Geology, petrology, and geochemistry of a portion of the High Cascades in southern Oregon-northern California, south of the Klamath River gorge.

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INTRODUCTION

Students on the 1997 Keck Geology Consortium research project in southern Oregon-northern California sampled and mapped a portion of the High Cascades near the Klamath River gorge. The students were divided into two field areas of study: north and south of the river. My field section is south of the Klamath River gorge, in the northwestern corner of the Secret Spring field area. It borders the river to the north and west, Secret Spring Mountain to the southeast, and six of the seven other field areas. The purpose of the project was to describe the geology, petrology, and geochemistry of the volcanic rocks in my field area and incorporate them into the geologic setting of the High Cascades, a volcanic region active since the mid-Miocene. Ten different volcanic units were distinguished in the field based on their texture, phenocryst assemblages, and outcrop pattern. Samples were collected from each unit for petrographic and geochemical analysis. Because of its central location, this section is important to correlation of volcanic units in the Secret Spring field area and with rocks north of the river.

FIELD DESCRIPTIONS AND PETROGRAPHY

The field area covers approximately 15 square kilometers and contains two prominent mesas and a ridge, which are at approximately the same elevation as the northern rim of the Klamath River gorge (Fig.1). The volcanic deposits in the area include lava flows, dikes, pyroclastic deposits, and volcaniclastic sediments that have been dated from 22 to 4 Ma (Mertzman, personal communication, 1998). Quaternary landslide debris cover much of the volcanic deposits on the steep river-facing slopes of the mesas and ridge.

The volcanic deposits are basaltic to andesitic with varying degrees of secondary hydrothermal alteration. The oldest units in the area are extremely weathered and are exposed on the western slopes of Cornflake mesa. The units extend south to at least the southern border of the Secret Spring field area. The oldest unit is the Topsy Road andesite, which has platy flow joints that range from 3-10mm at the base to 2cm near the top. The second oldest unit is a very weathered vesicular basalt, with pink weathering products. It is overlain by the middle andesite, and then the weathered hornblende basalt of which there are only a few ½m in diameter outcrops.

The lower pyroclastic unit includes tuffaceous sandstone, welded blue tuff, and unwelded tuff. Tuffaceous sandstone is exposed in 6 by 10m outcrop on the southwestern slope of Cornflake mesa. It is moderately lithified and thinly bedded (2mm) with ≤1mm diameter angular volcanic clasts with an ashy matrix. The overall structure of the tuffaceous sandstone changes dip along strike, following the slope topography. The welded blue tuff has pumice clasts and fiamme.

The 19.3my olivine-phyric basaltic andesite unit is exposed in the highlands in the southern part of the field section. It is distinguished by its thin horizontal flow joints (1.3-5cm) and weathered vertical joints. The unit strikes N-NW and is unconformably overlain by the mesa-capping basalt porphyry unit. It extends south to at least the southern border of the Secret Spring field area, where it has been called "Anders' basalt" (Nilsson, personal communication, 1998). It is distinguished petrographically by its pronounced olivine phenocrysts (2-3%, 2mm) which have been altered to limonite, and its trachytic texture. The groundmass is aphanitic and contains needle-like laths of plagioclase (12-13%), and pyroxenes.

At least four andesitic dikes intrude volcanic deposits on the northern side of Gum mesa (other dike material may be covered by talus debris). They strike radially outward from the mesa, forming ridges, and are overlain by the mesa-capping basalt porphyry unit. Vertical flow joints in the dikes range from 1cm-1/2m across. The groundmass is aphanitic, predominately composed of plagioclase and pyroxene. Many of the plagioclase phenocrysts (3mm) have been altered to sericite and/or psuedomorphs of calcite. Hornblende phenocrysts (4mm) are present in several of the dikes.

The 17.6my upper tuff is easily distinguishable by its white color and crops out in patches on the eastern slope of Gum mesa. It contains plagioclase, pyroxene, and hornblende crystals and volcanic, aphyric, lithic fragments (2%). Stratigraphy, petrology, and age dates suggest this unit is correlative to the Hershey Kiss Hill pyroclastic unit north of the river.

cover up most of the contact relationships between the other units. All HAOT's in thin section are characteristically diktytaxitic and highly vesicular with one sample containing pipe vesicles. They all display subophitic texture of plagioclase, clinopyroxene and occasionally olivine. Sample 27 has a plagioclase composition of An 60.

GEOCHEMISTRY

SiO_2 contents vary from 48-55 %. Harker plots show considerable scatter, however, MgO and MnO decrease with increasing SiO_2. TiO_2 and Al_2O_3 are relatively high for subduction-related lavas. Rare earth element plots show slight light rare earth element (LREE) enrichment and little to no Eu anomaly (Figure 3). Incompatible element plots normalized to C1-Chondrite and N-MORB show overall enrichment in Rb, Ba, Sr, and Th, and depletion in Cr, Co and Ni. Both the REE and spider plots reveal two distinct geochemical groups of lava based on significant differences in pattern shapes. Group A is characterized by a slightly higher abundance of REE than Group B. Group A has higher Hf, Ta, Eu, Ba, Th, and Ce, whereas Group B is higher in Co, Ni, Cr, and Sr.

DISCUSSION

The two geochemical groups can also be distinguished petrographically by mineral variations visible in thin section. For example, Group A is low in Cr, Ni and Co and has more clinopyroxene and less olivine than Group B. The large gap in REE abundances between the two groups implies there must be two distinct sources for these lavas. The processes responsible for generation of these melts produce lavas that alternate between groups A and B through time. The most likely explanation is two source regions that were active over the timespan of these flows.

Earlier work done in this area shows a fairly continuous range of geochemical trends that could be explained by fractionation. However, because in this mapping area only two of the geochemical groups were found, it is possible to identify two distinct sources. Thus, a simple processes such as crystal fractionation can not solely account for the evolution of these melts. Most likely, a combination of processes, which may include different source compositions, crustal assimilation, partial melting, or magma mixing, are responsible for the geochemical signatures of lavas in this portion of the arc.

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A small area of cinder within the upper tuff unit is exposed on the southeast side of Gum mesa. Bombs are ≤6cm in diameter and highly oxidized. Because of the amount of oxidation in the cinder, a sample was not collected for geochemical analysis. This isolated outcrop is the only reported cinder deposit in the Secret Spring field area.

The Secret Spring basalt unit is located on the flanks of Secret Spring Mountain and along the eastern side of Gum mesa, where it is covered in places by the mesa-capping basalt porphyry unit. It has been dated at 13 Ma and is related to the Secret Spring volcano, remnants of which are now Secret Spring Mountain (Mertzman, personal communication, 1998). It has olivine phenocrysts (1-5%) that have been altered to iddingsite and microphenocrysts of cumulophyric plagioclase (1%). The aphyric groundmass is made up of pyroxene (35-49%), plagioclase (50-60%), and a few opaque crystals (2-3%).

The 5.8my Antler basalt unit is exposed on Antler Ridge, underlying the mesa-capping basalt porphyry unit. It is approximately 76m thick and has 0.3-1.5m columnar joints. It is massive in the middle and vesicular at the base and top. The texture is mostly aphyric, with a few olivine phenocrysts near the top. The groundmass consists of diktytaxitic plagioclase (40%), pyroxene (50%), olivine crystals (5%), and opaques (5%). Stratigraphy, petrology, and age dates suggest this unit is correlative to the rim-capping basalt north of the river.

The 4.4my basalt porphyry unit is the youngest volcanic deposit in the field area, unconformably overlying older units and capping Cornflake and Gum mesas and Antler Ridge. It is distinguished by its porphyritic texture, columnar joints (0.3-1.5m), and blocky flow surface. It is approximately 5m thick on the southern side of Cornflake Mesa and thickens to 25m towards the Klamath River. It is highly vesicular with ½-1mm in diameter vesicles, which are concentrated in horizontal layers (6cm to ½m thick). The phenocrysts are glomerophyric plagioclase and olivine crystals. The plagioclase laths are diktytaxitic and the olivine crystals have iddingsite reaction rims. The groundmass is composed of pyroxenes (50%), plagioclase (40%) and olivine (10%) crystals with a few opaques.

GEOCHEMISTRY

Geochemical analysis was done on ten samples using x-ray fluorescence and iron titration for major and trace element chemistry. A few selected samples were also age-dated using K-Ar techniques (Fig.1). Because of secondary hydrothermal alteration and weathering products, many of the units were unsuitable for geochemical analysis.

DISCUSSION

Using the geochemical data, petrographic and hand sample descriptions, and field relationships, I verified my geologic map, made observations about the petrogenesis of the volcanic deposits in my field section and helped to correlate rocks in my area with rocks north and south of the Klamath River gorge.

The ten samples geochemically analyzed range from basalts to andesites (Fig.2) and are all subalkaline (Fig.3). The Secret Spring basalt, upper tuff, and Topsy Road andesite units are calc-alkaline, while the basalt porphyry and Antler basalt units are tholeiitic (Fig.4). Most of the units are relatively primitive with enriched MgO contents (Fig.4). The upper tuff and Topsy Road andesite units, however, are more enriched in alkalies. Spider diagrams indicate that all of the samples have low Nb values, which is indicative of crustal contamination (Wilson, 1989) (Fig.5). High Ba and Rb values in the upper tuff and Topsy Road andesite samples may also suggest contamination by a crustal component (Wilson, 1989), and their low Ti values are typical of orogenic andesites (Gill, 1981). The Secret Spring basalt, olivine-phyric basaltic andesite, basalt porphyry, and lower tuff samples also have high Ba, K and Sr values. No significant major element patterns for these samples are observable from Harker diagrams. This is most likely because the units erupted over a 22 to 4my time period and probably represent at least three different volcanic sources.

To better understand the petrogenesis of the rocks in my field section, I recommend further geologic mapping near the Secret Spring field area and correlation of units in the adjacent field areas. I suspect that the same units in my field section will be found nearby, possibly farther south along the southern rim of the Klamath River gorge. Further sampling and mapping may reveal significant petrogenetic trends, such as magmatic differentiation within major volcanic units.

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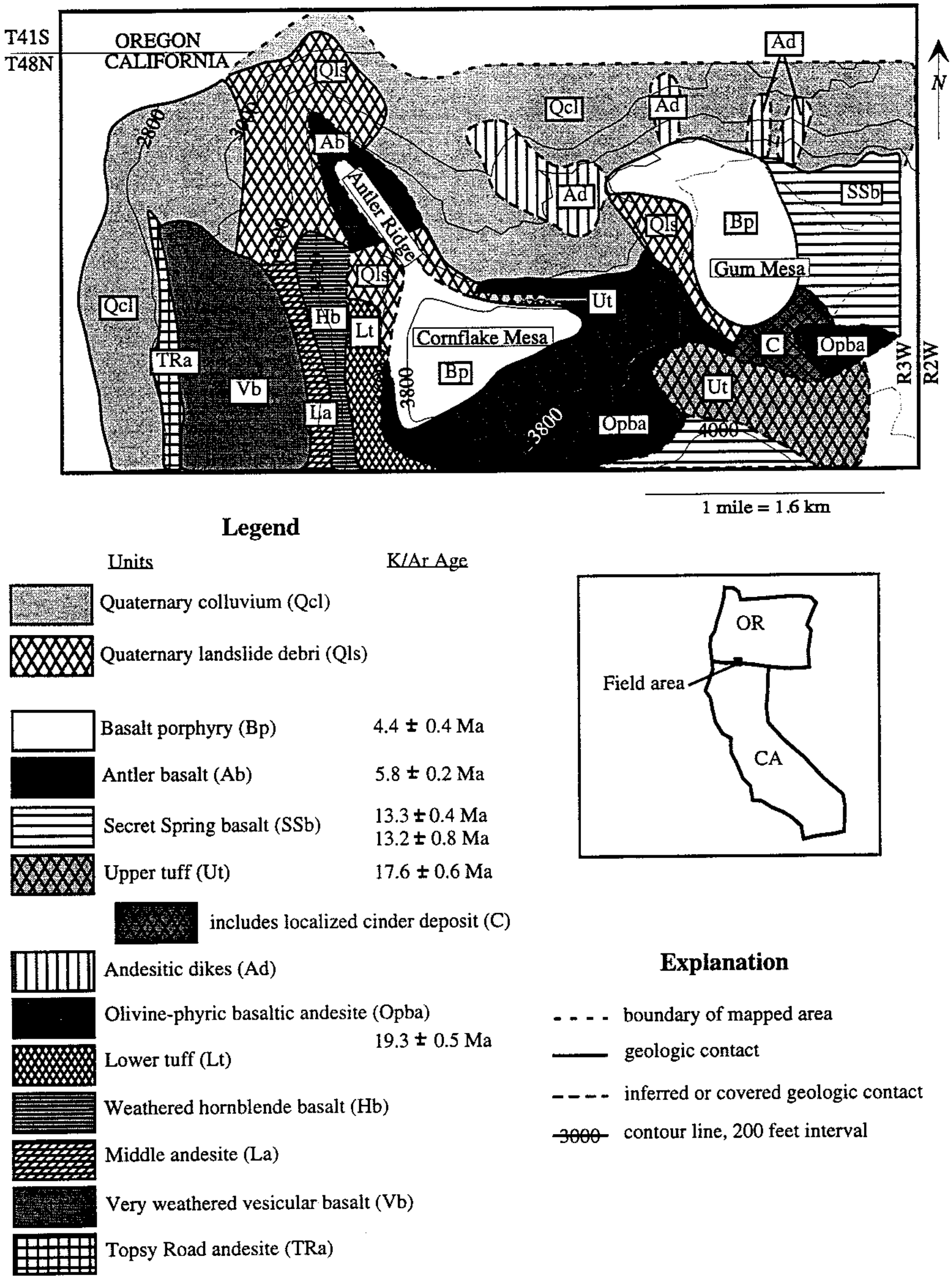


Legend

Units		K/Ar Age
▒	Quaternary colluvium (Qcl)	
▩	Quaternary landslide debri (Qls)	
☐	Basalt porphyry (Bp)	4.4 ± 0.4 Ma
■	Antler basalt (Ab)	5.8 ± 0.2 Ma
▤	Secret Spring basalt (SSb)	13.3 ± 0.4 Ma 13.2 ± 0.8 Ma
▩	Upper tuff (Ut)	17.6 ± 0.6 Ma
▩	includes localized cinder deposit (C)	
▥	Andesitic dikes (Ad)	
■	Olivine-phyric basaltic andesite (Opba)	19.3 ± 0.5 Ma
▩	Lower tuff (Lt)	
▤	Weathered hornblende basalt (Hb)	
▨	Middle andesite (La)	
▒	Very weathered vesicular basalt (Vb)	
▦	Topsy Road andesite (TRa)	

Explanation

- - - - boundary of mapped area
——— geologic contact
- - - - inferred or covered geologic contact
~~3000~~ contour line, 200 feet interval

Fig.1: Geologic map and stratigraphic column of field area. Age dates are from Stan Mertzman, unpublished data, 1998.

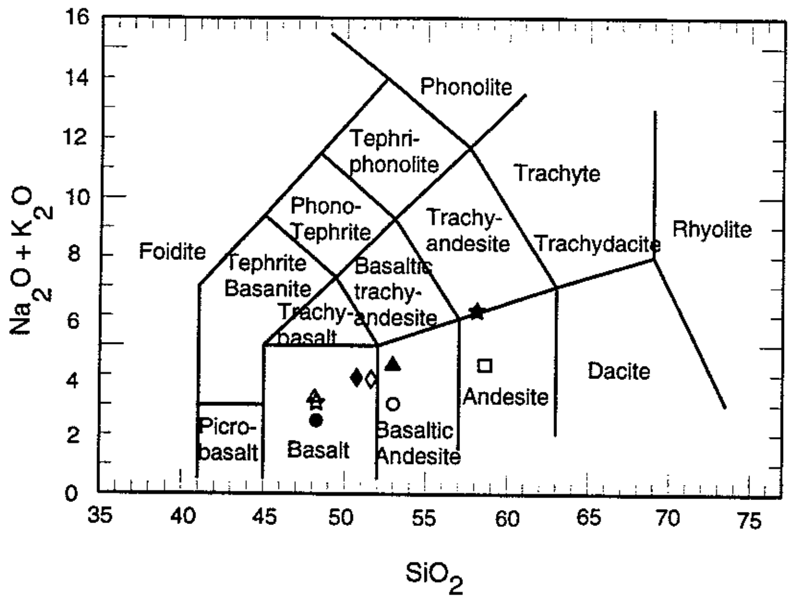


Figure 2: Total alkalies v. SiO_2 diagram after Le Bas, et., al., 1986.

Key

☆ △ Basalt porphyry
● Antler basalt
○ ◊ ♦ Secret Spring basalt
□ Upper tuff
▲ Olivine-phyric basaltic andesite
★ Topsy Road andesite

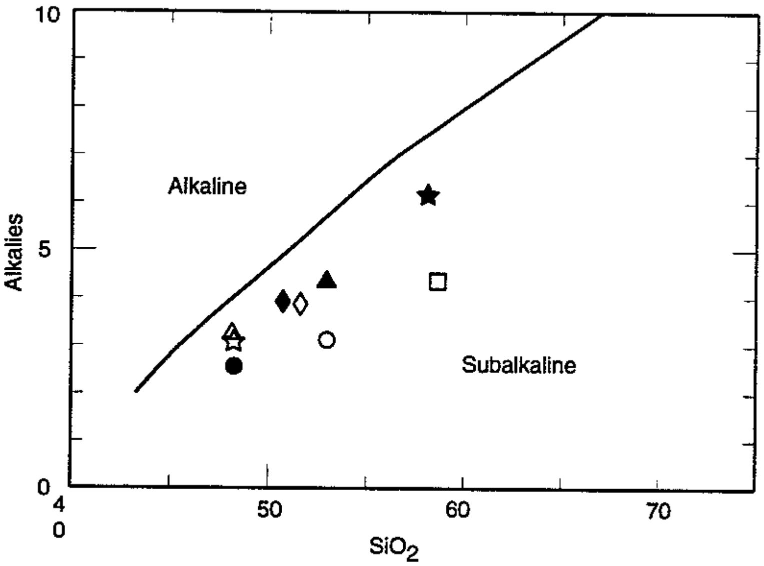


Figure 3: Total alkalies v. SiO_2 diagram: all samples analyzed are subalkaline.

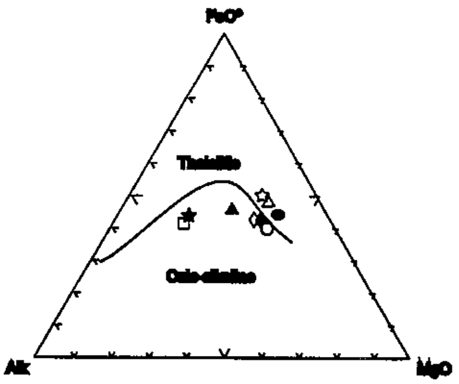
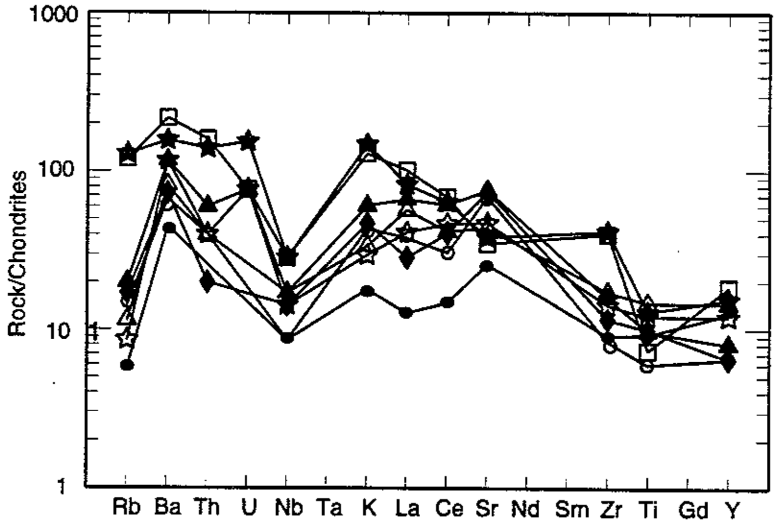


Figure 4: AFM diagram showing tholeiitic v. calc-alkaline samples.

Figure 5: Chondrite-normalized Spider diagram.



Structure and Petrology of Secret Spring Mountain's Western Slope

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INTRODUCTION

Secret Spring Mountain is an extinct volcano just on the California side of the Oregon / California border. It has been extinct since the late Miocene. The center of the volcano has been gouged out into an amphitheater by an extremely large landslide in the Pleistocene which deposited the material out into the Klamath River gorge to the north. Two relatively flat mesas rise off its flanks to the northwest, while the opposite side of the Klamath River gorge is covered in a series of large, table-like lava flows. The western flank of the volcano has been eroded by stream processes into a series of westward running ridges. The bedding on the western slope of the mountain, with the exception of the capping lavas on the two mesas and the uppermost lava on the mountain, dip ten degrees to the east.

Most of the layers are lavas of dacitic andesite to basalt in nature. However, scattered throughout these layers are several pyroclastic units of note, including tuff deposits, reworked tuffaceous sandstone, and a tuffaceous surge deposit. The most impressive layer here is a two hundred foot-thick tuff breccia layer: composed of ash, cinder, and clasts of vitrophyre. These layers on the western slope of Secret Spring Mountain all dip 10+ degrees east-- into the heart of the volcano. It is certainly not typical volcano behavior for all the beds on one side of the mountain to tip up and out into the air.

Secret Spring is also a kipuka, a relic of older rock (the summit flows are at least 14 MA old), surrounded by much younger lava flows located across the Klamath river to the north and west (from 2-8 MA). The flow at the Hessig Wall at the base of the slope [see Fig. 1] has been dated to early Miocene at 21 MA. It has been hypothesized that most of the layers on this western face are not from the Secret Spring Volcano vent. Rather, there might have once existed a larger volcano to the west or south which erupted explosively, and caused the massive volcaniclastic deposits. Secret Springs volcano would have then formed on the flanks of the remnants of the earlier volcano.

PROCEDURES

This region was field mapped over the summer and rock samples taken. Paleoslope of lava flows were determined through orientation of joint planes when only one set was present. No deductions were made of lava flows with perpendicular joint sets (the Lower Northern Andesite). Thin sections of most of the layers were made to identify more accurately the minerals involved. Major element analysis of 30 samples helped correlate layers, identify trends, and classify the rocks. Neutron activation analysis identified trends in REE, and K-Ar dating of several key layers helped solidify the temporal relationship between flows.

VOLCANICLASTIC UNITS

Airfall tuff / surge

This is the lowest portion of the pyroclastics in the region and rises approximately 100 ft along the slope. It outcrops above the vesicular basalt east/northeast of Hessig Ranch [see Fig. 1], towards and along the sides of Cornflake mesa (though not exposed very prominently there). It is noticeably absent on Albert's Peak and along the northern side of Train ridge as the tuff breccia above this layer continues through those regions. Continuing the regional trend, this layer also dips approximately 10 degrees to the east.

The first layer comprises of a white tuff layer exposed in the hillslopes, consisting of fine horizontal ash layers. This tuffaceous material varies in the level of stratification and organization. It primarily composed of a fine "dirty tuff" matrix, composed of small granules of tuff, pumice, and extra-fine vitric/crystal fragments. The outcrop often alternates between feet-thick beds of this dirty tuff and fine horizontal layers of white ashfall up to 6" thick. Due to the massive bedding and absence of fine laminations and juvenile lava fragments, this can be diagnosed as a tuff airfall.

Stratigraphically contemporaneous with this layer is another ash deposit immediately under the northern-most section of the Greywall. This outcrop is approximately sixty feet thick, and is composed of laminated layers of ash with semi-angular vitrophyre clasts (ranging in size from 1-25 cm. in diameter) interrupting the lamination/ bedding structure. The finer laminae in this formation often bend above and below the clasts, displaying "block sag"-- emplacement by a sub-aerial blast. Wavy-stratified laminae interspersed with juvenile vitric fragments (vitrophyre) is exemplary of a pyroclastic surge deposit. A pyroclastic "base surge," a turbulent, low-density flow caused by a