A PETROLOGICAL AND GEOCHEMICAL RECONSTRUCTION OF THE CASCADE RANGE, WINEMA NATIONAL FOREST, OREGON

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Introduction

The Cascade Range is a north-south trending line of composite volcanoes that have been active since the late Mesozoic era. Its formation has been attributed to the subduction of the Juan de Fuca plate beneath the North American plate. The range, which extends from southern British Columbia through western Washington and Oregon and into northern California and northwestern Nevada, is dominated by lavas of andesitic composition (Stanley, 1990). To the east of the Cascade Range is a region of extension called the Basin and Range Province. This region is characterized by flood basalts and a horst and graben topography (Guffanti and Weaver, 1988). The Keck Project group mapping area was located in southern Oregon, approximately 45 miles east of Medford and 6 miles east of one of the major composite Cascade volcanoes, Mt. McLoughlin. Twenty miles east of the mapping area is the Klamath Basin, a large graben that marks the westernmost edge of the Basin and Range Province. This location provides an interesting area for studying how the extensional and compressional environments interact in respect to the volcanic rocks produced.

Field Description

The study area of this paper is located in the Winema National Forest and the Mt. Lakes Wilderness Area. The western boundary is marked by Lake of the Woods and the eastern boundary by Crater Mt. Three weeks were spent in the field in the summer of 1992 reconnaissance mapping and sample collecting. Ten volcanic map units were identified based on their hand sample mineralogy and textures. Outcrops ranged from extensive platy flows 500 ft. in length and 100 ft. in width to solitary vegetated boulders. The easternmost area was severely modified by glaciation and was dominated by large tallus slopes. One rock unit was identified as a basaltic andesite, all others were classified as andesites with phenocrysts of plagioclase, orthopyroxene, clinopyroxene and in trace amounts, olivine.

Petrographic Description

Thin sections of thirty rocks were analyzed to confirm their mineralogic composition. Of these rocks, 19 were analyzed for trace and major element data using quantitative X-ray fluorescence spectroscopy. The initial number of rock units was modified after these analyses; the study area is composed of 7 distinct lava flows. The units are listed in stratigraphic order from oldest to youngest. A summary of modal percentages of minerals can be found in Table 1.

LOW ECHO ANDESITE- This unit has a relatively small amount of exposure and was initially identified as a basaltic andesite. It is a dark rock that outcrops as weathered boulders with 2-3 mm long olivine crystals visible in hand sample. Rocks could be highly vesicular to aphyric. Thin section study revels a lath-like form and alignment of the plagioclase crystals.

ESTHER APPLEGATE (II) ANDESITE- This unit outcrops primarily as spheroidal boulders 1-2 ft. in diameter. This unit is also phenocryst rich, 35-40% of the whole rock. Clinopyroxene occurs as large (1 cm) crystals and orthopyroxene typically occurs in glomoporphoritic clumps with the clinopyroxene and plagioclase.

ESTHER APPLEGATE (I) ANDESITE- This flow occurs as platy outcrops about 10 ft. in diameter and 3 ft. thick. Phenocrysts make up 35-40% of the rock.

SUNSET BASALTIC ANDESITE- This unit outcrops as highly weathered boulders generally 6-8 ft. in diameter. This unit contains close to 50% phenocrysts that form glomoporphoritic clumps 1-4 cm in size. Orthopyroxenes are the largest crystals (1 cm) and clinopryoxenes are also relatively large (5 mm).

AVALANCHE LAKE ANDESITE- This unit occured as small platy flows along the top ridge of Crater Mt. It is a light grey aphyric rock with 2-5 mm square orthopyroxene crystals. Plagioclase crystals were small and semi-angular.

CRATER MT. ANDESITE- This is the unit outcropping at the top of Crater Mt.; it is an extensive platy flow. The rock is aphyric in hand sample with small orthopyroxene crystals (1-2 mm). Analysis of the thin sections showed that there is very little matrix. The rock is held together by small interlocking plagioclase crystals that have a uniform size and exhibit a distinctive lath-like appearance.

SALT AND PEPPER ANDESITE- This is the most extensive of the flows, covering almost 4 sq. miles of the mapping area. Outcrops are large, 200 ft. in length is an average outcrop size. Phenocrysts can range in size from 2 mm to < .5 mm in hand sample. Samples are variable from aphyric to 40% phenocryst rich. Orthopyroxene forms the largest crystals (1-2 mm) and thin section study reveals angular plagioclase crystals.

Major & Trace Element Geochemistry

The major and trace element data, summarized in Table 2, have several distinctive features. The first is the obvious difference in SiO_2 content. Topographically lower units such as Esther Applegate (II) Andesite, Low Echo Andesite and Sunset Andesite all have a relatively low percentage of SiO_2. These units are also enhanced in Fe_2O_3 and TiO_2 weight percentages. The ppm values for Zn, Cr, V, Ba, La, and Y are also higher in these units and in Esther Applegate (I) Andesite. This chemical data suggest that these rocks are the most mafic rocks of the mapping area. It seems plausible that there be a concomitant increase in the amount of silica-poor minerals; this is true, olivine is present only in two of these units, Low Echo Andesite and Esther Applegate (II) Andesite.

Harker diagrams demonstrate the linear trend of the variations in major element weight percentages, Figure 1. Each diagram is based on a weight percentage of an oxide vs. the SiO_2 percentage. The trends show that for higher percentages of CaO and MgO, there is a depletion of Na_2O and K_2O. The Esther Applegate (II) andesite demonstrates this characteristic. Esther Applegate (I) Andesite shows an opposing trend; it has higher percentages of K_2O and Na_2O and depleted amounts of MgO and CaO. These trends are also a function of the SiO_2 content as well; Esther Applegate (II) Andesite has the lowest weight percentage of SiO_2 and correlates positively with MgO and CaO and Esther Applegate (I) Andesite has the highest SiO_2 content; it correlates positively with K_2O and Na_2O. This relationship between the potash and Fe-enrichment in respect to SiO_2 is a characteristic of orogenic andesites (Gill, 1981).

The topographically higher units, Crater Mt. Andesite, Avalanche Lake Andesite and Salt & Pepper Andesite all have a higher SiO_2 weight percentage. The only trace element that they are enriched in is Sr. Harker diagrams show that there is very little variation in oxide percentages between the flows. These flows, grouped in boxes in Figure 2, do not exhibit a linear trend. A plot on a scale that includes only these units still shows no distinctive trend. The data points group together according to rock type, but there is no coherency to the way they group between each oxide.

Discussion

The lava flows can be divided on one primary basis: their SiO_2 content. There is one source for the lower units and another source for the higher units. Based on information obtained by Keck participants in the summer of 1991, to the west is the source for the Esther Applegate (II) Andesite (Rowe, 1992). For those rocks that exhibit a petrographic and geochemical similarity to this unit, their source would also be to the west. The trends exhibited by the oxides would indicate some fractionation of the magma chamber; this is visible in the mineralogical variations of the rocks. The second source is to the east. Although these units do fall into the linear trend exhibited by the lower units, there are two excellent reasons for stating that the upper units are not related to the lower units. The most obvious is the age difference of the two suites; there is approximately a two million year gap between the upper suite and the lower suite. The topography supports this theory; the lower lying units outcrop poorly and have a low and flat elevation while the upper units outcrop in large expanses and form a steep mountain with a high elevation.

References Cited

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				Estimated Modal % of phenocrysts				
Mineral (% of phenocrysts)	% of Phenocrysts	Olivine	Cpx	Opx	Opaque Mins.	Plag	Prx	Vesicles
Rock Unit								
Esther Applegate (I) Andesite	35-40	-	5	25	5	65	-	-
Esther Applegate (II) Andesite	35-40	2	10	20	2	66	-	-
Low Echo Andesite	15	15	-	-	-	75	5	5
Sunset Andesite	50	-	10	15	5	65	-	5
Salt & Pepper Andesite	aphyric-40	-	5	30	5	60	-	-
Avalanche Lake Andesite	15	-	5	30	7	58		
Crater Mt. Andesite	5	-	3	7	2	88	-	-

Table 1. Modal Percntages of Phenocrysts. The values are estimated from hand samples and thin sections. The numbers are an average value for each rock unit.

	Esther A.G. I	Esther A.G. II	Low Echo Andesite		Sunset Andesite		Salt & Pepper Andesite								Avalanche Lake Andesite		Crater Mt. Andesite		
Sample #	92-129	92-132	92-17	92-81A	92-2	92-16	92-86	92-56	92-53	92-99	92-31	92-95	92-107	92-47	92-103	92-108	92-14	92-50	92-120
Elements																			
V (ppm)	93	143	127	129	126	129	110	91	93	90	100	101	102	102	98	114	111	113	100
Cr (ppm)	9	30	118	117	21	29	24	17	17	17	31	22	28	28	20	21	26	33	24
Ni (ppm)	13	27	81	81	29	32	23	21	24	23	27	26	25	26	27	27	27	28	25
Zn (ppm)	56	70	71	70	55	59	59	53	57	49	57	56	59	57	57	55	55	62	61
Ga (ppm)	20	19	18	19	21	22	22	20	19	20	20	20	20	18	20	19	20	20	22
Rb (ppm)	12	23	15	17	12	12	12	15	15	15	19	14	16	15	11	12	14	16	12
Sr (ppm)	748	680	794	786	1292	1216	1251	926	910	927	971	1002	1026	994	1067	1115	1165	1143	1084
Y (ppm)	12	20	13	16	15	13	10	12	11	11	11	11	11	10	10	11	11	11	11
Zr (ppm)	96	107	128	128	126	125	130	83	87	83	97	93	97	96	79	92	107	111	107
Nb (ppm)	2	4	6	6	2	3	2	2	2	2	3	2	3	3	2	2	2	3	3
Ba (ppm)	315	466	466	463	390	415	315	375	370	356	433	380	391	368	292	335	360	398	461
La (ppm)	14	12	19	14	20	24	9	11	11	11	10	13	11	9	11	11	17	15	18
Ce (ppm)	18	20	28	30	40	39	31	19	21	22	24	22	23	20	24	24	31	31	29
Pb (ppm)	3	7	7	5	3	2	7	5	5	8	7	6	6	5	5	4	10	7	7
Th (ppm)	1	2	2	2	2	2	2	2	1	2	1	1	1	1	1	1	2	2	2
U (ppm)	1	1	1	1	1	1	1	1	2	1	1	1	2	1	1	1	2	1	1
SiO2 (%)	60.84	57.44	56.75	56.97	57.23	56.83	59.03	59.29	59.20	59.03	60.04	59.37	59.38	59.54	58.75	59.05	59.34	59.06	59.10
TiO2 (%)	0.59	0.82	0.88	0.82	0.78	0.78	0.69	0.63	0.62	0.63	0.59	0.62	0.62	0.60	0.63	0.64	0.69	0.68	0.67
Al2O3 (%)	18.60	18.08	17.53	17.58	18.59	18.71	18.54	18.71	19.00	18.58	18.35	18.78	18.60	18.43	18.72	18.90	18.37	18.22	18.61
Fe2O3 (%)	5.76	7.01	7.05	6.99	6.44	6.53	5.95	6.22	5.99	6.06	5.65	6.01	6.02	5.86	6.10	5.97	5.92	5.93	6.00
MnO (%)	0.09	0.12	0.12	0.12	0.10	0.11	0.10	0.11	0.10	0.09	0.09	0.10	0.10	0.09	0.10	0.10	0.09	0.10	0.10
MgO (%)	2.85	3.51	4.84	4.84	4.18	4.18	3.49	3.46	3.22	3.33	3.23	3.41	3.52	3.46	3.58	3.47	3.48	3.54	3.48
CaO (%)	5.44	7.00	7.14	7.12	7.58	7.38	6.85	6.50	6.68	6.77	6.66	6.84	6.55	6.70	7.07	7.02	6.80	6.78	6.57
Na2O (%)	4.17	4.31	4.02	4.03	3.87	3.71	3.94	3.90	3.98	4.03	3.89	4.06	3.91	4.00	4.04	4.02	4.05	4.13	4.16
K2O (%)	1.10	1.24	1.04	1.06	0.92	0.92	0.85	0.96	0.94	0.95	1.06	0.93	0.97	0.94	0.82	0.84	0.92	0.98	1.07
P2O5 (%)	0.15	0.18	0.26	0.26	0.26	0.26	0.17	0.15	0.15	0.15	0.14	0.14	0.14	0.14	0.14	0.15	0.18	0.19	0.20
LOI (%)	1.35	0.01	0.00	0.00	0.24	0.71	0.86	0.65	0.62	0.24	0.17	0.04	0.59	0.21	0.33	0.36	0.21	0.39	0.87
TOTAL %	99.59	99.69	99.57	99.80	99.95	99.42	99.61	99.98	99.88	99.61	99.69	100.26	99.79	99.81	99.97	100.15	99.84	99.62	99.96

Table 2. Major and Trace Element Data.

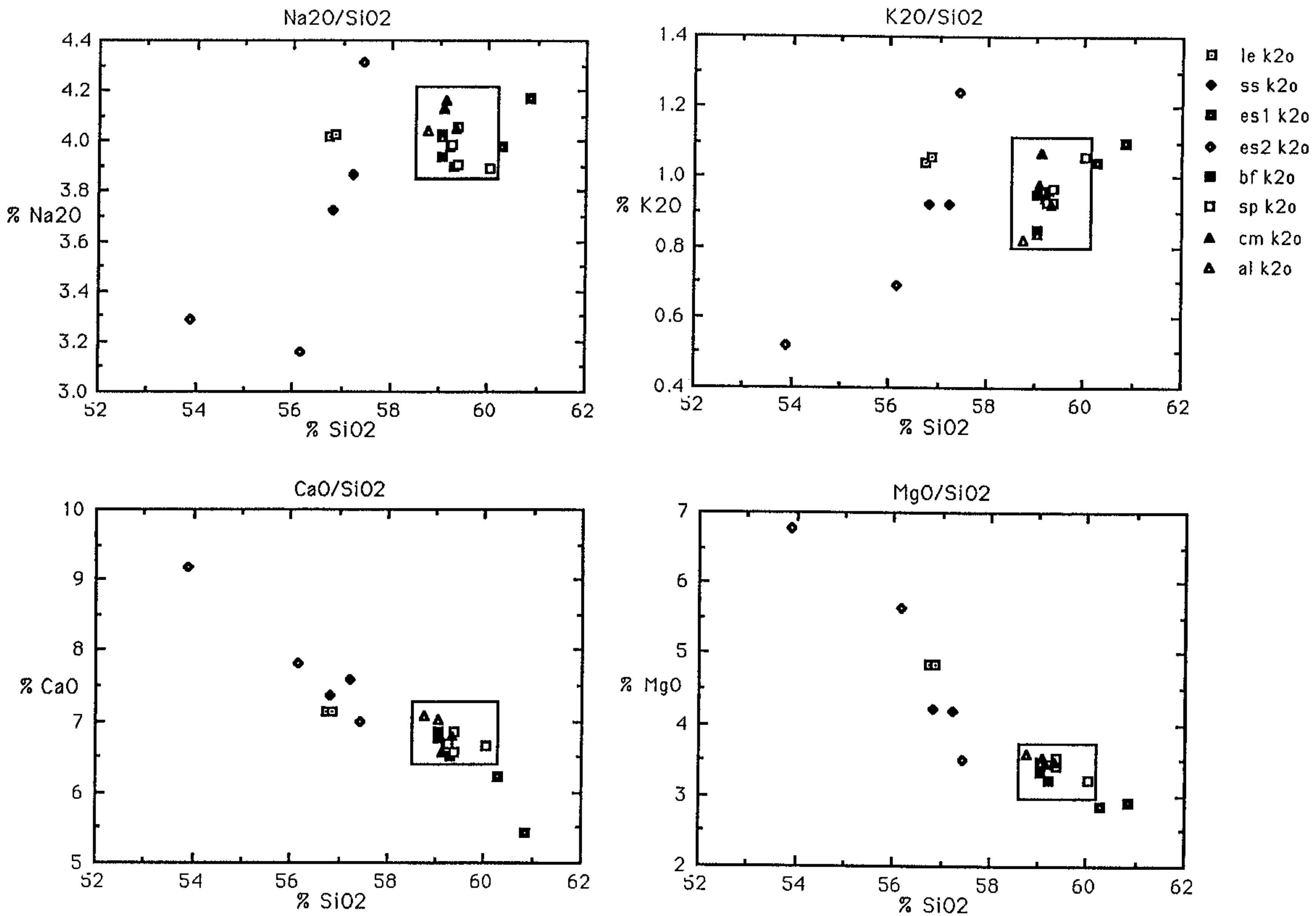

Figure 1. Harker diagrams showing weight percentages of oxides vs. weight percentage of SiO_2. The points in the highlighted in the box indicate the samples from the higher topographic areas. Abbreviations for the legend are: le-Low Echo Andesite, ss-Sunset Andesite, es1-Esther Applegate (I) Andesite, es2-Esther Applegate (II) Andesite, s&p-Salt & Pepper Andesite, cm-Crater Mt. Andesite, al-Avalanche Lake Andesite. Additional data points for the figure were taken from Bruant, 1993 and Rowe, 1992.