# THE OREGON KECK PROJECT:

## The Geology of the Klamath River Canyon Astride the California-Oregon Border

### Faculty

Stanley Mertzman, Franklin & Marshall College
Richard Hazlett, Pomona College

### Students

Sarah Barkin, Beloit College (No Abstract)
Brian Klawiter, Carleton College
Amber McIntosh, Colorado College
Jennifer McIntosh, Whitman College
Anders Nilsson, Carleton College
Jake Sewall, Washington and Lee University
Judy Wilson, University of New Orleans
Jeff Winick, Franklin and Marshall College

### Visitors

Dave Blackwell, Whitman College
Cameron Davidson, Beloit College
Kathleen Johnson, University of New Orleans
Steve Weaver, Colorado College
John Winter, Whitman College

|  | Artemis-Imdr Festoon (3) | Ovda Festoon | Atalanta Flow |
|---|---|---|---|
| Latitude | 35.9-38.7S | 6.0-6.5S | 69.8-70.8N |
| Longitude | 163.5-166.7E | 95.5E | 200.9-203.1E |
| Geologic Area | Dark lowland plains | Highland tessera | Northern trending ridge system in lowland plains |
| Region | Aino Planitia | Ovda Regio | Atalanta Planitia |
| Emissivity Values | .848-.898 | .5-.86 (2); .42-.78 (4); .26-.84 (1) | .87-.89; Mean=.88 |
| Reflectivity | .065-.150 | .16-.46 (4) | .07-.13 |
| RMS slope range (Degrees) | Average range1.03-4.16; total range 0.5-9.0 | 1.7-9.0 | 2.2-6.7 |
| Altitude (km) | 6051.14 | 6054.5-6056.6(2) | 6050.5-6051.75 |
| Thickness (estimated, m) | 500 | 50-150 (1); 180-280 (5); 52-144 (4) | 32-388; mean=65 |
| Ridge Spacing (m) | Mean=686m. | 640 (4); 625-770 (5); 500-750 (1) | 487-575 |
| Dimensions (km) | 180 x 250 | 250 x 300 (1); 280 x 320 (5) | 70 x 85 |
| Area ($km^2$) | 47,700 | 45,000 | 3500 |
| Volume ($km^3$) | 7,520-11,400 | 5,500 (1); 4,545 (4) | 215-430 |
| Yield Strength (Pa) | $2\text{-}30\times10^4$ | $2\text{-}6 \times 10^5$ (5) | $2.3 \times 10^3\text{-}3.4 \times 10^5$ (see table 2) |
| Viscosity (inferred) (Pa-s) | $1.0 \times 10^7\text{-}8.0 \times 10^9$ | $2.0 \times 10^7\text{-}2.6 \times 10^9$ (4); $10^{11}$ & $10^4$ (5) | $7.21 \times 10^4\text{-}1.14 \times 10^{10}$ (see table 2) |
| Bulk Density $kg/m^3$ | 2,110-2,360 | 3,010 and 2,550 (4) | 1,649-2,297 |

1) *Head J.W. and Hess P.C.,* 1996
2) *Izenberg N.R. and Arvidson R.E.,* 1994
3) *Moore et al.,* 1992
4) *Permenter J.L. and Nusbaum R.L.,* 1994
5) *Schenk p. and Moore H.J.,* 1992

Table 1

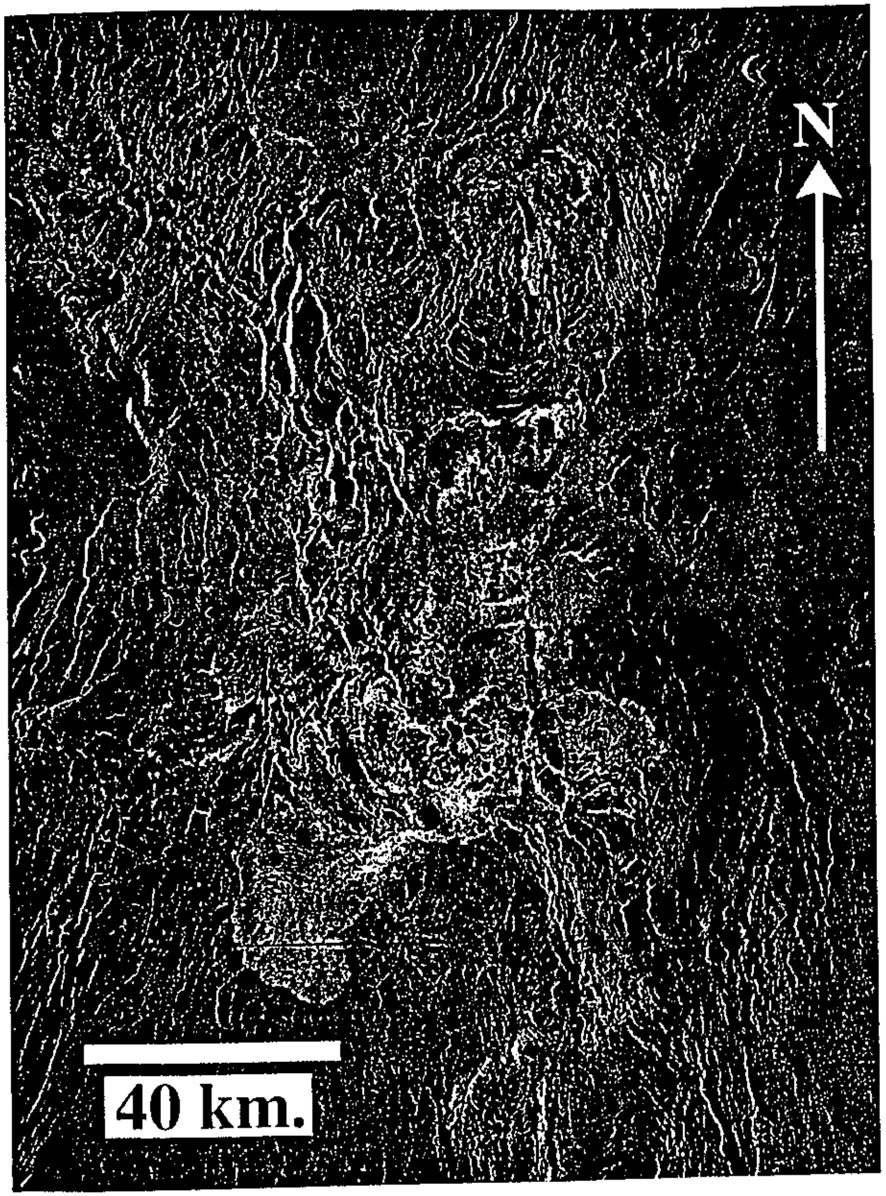

Figure 1

# THE GEOLOGY OF THE KLAMATH RIVER CANYON REGION

**Stanley A. Mertzman**
Department of Geosciences, Franklin and Marshall College, Lancaster, PA 17604

**Richard W. Hazlett**
Department of Geology, Pomona College, Claremont, CA 91711

## INTRODUCTION

The 1997-98 Keck Geology Consortium research project in the southern Oregonian Cascades was conducted on both sides of the Klamath River Canyon, essentially on the California-Oregon border, during July and August. The research group consisted of eight rising senior geology majors and two faculty. During the time of the project, the group received several faculty visitors: Dave Blackwell (Whitman College), Cameron Davidson (Beloit College), Kathleen Johnson (University of New Orleans), Steve Weaver (Colorado College), and John Winter (Whitman College). Each of these visitors was of much assistance in helping the students formulate their research plans and getting them started in the right direction.

## GEOLOGIC SETTING

The Cascade volcanic province is often divided into two parts on the basis of age and style of volcanism. Calc-alkaline volcanic rocks of the Western Cascades erupted from Late Eocene to Miocene time in a broad band across much of western Oregon and Washington. The arc narrowed markedly during Pliocene and Pleistocene time to form the majestic High Cascade volcanoes of today. The Cascade arc of today is on average 80 km wide and stretches from Lassen Peak in northern California to Mt. Meager in British Columbia.

The Cascade subduction zone is somewhat peculiar compared to other convergent plate margins. No deep focus earthquakes (>100 km) have been detected with the present subduction zone even though seismic tomography has detected and imaged a subducting slab at depths greater than 100 km (Rasmussen and Humphreys, 1988).

With the Gorda, Juan de Fuca, and Explorer divergent boundaries being quite close to the subduction zone, the development of the High Cascade volcanoes is likely linked to the subduction of very young (<25 Ma), hot oceanic crust beneath the northwestern coast continental margin. This situation may be a root cause for the lack of intermediate and deep seismicity. It may also affect the angle at which the oceanic plate segments are being subducted as well as the rate at which it is occurring. Presently, subduction is on the order of 4 cm/year at an angle of approximately N50$^{o}$E to the Pacific Northwest continental margin. This oblique subduction results in a regional stress field in which the greatest principal stress (horizontal compression) is oriented nearly north-south while the least principal stress (horizontal extension) is aligned nearby east-west (Smith, 1982; Blakely and Others, 1997). The Upper Klamath graben situated immediately to the east of the field area may be a direct result of this stress field orientation.

## OVERVIEW OF RESULTS

Eight students mapped and sampled nearly 70 mi$^2$ in the Oregonian Cascades (see Figure 1) on the California-Oregon border; four students (Klawiter, McIntosh, Nilsson, and Wilson) worked south of the Klamath River with the guidance of Rick Hazlett and four (Barkin, McIntosh, Sewall, and Winick) worked north of the Klamath River in conjunction with Stan Mertzman. The 1997 project required a substantial K-Ar component because of the lack of lateral continuity amongst many of the stratigraphic units. The K-Ar results for the 1995 and the 1997 projects, both of which were focused on the Klamath River region, stand in marked contrast to those which resulted from the 1991, 1992, and the 1994 projects. These latter projects were focused 20 miles to the north of Keno, Oregon on the Mt. McLoughlin - Brown Mountain area where a 10 Ma gap exists in the volcanic record (see Figure 2). This time gap in volcanic activity is not seen in the data from the Klamath River region. Using the stratigraphic nomenclature summarized by Priest (1990) the Late Western Cascade volcanic episode (17 Ma to 7.4 Ma) is absent to the north but well represented further to the south. Both the Early Western Cascade volcanic episode (>17 Ma) and the High Cascade episode (≤ 7.4 Ma) are well represented in both regions. It is also worth noting that most of the pyroclastic units mapped are from the southern region and are >17 Ma in age. Also, the K2O content of the samples <7.4 Ma decrease with decreasing age (Figure 2). Lastly, it is evident from the SiO2 - K2O relationship that extrusives more silicic than andesite are infrequently encountered, and the slopes of the trends depicted are different such that the K2O @ 55% SiO2 may reflect significantly thicker continental crust and / or a more steeply inclined subduction zone to the south.

With regard to regional petrogenesis Figure 3 depicts three MgO variation diagrams which document broad, general trends concerning SiO2, Al2O3, and Fe2O3T. The MgO - SiO2 relationship, interpreted in light of thin section petrography, suggests olivine fractionation (with Cr-spinel inclusions) plays a significant role in mafic magma evolution. The Al2O3 trend suggests plagioclase fractionation plays a rather minor role until MgO becomes ≤ 4%. The Fe2O3T trend sharply decreases at MgO ≤ 5% which, broadly speaking, coincides with the petrographic appearance of titanomagnetite as a significant microphenocryst to phenocryst phase and, therefore, its potential participation in magmatic differentiation. At isolated volcanic centers, clinopyroxene has a role to play in magma evolution; but, on a regional scale, it is of minor importance in terms of participation in a fractionating mineral assemblage.

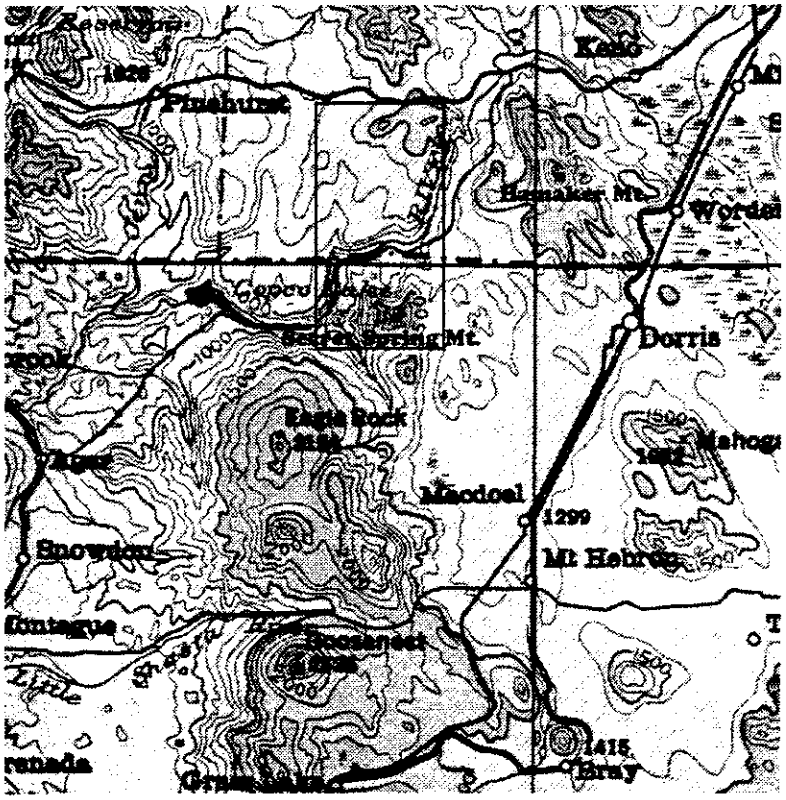

Figure 1. Location map for the 1997 Oregon Keck Project field area (Scale: 1" = 10 miles)

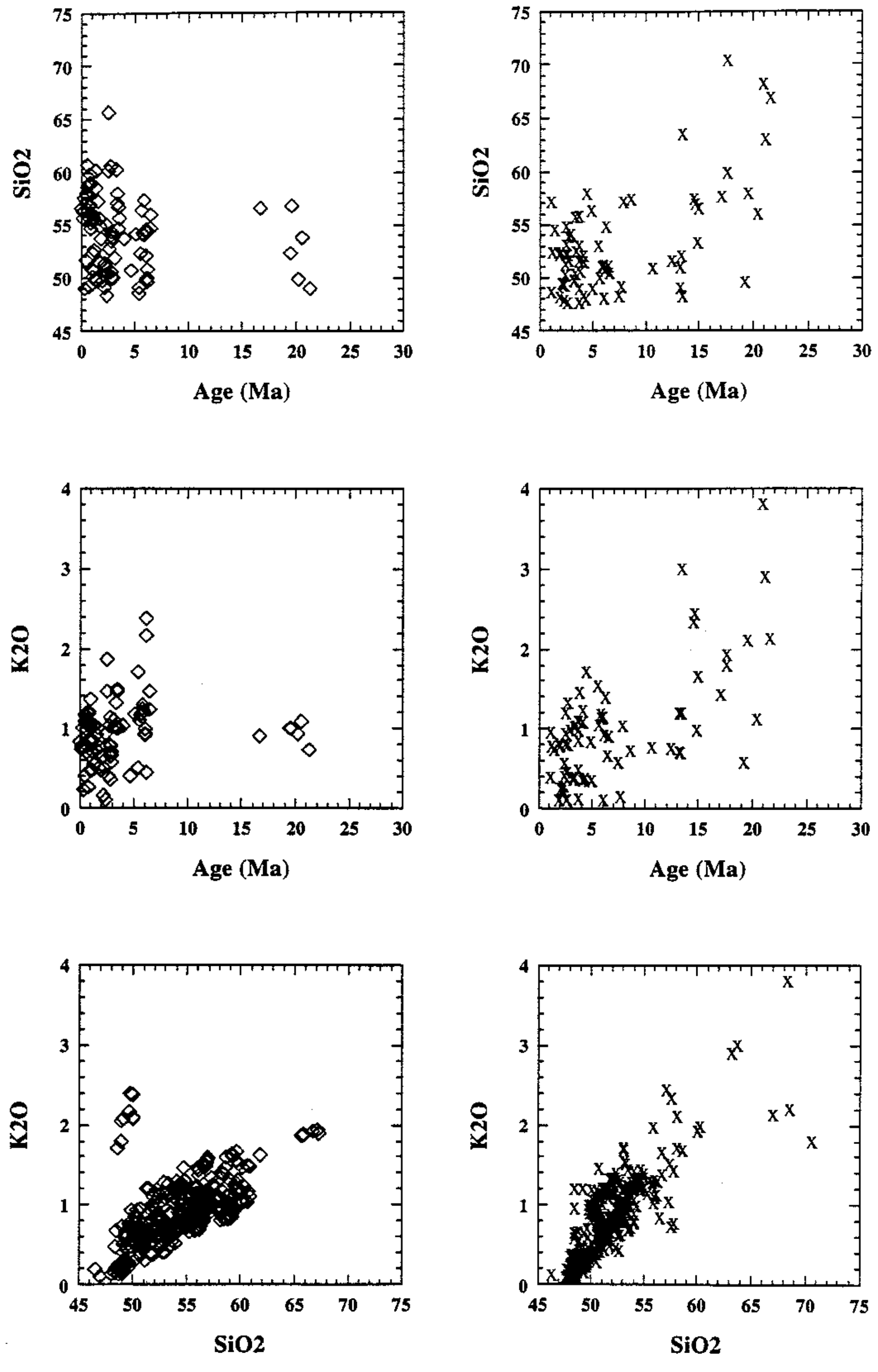

Figure 2. The left-hand side diagrams (diamond symbol) depict data from the Mt. McLoughlin region to the north of Keno, OR, while the right-hand side diagrams (X symbol) portray data from the Klamath River region southwest of Keno.

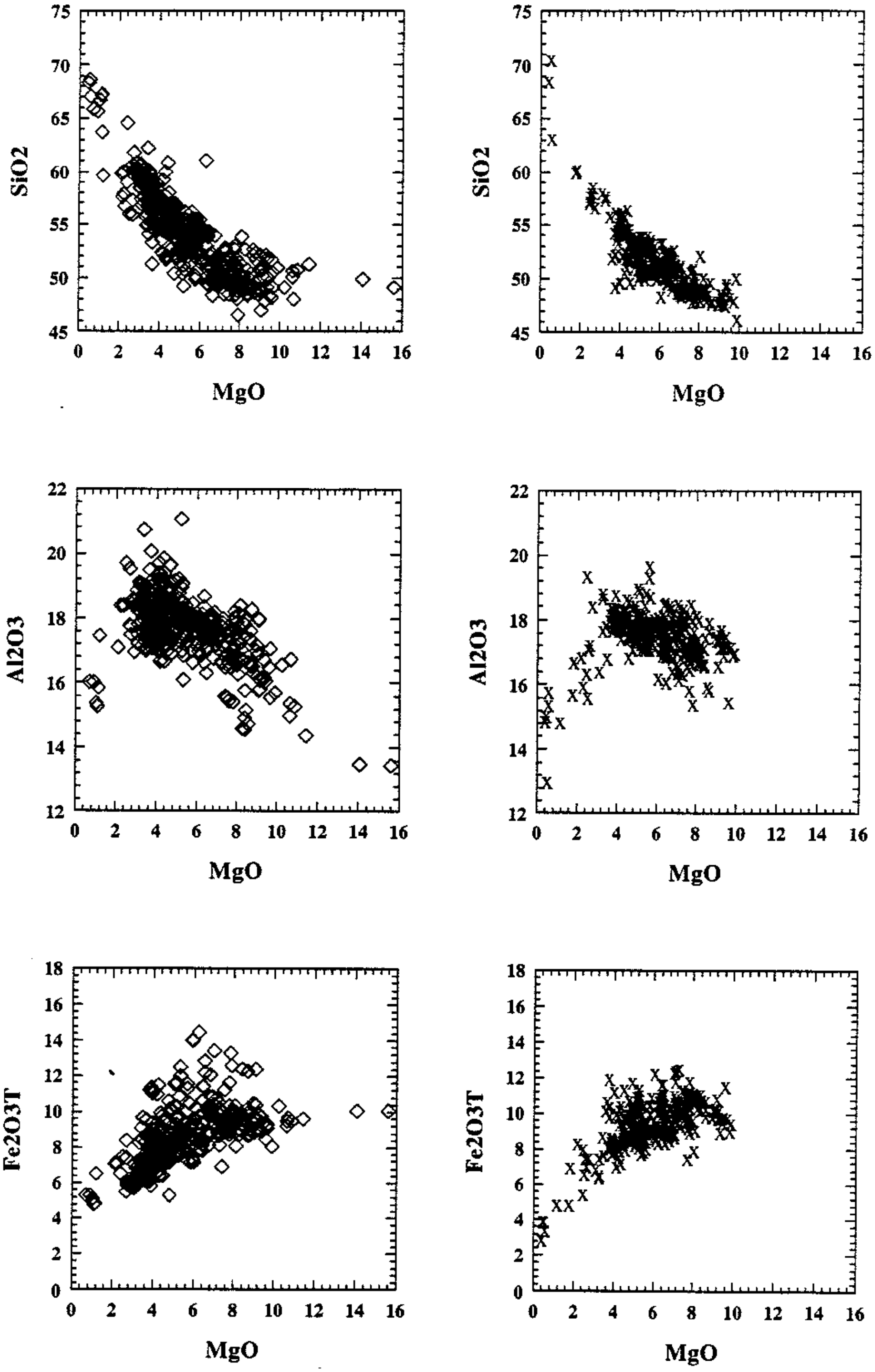

Figure 3. MgO variation diagrams which delineate regional geochemical trends. Symbolism is the same as in Figure 2.

## Present and Future Work

Hazlett and others (1997) report data concerning one of the larger landsliding events to occur in the U.S. which indelibly marked the north side of Secret Spring Mountain. Reconnaissance work done at the end of the 1997 field season and a K-Ar age date completed in February, 1998 suggest a possible source for the pyroclastic materials which are so evident on the south side of the Klamath River in the vicinity of Secret Spring Mountain. The likely source is an area of older rock sandwiched between the much younger lavas from the Eagle Rock and Goosenest volcanoes located west of Macdoel, CA (see Figure 1). Williams (1949) mapped much of this area as "Tb" (Pliocene basalts), but new research demonstrates an age variation from at least 20 Ma to 2 Ma. Several exogenous andesite domes in this area are similar in both mineralogy and chemistry to some of the pyroclastics which occur to the north in the vicinity of Secret Spring Mt. Interestingly, these Early Western Cascade andesite pyroclastic extrusives are also similar to 1997-1998 pyroclastic extrusives from Montserrat volcano in the Caribbean region. Further field work will be accomplished in northern California during the summer of 1998. Naturally, completing work on two manuscripts which summarize this Oregon Cascade research is also a top priority.

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# Petrographic and geochemical analysis of a portion of the High Cascades along the Klamath River on the California-Oregon border

**Brian Klawiter**
Carleton College, Department of Geology, Northfield, MN 55057
*Faculty sponsor: Bereket Haileab, Carleton College*

## INTRODUCTION

The Pacific coast of North America has been a zone of convergence throughout much of the Cenozoic. Some major changes in the manner of plate interaction originated in the Late Oligocene with the subduction of an oceanic spreading ridge under the western edge of the continent, and resulted in the creation of the Cascade volcanic arc in the basic form which we see today (Hart and Carlson, 1987). More recent changes in tectonic environment have also had marked effects on the Cascade Range. The rate of subduction of oceanic plates under the North American continent has been generally slowing down over the past 35 million years, and in particular the rate has decreased from 7 Ma to the present (Hughes, 1990). It is this slowing of convergence, the oblique angle of subduction, and transverse motion related to the Walker Lane belt which may be responsible for the inception of Cenozoic westward clockwise rotation of the southern Cascade Range (Blakely et al., 1997). This rotation is probably the source of the regional east-west extensional stress which has allowed the westward migration of the Basin and Range province into the southern Cascade region over the past 10 million years (Guffanti and Weaver, 1988). The arrival of Basin and Range extension and volcanism has complicated the volcanic history of the Cascade Range. Widespread north-south normal faulting and thinning of the crust associated with Basin and Range extension has allowed primitive basaltic and bimodal magmas to be erupted in the southern Cascade area in addition to the normal calc-alkaline andesitic lavas (Hart and Carlson, 1987).

In order to gain a better understanding of this volcanic history of the southern Cascade Range, a project was conducted during the summer of 1997 through the W.M. Keck Foundation in Geology. This project investigated a small portion of the High Cascade Range on the Oregon-California border. In this paper are presented the results of investigation of a section approximately ten square miles in size, straddling the Oregon-California border and located along the south rim of the Klamath River Gorge. The main focus within this project area was Secret Spring Mountain, a small extinct volcano on the south side of the Klamath River. The investigation involved field mapping of the project area and collection of rock samples for petrographic and geochemical analysis. The goals of this project were the production of an accurate geologic map and stratigraphic column for the area, petrographic and geochemical descriptions of the rock units found within it, and the interpretation of the geologic history.

## STRATIGRAPHY AND PETROGRAPHY

The field area is divided into three sections: Secret Spring Mountain, Rock Creek Canyon, and the Topsy Grade. Each of these sections has a distinct stratigraphic column. The section of Secret Spring Mountain consists of six units. This is in contrast to the sections of Rock Creek Canyon and the Topsy Grade Road further to the northeast along the Klamath River Gorge rim, each of which has a more complicated stratigraphic collection with a total of twenty different volcanic units. For the sake of brevity, only the major units will be discussed.

The lowest unit at Secret Spring Mountain and the oldest material in the area is the Secret Spring Tuffaceous Unit (Tvts) (figure 1). This unit underlies the entire mountain, with a total vertical exposure of approximately 100 meters. Much of the unit appears as massive beds 2-10 meters thick, but also has occurrences of fine bedding less than 1 cm in thickness and occassional layers containing rounded clasts, suggesting that both direct air fall and sub-aqueous deposition may be present. Thin-section analysis from one of the more massive sections indicates that the unit consists of approximately 70% tiny groundmass glass fragments, 20% pumice clasts less than 2 mm in diameter, ~6% fragmented andesine phenocrysts, and rare fragmented olivine and magnetite crystals. This underlying tuffaceous material was instrumental in the formation of a landslide which removed a portion of the northern side of Secret Spring Mountain.

The main bulk of Secret Spring Mountain consists of the Secret Spring Olivine Basalt (Tvbs), which geochemical data shows to fall within both the basalt and basaltic andesite ranges (see figure 2). In the central peak area, the maximum thickness of this unit is approximately 100 meters, and is made up of individual flows 2-8 meters