THE CASCADE VOLCANISM PROJECT IN SOUTHERN OREGON

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Late Tertiary Cascades Volcanism in the Area West of Klamath Falls, Oregon

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INTRODUCTION

Four of the past five summers, between eight and eleven students have participated in Keck research projects focused on the volcanic evolution of the Cascade Mountains in south-central Oregon. Each student has at the foundation of her or his project the mapping of the bedrock geology of a seven to nine square mile area and the collection of a representative suite of hand samples from each of the rock units which outcrop there. Before breaking camp, each student writes a detailed summary of the field work accomplished, a copy of which is subsequently sent to the home institution advisor. The student also cuts 30 rock chips for thin sections as well as clean slices for geochemistry. These thin section blanks are mailed from camp so that the finished sections will be waiting for each student at the beginning of the fall semester or quarter, thus getting the project off to a fast-paced start. The analytical techniques necessary to accomplish whole rock major and trace element geochemistry are either taught at the home institution, or the student travels to Franklin & Marshall for an intense learning experience which spans five to six days. Each student successfully determines twenty to thirty whole rock chemical analyses-data which constitute the foundation upon which petrological interpretations or hypotheses are grounded. Supplemental analytical data includes INAA data for select samples and K-Ar whole rock geochronological data which provides an absolute time-stratigraphic framework. The latter data are especially important if the investigator is to say anything meaningful about patterns of change in mineralogy or whole rock geochemistry as a function of time. Just as one would want to know how a particular organism has evolved through geologic time, petrologists strive to understand the evolution of continental margin subduction zones as a function of geologic time.

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 (approximately on average), 80 km wide and stretches from Lassen Peak in northern California to isolated volcanic centers in west central British Columbia (Figure 1).

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 Juan de Fuca plate subduction even though seismic tomography has detected and imaged a subducting slab at depths greater than 100 km (Rasmussen and Humphreys, 1988).

As the Juan De Fuca divergent boundary is quite close to the subduction zone, the plate being subducted is relatively warm and thin. This situation may be a root cause for the lack of intermediate and deep seismicity. It may also affect the angle at which the Juan de Fuca plate is being subducted as well as the rate at which this 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 nearly east-west (Smith, 1982). The Upper Klamath graben, the eastern boundary of the 1992 field area, may be a direct result of this stress field orientation.

OVERVIEW OF RESULTS

Twelve miles southwest of Klamath Falls, Oregon, eight students mapped 64 mi^2 during the summer of 1995 in 8 mile long (E-W orientation), 1 mile wide (N-S orientation) strips which have the Klamath River literally bisecting each student's area. Only basalts and andesites were identified in the field, and subsequent petrographic observations corroborate the relatively limited range in bulk composition. The mineralogy of these extrusives include only olivine, plagioclase, Cpx, Opx, and two opaque phases, Cr-spinel and titanomagnetite. No hornblende, biotite, quartz, or K-feldspar were identified in any of the nearly 240 thin sections that were investigated

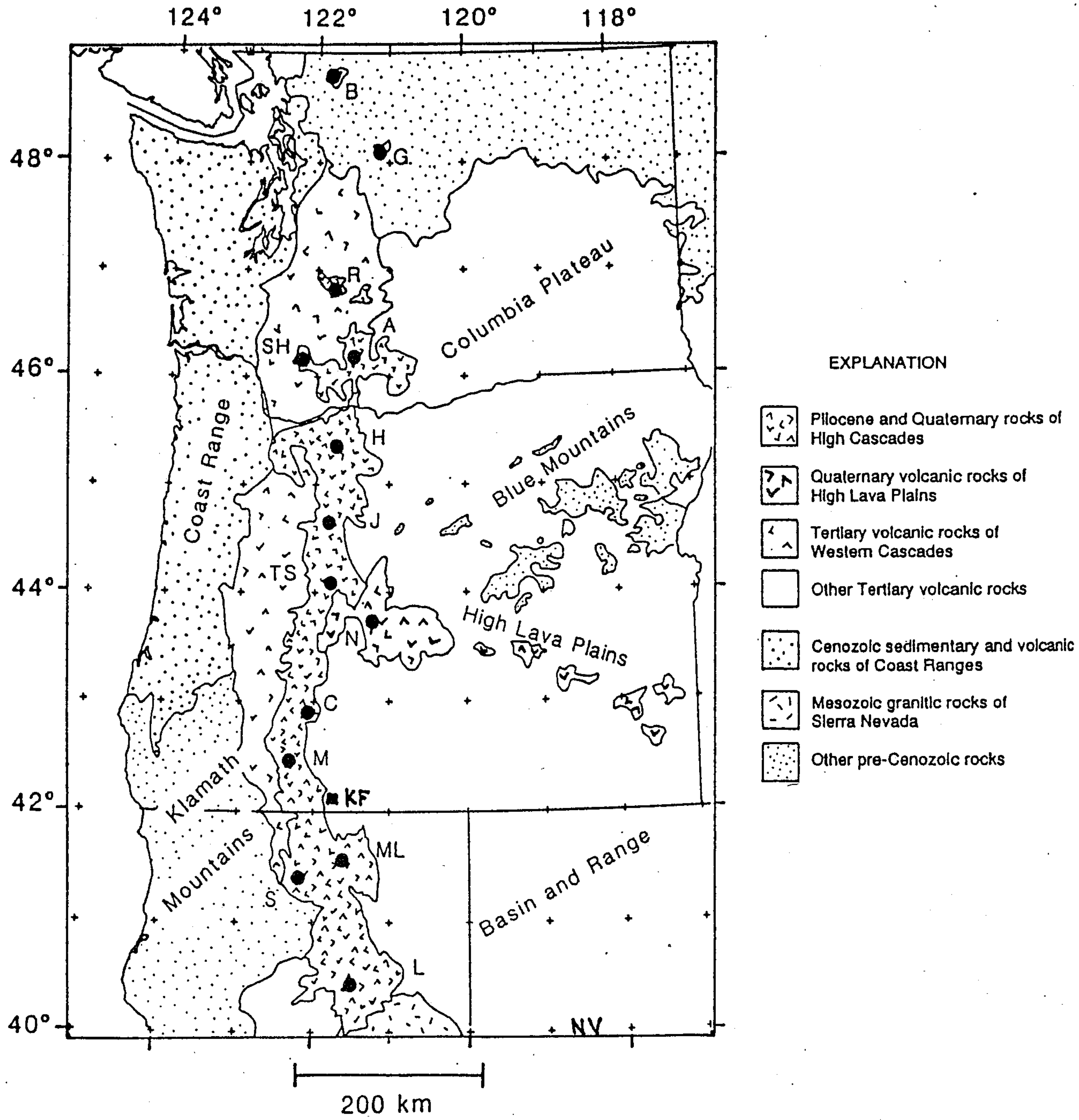


Figure 1. Generalized geologic map of the Cascade volcanic province and surrounding areas of the Pacific Northwest (States of Washington, Oregon, California and Nevada). modified from Blakely and Jachens, 1990). Most letters refer to major volcanoes; M - Mt. McLoughlin, S - Mt. Shasta, ML - Medicine Lake, C - Crater Lake. KF locates the town of Klamath Falls, Oregon.

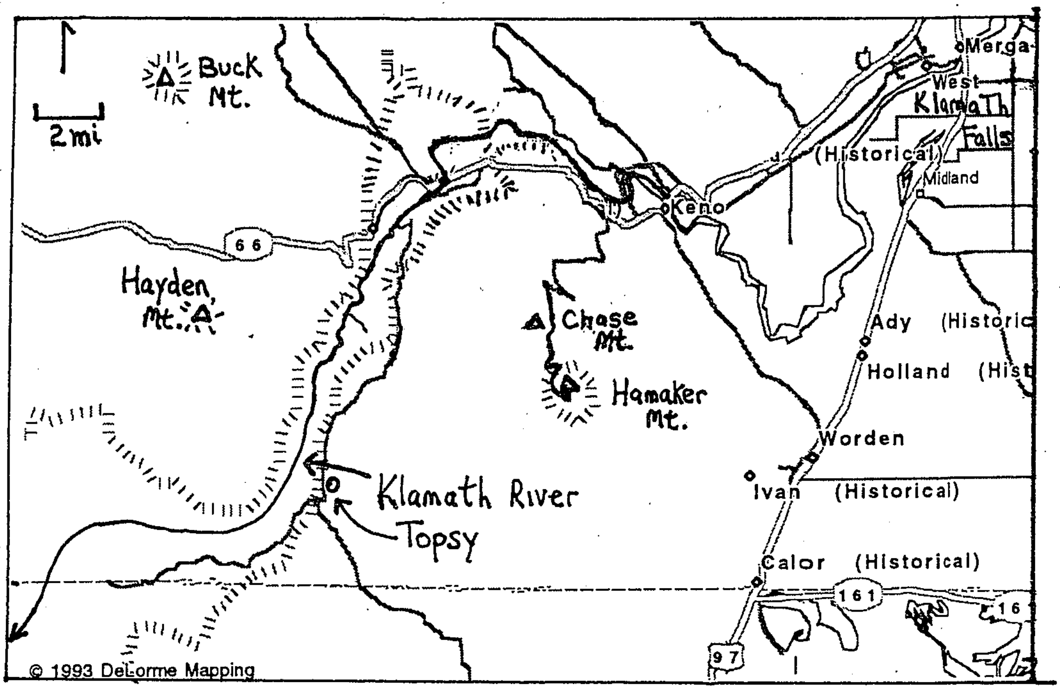


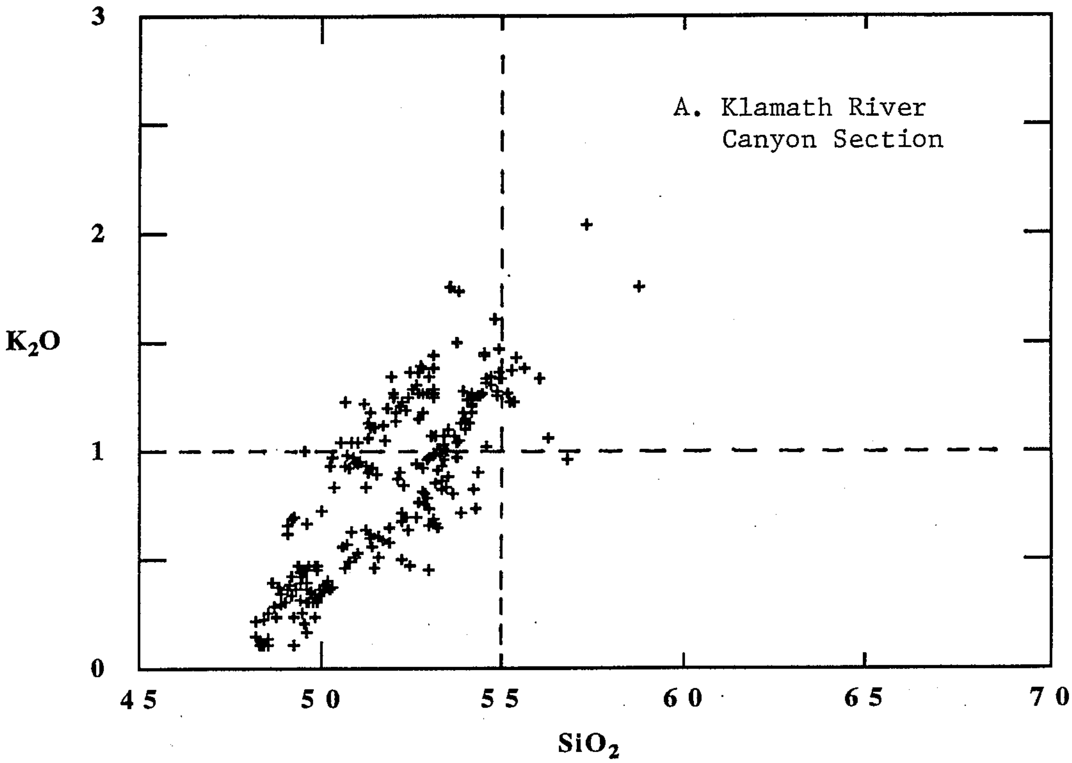
Figure 2. General location map for the 1995 summer field projects. Eight field areas oriented E - W extended from the western flanks of Hamaker and Chase Mountains to a N - S line located approximately 3 to 4 miles west of Topsy. The Klamath River Canyon essentially bisects many of the student's field areas.

as part of this project. The age of the volcanism in this area ranges from 7.4 to 1.1 Ma; to the north, in the Mt. McLoughlin area, the volcanism ranges in age from 6.5 Ma to ~ 50,000 years old. In the area mapped this past summer, the youngest lavas are high alumina olivine tholeiite basalts, whereas, to the north, the youngest lavas are extensively fractionated basaltic andesites and andesites which constitute Mt. McLoughlin and Brown Mountain respectively.

Compiled geochemical data from the north (summers of 1991, 1992, 1994) are expressed in Figure 3B as a SiO_2 - K_2O diagram; the data from 1995 are depicted in Figure 3A. Notice the gross similarities of two plots; in particular, the data congregations which suggest two sub-parallel trends defining increasing K_2O as SiO_2 increases. The higher K_2O trend is likely defined by samples whose parental magmas have had extensive interactions with pre-existing crustal materials. Given the youthfulness of the crust in this portion of the Pacific Northwest, Sr and Nd isotopes will be very insensitive isotopic tracers in attempting to verify this hypothesis. On the other hand, combining oxygen isotopes, a stable isotopic system, with a radiogenic system may constitute the tools necessary to unravel the origin of these parallel trends. In addition to the common shape of the data distribution, notice the slope of the trend for the southern data points is more steeply inclined than the slope of the trend for the data from the north. If the K_2O - SiO_2 relationship is ultimately related to the depth of the inclined seismic plane, the data in Figures 3A and 3B suggest significant along-strike variation in the angle of subduction, in this case dipping more steeply in the south and less steeply to the north. Since all the samples which constitute the parallel K_2O - SiO_2 data arrays also have substantial negative Ta and Nb anomalies, it is safe to assume the origin of the basalts and andesites is related to the process of subduction and not to Basin and Range tectonism.

Acknowledgment

I would like to thank the 39 students who worked on this project over the past two years. Some of you are among the very best students I have had the pleasure of working with during my twenty-three years of teaching and doing research.



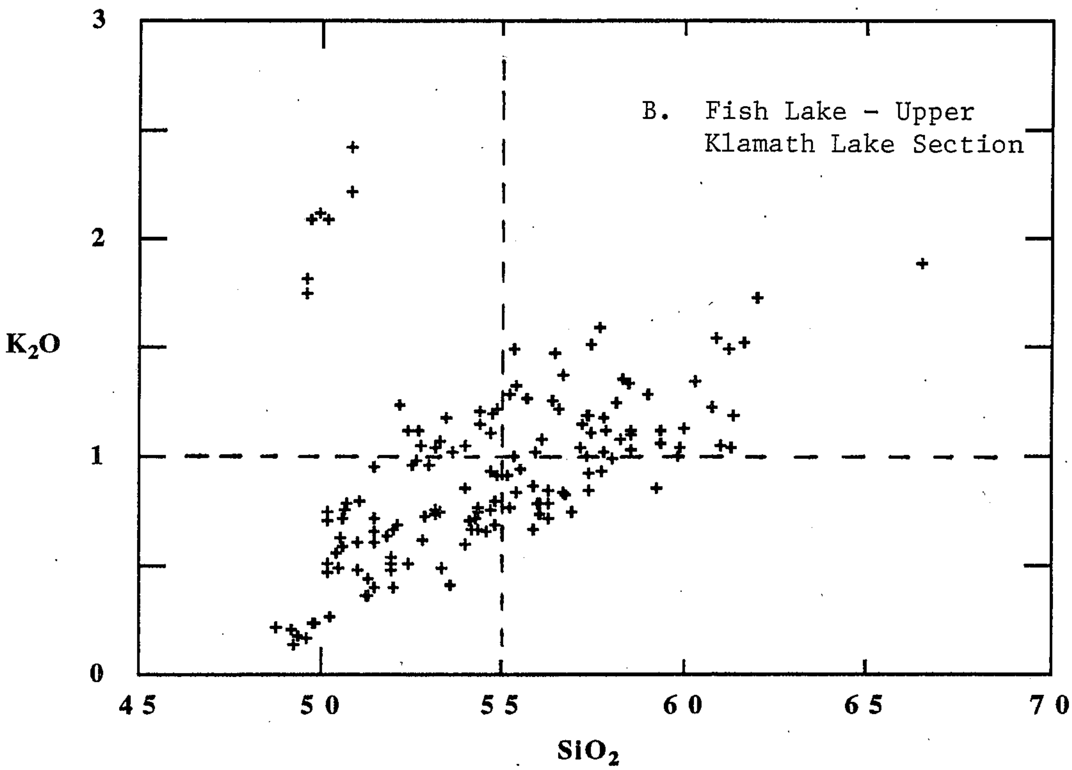


Figure 3. K_2O versus SiO_2 for the 1995 Klamath River Canyon project (diagram A) and for the 1991, 1992 and 1994 cross-section of the volcanic arc located 25 miles further to the north.