Quadrangle) (Fig. 1). Three additional one mile wide swaths were mapped by other workers, one immediately to the east, and two to the west. Geology of the area was mapped, field units were identified, and representative hand samples were collected from each unit. From these samples, thirty were selected for thin section analysis. Using thin sections and hand samples, the petrography of the units was described. Geochemical analyses (x-ray fluorescence, loss on ignition, and Fe^{+2} titration) were performed on 27 of those samples. Geochemical data was then analyzed to confirm unit identities and distinguish petrogenetic trends within units and the entire study area. K-Ar age dating was performed by Dr. Stanley Mertzman.

Figure 1



eventually erupts as a silica rich flow. Successive surges rise to the same spot and partially melt more crust above the "plume." Since the crust above had been already been partially melted, less silicic material is added to the successive melts. (McBirney & White, 1982) Eventually the melt rises through the crust with little contamination, forming such layers as the Lower Basalt.

Fractional crystallization is also at work in the complex plumbing system of stratovolcanoes. As magma lingers in chambers, it is postulated that it differentiates gradually into increasingly variable products. The longer the magma spends fractionating, the more silicic the magma can become. This explains the increasing silica trend, such as the progression from Lower Basalt to Lower Southern Andesite to Greywall volcaniclastics. The presence of high-alumina Anders' Basalt is explained, as Crawford et al. (1987) has demonstrated that this form of basalt originates by differentiation and plagioclase accumulation from more mafic parents. The separation of a magma into basaltic and andesitic end members is evident in the alternation of Anders' Basalt with the andesitic Upper Tuff layer. This behavior is typical of complex volcanos (McBirney & White, 1982) as they often simultaneously erupt basalt in flank flows and dacite/rhyolite from the main vent.

CONCLUSION

With the exception of the capping Secret Spring basalt, the layers exposed on the western slope of Secret Spring Mountain originated from an unknown vent located somewhere to the west. Petrologic analysis concludes that the vent involved has a history of cyclical melt composition. This complex behavior can be explained by rising diapirs of magma from the mantle wedge successively assimilating the continental crust. Further research might be able to determine to what extent the crust played in the development of the extrusives as well as unravelling the exact nature of the tuff breccia deposition.

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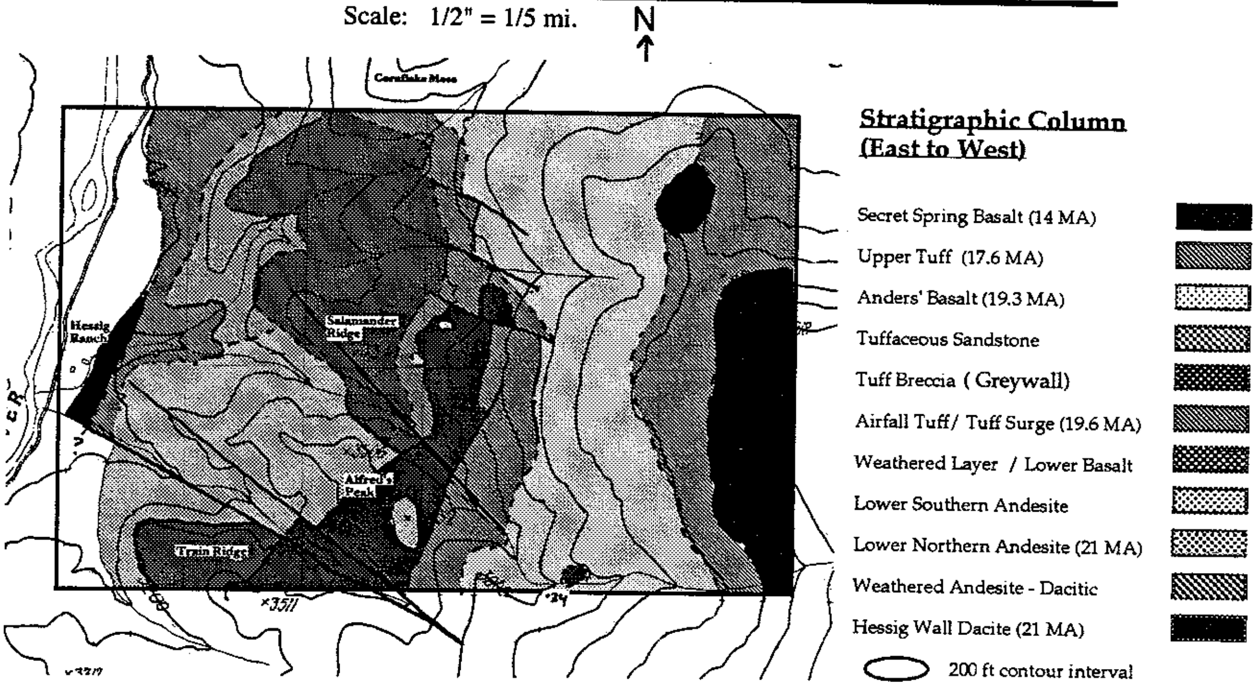
Fig. 1

Geologic map of the western slope of Secret Spring Mountain

Scale: 1/2" = 1/5 mi.



Results:

Lithologic Units: On the basis of hand samples, thin sections, and geochemical data, nine distinct units were identified and then classified using the total alkali-silica diagram of Le Bas et al. (1986) (Fig. 2).

Unit	Age (Ma)
O-HAOT	1.9 +/- 0.4
E-HAOT	≈ 2.2
MSM	2.6 +/- 0.2
pbp	3.2 +/- 0.2
66 pba	3.4 +/- 0.1
Mystery	-------------
S-87	3.8 +/- 0.01
orb	6.2 +/- 0.02
Kipuka	13.2 - 15.0

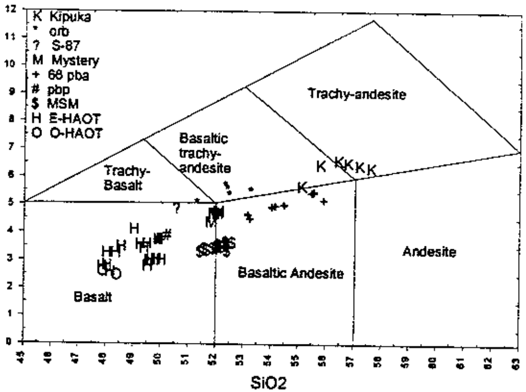


Figure 2: Classification Plot (after Lebas et al, 1986)

Kipuka: Based on age date similarities and proximity in the field, two field units were combined to form this final unit. On major oxide diagrams the majority of the samples coincide though there is some scatter. There are no distinguishable trends.

orb: Like the Kipuka, samples from this unit plot together on major element diagrams with some random scatter (though less than the Kipuka) and no distinguishable trends.

An explanation for the scatter and lack of trends in these two units is derived from the work of Hooper (1988). Within a given unit, incompatible element ratios should be constant. Changing incompatible element ratios indicate that the original melt has been contaminated, either through magma mixing or crustal assimilation en route to the surface. As can be seen from the plot of P2O5 *vs* Zr (Fig. 3), the incompatible element ratios of the Kipuka and orb units are not constant. Based especially on the felsic nature of the Kipuka, it is concluded that the changing incompatible element ratios result from assimilation of continental crustal material as the magmas rose to the surface.

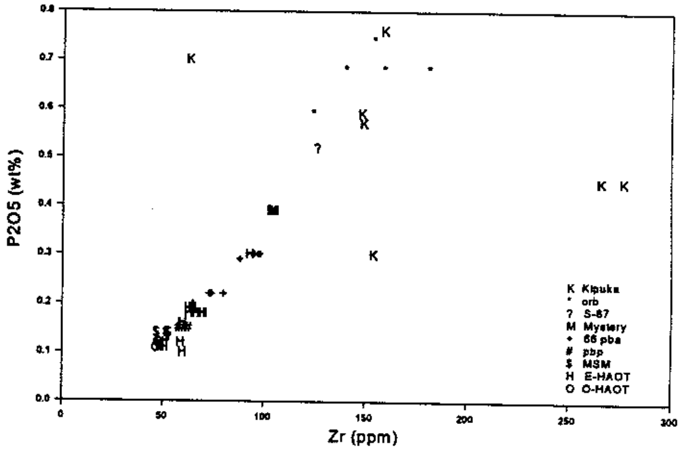


Figure 3: Mixing Determination Plot (after Hooper, 1988)

Mystery: Outcrop for this unit was limited and, consequently, available data points are limited. Based on field relationships this unit is older than 3.4 Ma. A possible source is high point 4468T in T40S R5E Sec 1.

S-87: One sample of this unit was collected. Field relationships were ambiguous and suggest that this unit is almost completely covered by the 66 pba. Atypical values for some components (ie. 1300 ppm Sr) indicate an unusual history for this unit.

66 pba: Data points are limited; however, the Ni *vs* MgO plot (Fig. 4) indicates that olivine was fractionating. This trend is further constrained by additional data from Winick (this volume).

pbp: (Plagioclase Basalt Porphyry) The one collected sample from this unit is chemically identical to a sample found two miles to the east. There is no available information on the evolution or source of this unit.

MSM: (Mud Spring Mtn.) The two samples of this unit taken from the map area correspond perfectly with a sample taken from the summit of Mud Spring Mtn, confirming the origin of these samples. Additional data points from Winick (this volume) delineate no trends, indicating that this unit is chemically homogeneous.

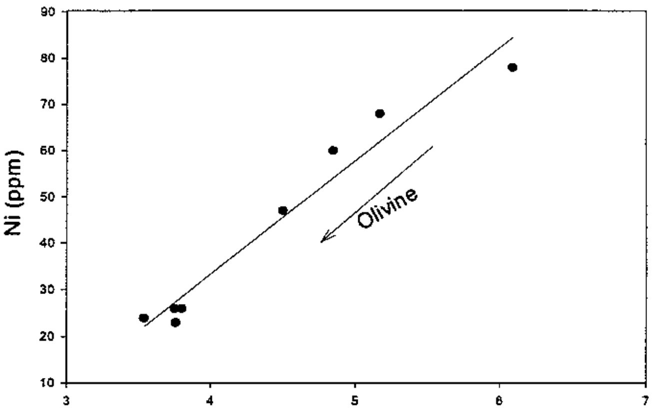


Figure 4: Ni vs MgO for 66 Basaltic Andesite

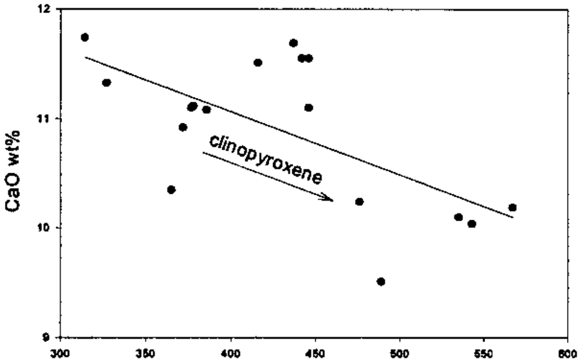


Figure 5: CaO vs Sr For E-HAOT

E-HAOT: (Equigranular HAOT) CaO *vs* Sr (Fig. 5) indicates that clinopyroxene fractionation occurred in this unit. No other geochemical trends were distinguished.

O-HAOT: (Olivine Phyric HAOT) The two available data points for this unit correspond perfectly on major and trace element diagrams. Even if more samples were collected, it is likely that no trends would be discernible due to the young age of this unit. Field relationships and the age of this unit indicate that quite possibly the entire unit consists of one flow, and thus all samples would be virtually identical.

Discussion:

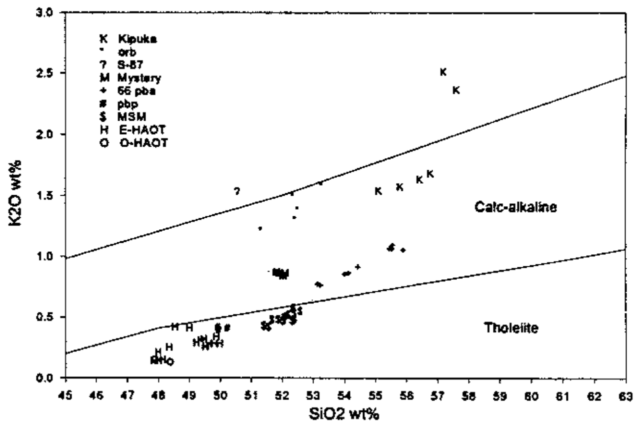


Figure 6: K2O vs SiO2 for all Samples (Field lines after Rickwood, 1989)

Over the past 14 Ma the rocks in this field area have become increasingly mafic. The oldest rocks are calc-alkaline while the youngest are tholeiitic (Fig. 6). Low K rocks are usually poorly represented in active margin volcanic arcs, however, the customary high K of active margin volcanics may be the result of crustal contamination (Wilson, 1989). The more open and direct a magma's path to the surface, the less crustal contamination occurs. Thus, as fractures open and magma can move more directly to the surface, the likelihood of crustal contamination decreases. Both the Kipuka and the orb units plot on the high end of the calc-alkaline field. Some time between 6.2 Ma (orb) and 3.4 - 3.8 Ma (Mystery) a change occurred and erupted magmas became more tholeiitic. Lavas continued to become increasingly tholeiitic until the youngest unit (Olivine Phyric HAOT) erupted at 1.9 Ma. This trend of increasingly tholeiitic lavas over time is probably related to decreasing crustal contamination. This is supported by Figure 3. The points of the Kipuka and orb show changing P2O5/Zr ratios, indicating crustal contamination; while those of the units from Mystery to Olivine Phyric HAOT show consistent P2O5/Zr ratios, indicating that crustal contamination was not a factor. At some time between 6.2 Ma and 3.4 - 3.8 Ma crustal contamination ceased to be a major factor in lavas erupted in this region. This time interval corresponds to that of the change from extremely calc-alkaline magmatism to increasingly tholeiitic magmatism. Based on this relationship it is concluded that between 6.2 Ma and 3.4 - 3.8 Ma a change occurred allowing magma to reach the surface more easily. This change may have been caused by the onset of extension related to the formation of the Blanco Fracture Zone at 4.9 Ma (Embley et al., 1984). As subduction of the Gorda Block ceased, lateral movement on the Blanco Fracture Zone increased as did the resulting extension in Southern Oregon and Northern California. The resultant fracture system grew, allowing progressively more mafic magmas to reach the surface. This trend of increasingly mafic magmatism occurred between 3.4 - 3.8 and 1.9 Ma, a time period that corresponds to the northward migration of the andesite belt in southern Oregon between 5 and 1 Ma (Guffanti and Weaver, 1988).

Conclusions:

From at least 14 Ma to ≈5 Ma the Southern Oregon study area was characterized by calc-alkaline magmatism. At approximately 5 Ma the Blanco Fracture Zone began forming. Opening fractures allowed increasingly mafic lavas to reach the surface. As fracturing due to the Blanco Fracture Zone became more regionally extensive, andesitic magmatism migrated north. This process took place over a period of 4 Ma. The changeover to tholeiitic magmatism in the map area occurred between 3.4 and 3.2 Ma and lavas continued to become increasingly tholeiitic until 1.9 +/- .4 Ma when eruption ceased. To further validate this hypothesis, petrologic data from the entire tectonic region in question should be analyzed.

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Volcanology and Stratigraphy of the Hessig Ranch Area of Secret Springs Volcano, Oregon

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INTRODUCTION

The Hessig Ranch Area, east of the Klamath River gorge on the Oregon-California border, offers a unique opportunity to study a little known older "Western Cascades" type extrusive regime. This area of the Western Cascades has been active for over 35 million years as a convergent continental plate margin environment. Given the large time span of continuing volcanic activity many younger vents erupted on the eroded remains of older volcanoes. For example, older lavas and pyroclastic flows unconformably underlie the lavas of adjacent Secret Springs Mountain in this area. Mapping these various units, determining the stratigraphy, and developing a hypothesis of eruptive patterns based on field observations, thin section studies, and geochemical data, were the goals of the project.

FIELD OBSERVATIONS

The field area (Figure 1) consists of ridges oriented northwest-southeast and relatively flat plateaus at an elevation of approximately 1000 feet above the river valley, and a moderately sloping highland area which terminates eastward Secret Springs crater rim. The deeply eroded drainage systems also trend northwest-southeast, as do the apparent faults in this area.

The oldest unit in this area is a badly weathered basalt (bb) occurring in elongate ridges close to the Klamath River. The basalt in the ridge north of Shovel Creek dips from sixty to twenty-five degrees northeast, an anomaly given the prevalent dip of this basalt of fifteen degrees east seen throughout the rest of the field area. The unit generally appears massive in outcrop, and sometimes displays spheroidal weathering. In thin section the lava is glomeroporphyritic (plagioclase + olivine) with a fine-grained intersertal matrix of plagioclase, olivine, and clinopyroxene.

Atop these basalts is a pyroclastic section (pts) of approximately 100 feet in thickness. This unit is characterized by pumice and lithic fragments in a layered sequence; with cross-bedding, small thrust and normal faulting, uneven erosional resistance, and "block sags" suggesting a pyroclastic origin. The symmetrically graded layers show a complex depositional process in the varying size and arrangements of the lithic fragments, which range from an extremely fine-grained ash to occasional layers of lithics up to two inches in diameter. Most mafic particles are angular while the pumice is generally of rounded appearance. In the upper ten feet of this unit are larger, apparently monolithologic, clasts from one to one and a half foot in diameter. The pumice at this location displays various colors and compositions. These clasts are entirely matrix supported, and well-spaced throughout this mixing zone, although the spacing decreases upward until the clasts are in continuos contact with each other with no supporting matrix.

Immediately above this section is a wide-spread agglomerate breccia (tb) that has a known north-south lateral extent of over three miles and a vertical thickness of up to three hundred feet. This is the dominant cliff-forming unit in the area and also the largest single unit. Individual clasts are supported by a grey, grainy matrix in weathered outcrops. In the upper zones the matrix has weathered away leaving clasts only. Many parts of the breccia unit are thin one to five feet thick basaltic lavas. The resistant rim and capping units (rb) are also composed of various basalt flows. In thin section these basalts are similar to the lower basalts (bb), but with slightly smaller phenocrysts.

A mid-level epiclastic unit (ts) overlies the basalt-breccia complex. It is composed of tuffaceous sandstone which has been extensively altered by hydrothermal activity. Cross-bedding on a fine scale occurs, with alteration zones of oxides accenting the flow patterns. The particles are generally sand-sized grains of felsic composition interspersed with mafic minerals of slightly larger size. The upper areas of this unit are less sorted and layered.