Geochemistry and Petrology of Neogene Volcanics of the Southern High Cascades near Keno, Oregon

Jeffrey A. Winick
Department of Geosciences, Franklin & Marshall College, P.O. Box 3003, Lancaster, PA 17604-3003
Faculty Sponsor: Stanley A. Mertzman, Franklin & Marshall College

INTRODUCTION

The Cenozoic evolution of the Cascades been marked by a northwestern migration of volcanism coincident with subduction of the East Pacific rise spreading center under the North American Plate beginning approximately 30 Ma. In more recent times (Late Miocene to Holocene), active calc-alkaline volcanism of the Cascades has been focused in the High Cascades which extends from Lassen Peak in California to Mount Meager in British Columbia. This young volcanic arc is primarily a result of oblique subduction of the Juan de Fuca, Gorda, and Explorer plates under the North American plate. Structurally, the region is characterized by numerous NW-SE trending normal faults due to the recent impingement of Basin and Range extension on the High Cascades (Blakely et al., 1997). Because of its proximity to Basin and Range extension and volcanism, it is possible that two different mantle source regimes are involved in the latest magmatism which has sporadically occurred in this region. This study focuses on a suite of subalkaline Cascade rocks collected immediately north of the California-Oregon border. Geochemical and petrographic analysis of these rocks may yield a clearer picture of the complicated magmatic processes ongoing in this region.

FIELD AND ANALYTICAL METHODS

The study section consists of a ten square mile area (from north to south on the Mule Hill Quadrangle: R5E, T40S, Sections 2, 11, 14, 23, 26, 35; and R5E, T41S, Sections 2, 11, 14) located just north of the Klamath River. Lithologic units, as well as individual flows within units, were delineated in the field based on hand sample mineralogies and textures. Relative ages were difficult to interpret due to poor exposure of contacts between many of the units.

A suite of 38 rocks representative of the various lithologic units was chosen for geochemical and petrographic thin section analysis. Various procedures including rock crushing, X-ray fluorescence analysis, loss on ignition, and iron titration were performed at Franklin & Marshall College.

PETROGRAPHY AND STRATIGRAPHY

A 1000-point count of each thin section was performed to provide an accurate measure of the modal abundance of phenocryst and groundmass phases. On the basis of field relationships, petrography, and geochemistry of the 38 rock specimens, eight distinct lithologic units ranging in composition from basalt to basaltic trachy-andesite have been defined:

Andesite Kipuka (A) (15.0 +/- 0.4 Ma) (All K/Ar dates from Mertzman, 1998): This unit is the oldest in the study section and is found only in the southern portion as a topographic high point. In hand sample, the rock is a flow laminated, medium-gray, aphanitic andesite, with a very fine-grained groundmass. In thin section, trachytic plagioclase laths dominate the rock. Clinopyroxene is the dominant ferromagnesian phenocryst phase, and both clinopyroxene and orthopyroxene exist as intergranular phases. An abundance of fine grained (<.01 mm) apatite needles is characteristic of this rock. The modal mineralogy ranges from 60-65% plagioclase, 10-15% clinopyroxene, 10% orthopyroxene, and 5-11% opqaque oxides. Using the Le Bas and others, 1986 classification, reveals this rock to be a basaltic trachy-andesite, quite anomalous in the context of the surrounding lavas.

Northern Equigranular HAOT (Neh) (3.66 +/- 0.24 Ma): This unit consists of a NW-SE trending flow front situated about one mile south of Oregon State Rt. 66. In hand sample, the unit appears as a light-gray, diktytaxitic, high alumina olivine tholeiite (HAOT) basalt. In thin section, the subophitic texture of this unit is revealed. Olivine is the dominant ferromagnesian phenocryst phase containing numerous poikolitically enclosed euhedral picotites. The unit is comprised of 48-50% plagioclase, 20-23% clinopyroxene, 15-20% olivine, 4-5% vesicles, and 3-4% opaque oxides.

66 Basaltic Andesite (66Pba) (3.4 +/- 0.1 Ma): This unit is located directly south of Oregon State Rt. 66, and in outcrop exhibits flow jointing and spheroidal weathering. A hand sample reveals a medium grained, dark-gray, porphyritic basaltic andesite. In thin section, plagioclase occurs as both small laths in the groundmass and larger tabular phenocrysts. Small resorbed zones are present within the plagioclase phenocrysts giving them a "moth eaten" texture. Olivine, clinopyroxene, and plagioclase often occur in glomeroporphyritic

The least understood areas are the Shovel Creek "cones" which appear superimposed on lavas that are approximately 10 million years older. These cones are in a linear array, with the cone nearest the river the highest topographically. It appears that the structures are fault related, especially in light of the age discrepancy. They may be linked to the unit south of the creek as a cross-creek unit appears exactly where the cones stop north of the creek. Continued research would be required to fully understand the volcanological history of the Secret Springs area.

REFERENCES CITED

Cas R.A.F. and Wright J.V. 1988, Volcanic Successions, Modern and Ancient: London, Chapman and Hall 528 p.

Fisher R.V. and Schmincke H. 1984, Pyroclastic Rocks: Berlin, Springer-Verlag, 472 p.

Guffanti,M. and Weaver, C.S., 1988, Distribution of late Cenozoic volcanic vents in the Cascade Range: Journal of Geophysical Research, v.95, B12, p. 6513-6529

Tatsumi, Y. and Eggins, S. 1995, Subduction Zone Magmatism : Cambridge, Blackwell Science, 212 p.

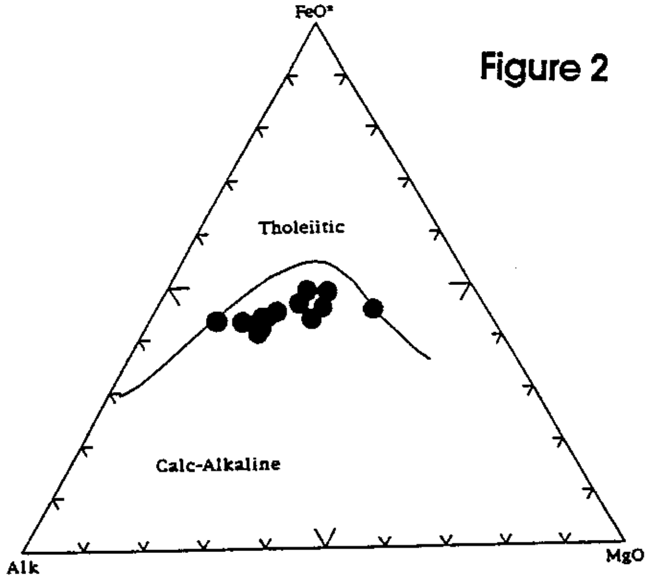

Figure 2

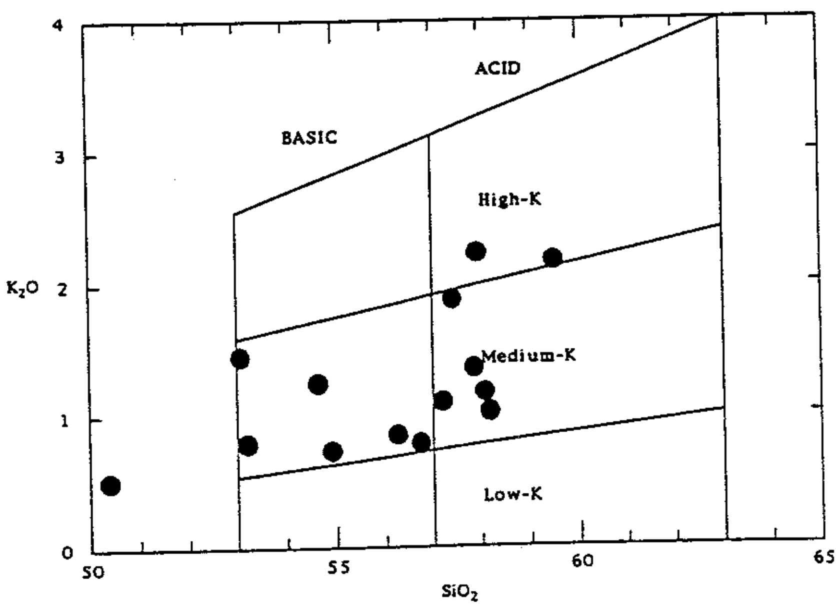

Figure 3

clumps. The modal mineralogy ranges from 55-60% plagioclase, 25% clinopyroxene, 5-9% opaque oxides, and 5-7% olivine phenocrysts.

Mud Spring Mountain Basaltic Andesite (Msm) (2.6 +/- 0.2 Ma): This unit is the most voluminous basaltic andesite unit in the study section. It is composed of at least seven distinct flow sub-units, all classified as Msm. In hand sample, this unit occurs as a medium-gray, fine grained basaltic andesite. In thin section, olivine characteristically is iddingsitized and occurs in glomeroporphyritic clumps with plagioclase and clinopyroxene. The rock is comprised of 40-55% plagioclase, 35-39% clinopyroxene, 5% olivine, and 2-5% opaque oxides.

Long Prairie Creek Fissure Basalt (Lpc-g) (2.4 +/- 0.2 Ma): This unit originates from a fissure eruption north of the study section (located in the NW 1/4 of Section 3, T40S, R5E) and blankets the northwestern-most portion of the field area. A flow lobe of the unit also exists between the Msm and Mfba units. Hand specimens appear as medium-gray, glomeroporphyritic to porphyritic basalts. In thin section, the very fine grained intergranular texture dominated by granular clinopyroxene is the most distinctive feature. Samples in closest proximity to the source exhibit large (0.5-1 cm) glomeroporphyritic clumps of plagioclase and olivine, while samples from the distal flow end contain mainly olivine phenocrysts. The modal mineralogy consists of 45-47% plagioclase, 26-28% clinopyroxene, 14-15% olivine, and 6-9% opaque oxides.

Mud Spring Mountain Fissure Basalt (Mfba): This unit has not been radiometrically dated; however, strong field evidence that suggests Mfba stratigraphically overlies both Lpc-g and Msm. The upper age boundary is not as well constrained, and it is hoped that future study of the area will yield a K/Ar date for this unit. Mfba occurs as a NW-SE trending series of three hills just north of Mud Spring Mountain Basaltic Andesite. Hand samples occur as both vesicular scoriatious basalts and porphyritic basalts. In thin section, large tabular zoned plagioclase exhibits the "moth eaten" texture, a characteristic this unit has in common with 66Pba. Complete post-crystallization alteration of olivine to opaque oxide is another distinctive petrographic feature. The rock consists of 40-47% plagioclase, 16-20% clinopyroxene, 10-14% olivine, 5-10% opaque oxides.

Southern Equigranular HAOT (Seh) (2.1 +/- 0.3 Ma): This unit lies just south of Mud Spring Mountain and is laterally extensive both east and west of the study area. Hand samples of this unit appear as light-grey, fine-grained, diktytaxitic HAOT basalts, with subhedral phenocrysts of olivine. In thin section, this unit is distinguishable from its northern relative (Neh) by its lack of subophitic texture and more pronounced diktytaxitic texture. The rock is comprised of 50-54% plagioclase, 17-18% clinopyroxene, 17-18% olivine, 8-10% vesicles, and 1-3% opaque oxides.

Olivine-"rich" HAOT (Orh) (1.9 +/- 0.4 Ma): This unit is the youngest and volumetrically most abundant in the area. Its source, though still undefined, is believed to lie west of the study section. Flows from this unit extend to the Klamath River canyon where it is observed to be at least 75 ft thick and composed of at least three distinct flow sub-units. In hand sample, this unit is a dark-grey, vesicular HAOT basalt. Thin section reveals that the diktytaxitic texture is strikingly similar to the Seh unit, the main difference being a slightly subophitic component to the groundmass. The unit is comprised of, 45-47% plagioclase, 29-30% clinopyroxene, 11-14% olivine, 8% vesicles, and 0.5-1% opaque oxides.

GEOCHEMISTRY

A Total Alkalis vs. Silica (TAS) plot of the analytical data indicates several important trends. All of the lithologic units plot as subalkaline, fall within a fairly narrow range of SiO_2 content (~48-57 wgt%), and are classified as basalt, basaltic andesite, and basaltic trachy-andesite. On the TAS plot, the data form two distinct sub-parallel linear trends labeled "Trend 1" and "Trend 2" (Figure 1). The subalkaline nature of these units is further subdivided on an AFM plot (Figure 2, after Irvine and Baragar, 1971). The Msm, Lpc-g, Mfba, and 66Pba follow a calc-alkaline trend while the Orh, Neh, Seh units follow a more tholeiitic trend.

The two TAS sub-parallel trends were plotted separately on a chondrite normalized spider diagram to illustrate some interesting similarities and differences (Figures 3 and 4, after Sun, 1980). Both trends display a distinct Nb depletion in addition to high Ba/Rb ratios. The main difference between trends is the degree of enrichment of large ion lithophile elements (LILE), with Trend 1 indicating a lesser degree of enrichment than Trend 2. With the exception of La, differences between the two trends in the concentrations of high field strength elements (HFS) and light rare earth elements (LREE) are minimal.

Bivariate major and trace element plots indicate interesting trends as well. In general, as a function of decreasing MgO; Ni, Cr, Fe_2O_3T, and CaO behave compatibly, while Al_2O_3, K_2O, TiO_2, P_2O_5, Rb, Zr, and Ba behave incompatibly. As a function of decreasing CaO; Al_2O_3, P_2O_5, Rb, and Sr generally behave incompatibly. Additional bivariate plots of CaO vs. Y show that Y is nearly constant as a function of decreasing CaO, except in unit A where a strong incompatible trend is observed.

DISCUSSION

The Nb depletion indicated by the spidergrams may be due to residual titanite in the mantle source, crustal contamination, or some combination of the two (Reagan and Gill, 1989). The high Ba/Rb ratio, in addition to enriched LILEs depicted in both diagrams, suggests a subduction related origin for the rocks (Carlson and Hart, 1988). This is further strengthened by a Zr/Y vs. Ti/Y discrimination diagram which separates "Within-plate" from "Plate margin" rocks (Figure 5, after Pearce and Gale, 1977).

Given the proximity of Basin and Range impingement, and if examined separately from the calc-alkaline and tholeiitic trends, the TAS trends seem to suggest two separate mantle sources for the rocks under investigation. There is, however, significant overlap of the calc-alkaline and tholeiitic trends if viewed in the context of the sub-parallel trends on the TAS plot. A more likely scenario is one in which two or more batches of magma experience different evolutionary paths, but originate from the same mantle source. Because of the lack of Sr and Nd isotope data, no direct inferences can be made.

The bivariate plots suggest several fractionation schemes which may characterize the units further. The data indicate that for all units except A, olivine fractionation is occurring, evidence for which is also observed in thin section. In addition, plagioclase does not appear to be a fractionating phase for any units except A. Clinopyroxene fractionation seems to be an ongoing process for all of the HAOT units; however, this is unlikely due to clinopyroxene being a near solidus phase in these rocks. Instead, a fractional partial melting scheme is proposed for the HAOT units which is consistent with both geochemistry and petrography.

The presence of laterally extensive volumes of HAOT extrusives in a short time span, compounded by the fact that younger flows are more mafic than older is intriguing. Over time, faulting related to Basin and Range extension may be permitting the more mafic partial melts to reach the surface in this area. No source vents have been found for the HAOT units in this area. On the basis of field relationships, this indicates that within a short span of time, lavas of nearly identical composition were being extruded from vents at least four miles apart.

Legend:

A	Neh	66pba	Msm	Lpc-g	Mfba	Seh	Orh
×	✱	●	▲	■	◆	Y	

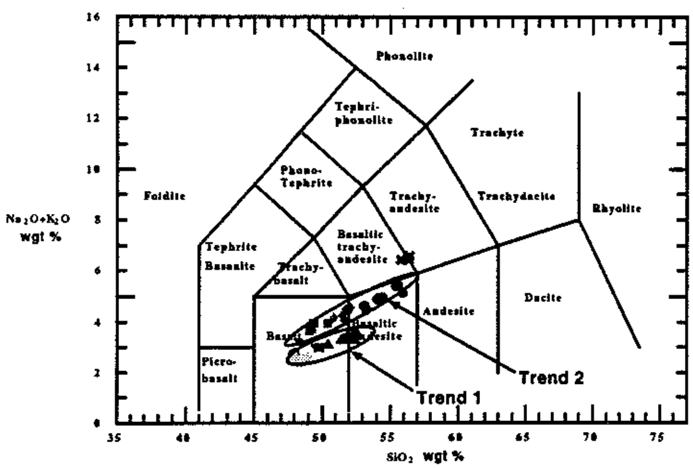

Fig. 1. A Total Alkalis vs. Silica plot showing two sub-parallel linear trends (after Le Bas and others, 1986).

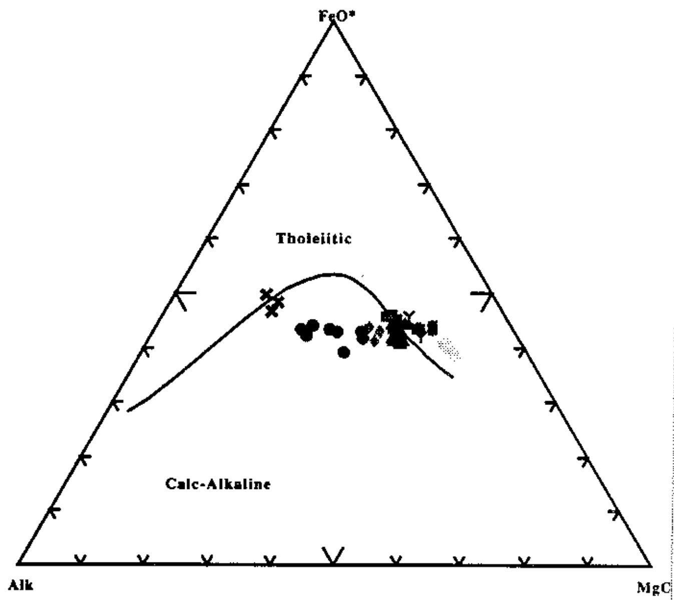

Fig. 2. AFM plot showing tholeiitic and calc-alkaline trends (after Irvine and Baragar, 1971).

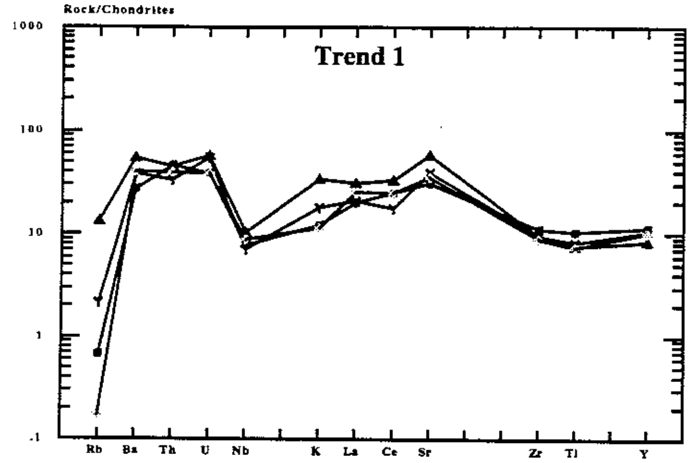

Fig. 3. Chondrite normalized spider diagram of Trend 1 showing Nb trough and high Ba/Rb ratio (after Sun, 1980).

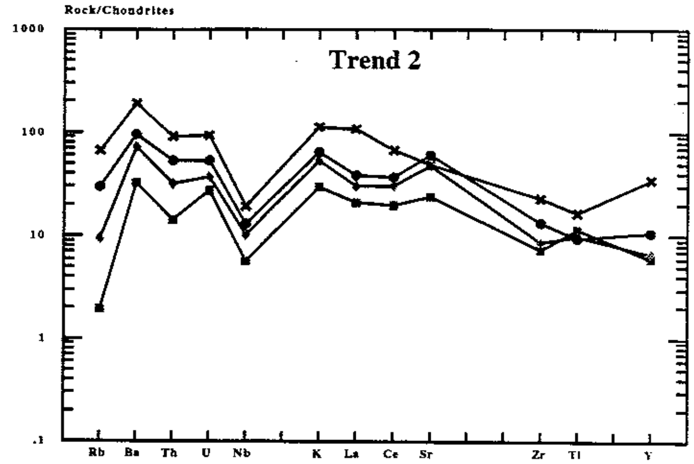

Fig. 4. Chondrite normalized spider diagram of Trend 2 showing Nb trough and high Ba/Rb ratio (after Sun, 1980).

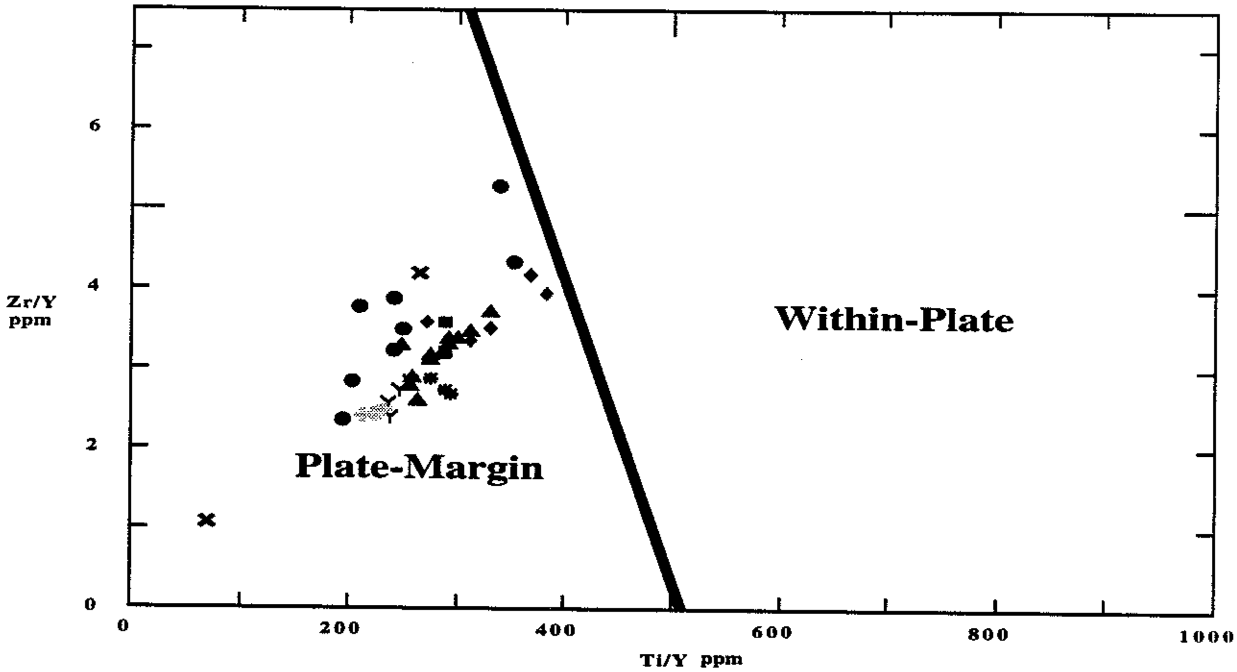

Fig. 5. Zr/Y-Ti/Y discrimination diagram indicating plate-margin nature of rocks of the study area (after Pearce and Gale, 1977).

REFERENCES CITED

Blakely, R.J., Christiansen, R.L., Guffanti, M., Wells, R.E., Donnelly-Nolan, J.M., Muffler, P.L.J., Clynne, M.A., Smith, J.G., 1997, Gravity anomalies, Quaternary vents, and Quaternary faults in the southern Cascade Range, Oregon and California: Implications for arc and backarc evolution: Journal of Geophysical Research, v. 102, p. 22513-22527.

Carlson, R.W., and Hart, W.K., 1988, Flood basalt volcanism in the northwestern United States: Continental Flood Basalts, J.D. Macdougall (ed.), p. 36-61.

Irvine, T.N., and Baragar, W.R.A., 1971, A guide to the chemical classification of the common volcanic rocks: Canadian Journal of Earth Sciences, v. 8, p. 523-548.

Le Bas, M.J., Le Maitre, R.W., Streckeneisen, A., and Zanettin, B., 1986, A chemical classification of volcanic rocks based on the Total Alkali-Silica Diagram: Journal of Petrology, v. 27, p. 745-750.

Mertzman, S.A., 1998, Unpublished K/Ar dates.

Pearce J.A., and Gale, G.H., 1977, Identification of ore-deposition environment from trace element geochemistry of associated igneous host rocks: Geologic Society of London Special Publication, 7, p. 14-24.

Reagan, M.K., and Gill, J.B., 1989, Coexisting calcalkaline and high-Nb basalts from Turrialba Volcano, Costa Rica: Implications for residual titanites in arc magma sources: Journal of Geophysical Research, v. 94, p. 4619-4633.

Sun, S.S., 1980, Lead isotope study of young volcanic rocks from mid-ocean ridges, ocean islands and island arcs: Philosophic Transactions of the Royal Society, A297, p.409-445.

PRECAMBRIAN GEOLOGY OF CENTRAL COLORADO

FACULTY

Jeffrey B. Noblett, Colorado College
Christine S. Siddoway, Colorado College
Reinhard A. Wobus, Williams College

STUDENTS

Chris Bodle, College of Wooster
Erik Ekdahl, Carleton College
David Gentry, Washington and Lee
Rima Givot, Colorado College
Elijah Levitt, Carleton College
Sarah Stevens, Colorado College
Kati Szramek, Carleton College
Kate Wearn, Williams College
Martha Wilson, Whitman College

VISITORS

Shelby Boardman, Carleton College
John Shallow, Colorado School of Mines