KECK GEOLOGY CONSORTIUM
PROCEEDINGS OF THE TWENTY-THIRD ANNUAL KECK RESEARCH SYMPOSIUM IN GEOLOGY

ISSN# 1528-7491

April 2010

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Editor & Keck Director	Franklin & Marshall College	Symposium Convenor
Franklin & Marshall College	PO Box 3003, Lanc. Pa, 17604	ExxonMobil Corp.

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Funding Provided by: Keck Geology Consortium Member Institutions and NSF (NSF-REU: 0648782) and ExxonMobil

Keck Geology Consortium: Projects 2009-2010
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Project Faculty: ***HOLLI FREY***, Union College & ***KATHRYN SZRAMEK***, Drake University

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Research Advisor: Holli Frey

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ASHLEY MELENDEZ: California State University, Fullerton
Research Advisor: Brandon Browne

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LAUREN WERCKENTHIEN: DePauw University
Research Advisor: Dr. James G. Mills, Jr.

Funding provided by: Keck Geology Consortium Member Institutions and NSF (NSF-REU: 0648782)

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PLAGIOCLASE WEATHERING WITH DISTANCE FROM VOIDS IN VOLCANIC ROCKS OF THE DESCHUTES BASIN, CENTRAL OREGON

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California State University, Fullerton
Research Advisor: Brandon Browne

INTRODUCTION

The geology of the Deschutes Basin of Central Oregon is dominated by volcanic rocks. The rocks in this project are Quaternary in age ranging from the Holocene to the Pleistocene. The composition ranges from basalt to rhyolite, but all contain plagioclase. Plagioclase is a good index mineral because the composition includes mobile elements (Na, Ca) that leave the mineral fairly readily during chemical weathering as well as immobile elements (Al) that do not. Plagioclase is generally not the first mineral to display evidence of weathering in volcanic rocks. Volcanic glass, olivine and pyroxene will all begin to weather before plagioclase (Eggleton et al., 1987). There have been many previous works done regarding the weathering of plagioclase in volcanic rocks because plagioclase is a very common mineral, but most of this work has been in warm, wet environments (Dorn and Brady, 1995; Velbel and Losiak, 2008).

The field area for this project focuses on the Deschutes Basin in the Oregon High Desert east of the Cascades (Fig. 1). The Deschutes Basin is a semi-desert, receiving less than 30 cm of rain annually (www.noaa.gov). The samples collected include rocks from basaltic to rhyolitic in composition taken from flow fronts as well as from domes. The most important constraint to dissolution of rock into a watershed is the amount of precipitation received in the area. This constraint can account for 58-71% of dissolved ions found in river runoff (Bluth and Kump, 1993). In the dry, semi-desert environment of the Deschutes Basin, this constraint does not have as much as an effect on the rocks as it does on the rocks in the wet climate of the Cascades to the West or on rocks in tropical regions. Weathering does, however vary with distance from cracks, vesicles and pore space in the rock (Eggleton et al., 1987). Void spaces allow water to get into the rock and begin to alter the minerals. When reactions occur between the water and the elemental constituents of the minerals, some of these ions are carried out of the rock and into the watershed. This paper discusses the weathering of plagioclase in the Holocene to the Pleistocene rocks of the study.

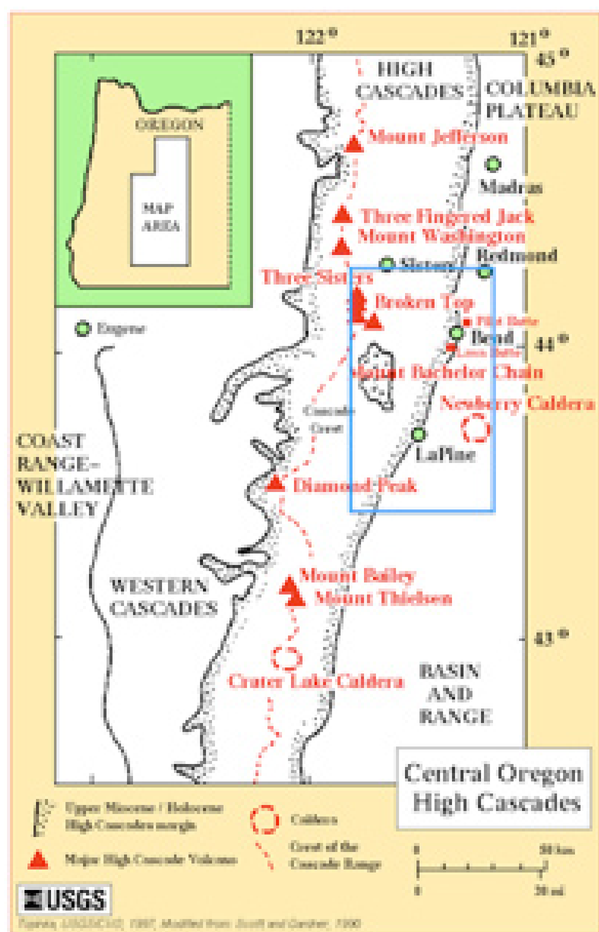

Figure 1: Map of the Deschutes Basin of Central Oregon. Field area is outlined.

METHODS

Forty-eight samples were collected from 22 unique rock outcrops. Rocks were collected from the surface of an outcrop where a higher degree of weathering was expected and from a more central part of the same feature where the rocks were expected to be fresh. Locations of specific rock types were determined using a geological map of the area (Sherrod and Smith, 2000). Thin sections of the samples were prepared and examined by a Nikon Eclipse LV100 POL petrographic microscope in polarized light. Thin sections with cracks or vesicles were of special interest and were examined for evidence of whole rock weathering. The alteration of the susceptible volcanic glass in the samples turns the glass to palagonite and smectie (Glassman, 1982). The altered glass becomes discolored, turning yellow or brownish. The alteration of pyroxenes causes the crystal surfaces to appear etched (Glassman, 1982). While these general indicators of weathering were examined for evidence of general weathering, plagioclase crystals were observed specifically. Plagioclase crystals were checked for evidence of alteration including a decrease in birefringence, yellowish brown discoloration, scalloped rims on the individual phenocrysts, and dusty textures within crystals or evidence of sausserization (Eggleton et al., 1987; Glassman, 1982).

Of the samples collected from the field, three were chosen for examination by electron microprobe based on apparent amount of weathering and the presence void spaces across the surface of the thin section. These three samples were carbon coated and examined by a JEOL JEM 1200-EX electron microprobe (EMP) at UCLA for the elemental abundances of individual plagioclase crystals. A total of 14 points were collected from plagioclase crystals from the first thin section. Three images were taken from this sample and of those 2 data points were taken from the first image, 3 from the second and 9 from the third. Nine data points total were taken from one image in the second sample. Six data points were taken from the third sample. For each of these samples, points were collected from plagioclase crystals at varying distances from a void feature. Samples were also taken at a distance from any void feature. The rock samples were crushed and powdered and ICP-OES analyses were completed on all samples collected. The major elements were determined by ICP-OES at ActLabs and trace elements by ICP-MS at Union College.

RESULTS

The rocks examined by thin section were found be composed of volcanic glass, plagioclase, pyroxenes, olivine and opaque minerals. In hand sample, the outer portions of rock collected appeared weathered. Discoloration to a reddish brown or brown was visible, and the outer rock was more friable than the inner portion of the rock. In thin section, the rocks also appeared to be weathered to a slight degree. The interstitial glass was becoming yellowed in some higher silica samples and olivine and pyroxene phenocrysts exhibited a rough texture on the surface and edges of the crystals in some samples. Plagioclase phenocrysts also appeared to be scalloped around the edges and some appeared dusty in the central area of the crystal. The birefringence was also lower than expected for the plagioclase phenocrysts. They were not the first order grays and whites expected for plagioclase under cross polarized light, but yellowed.

The fine microcrysts that make up the groundmass of many of the rocks were foggy and dusty looking indicating that weathering had begun in that area. The alteration of the groundmass was most noticeable close to voids and decreased away from them as expected (Glassman, 1982). These indicators of weathering were observed mostly in the samples closer to the surface of the rock, but also alongside cracks and vesicles (Fig. 2). As the minerals are weathered, cracks and void space forms within the rock that allow even more water to flow through the rock and continue alteration (Glassman, 1982). Even so, some samples were found with cracks running directly through a plagioclase crystal with no apparent weathering taking place (Fig. 3).

The three samples that were examined by EMP did not exhibit a high degree of chemical weathering

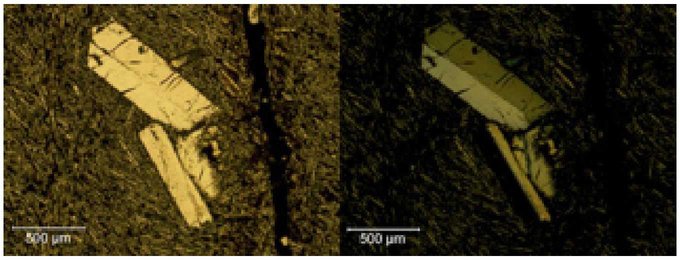

Figure 2: Photomicrographs in plane and crossed- polarized light of Plagioclase phenocrysts in andesite. Notice apparent weathering of plagioclase near fracture.

of plagioclase. It was expected that ratios of K/Na and K/Ca would increase with distance from voids. There was only a very weak relation between the removal of Na and Ca and distance from voids. Plagioclase weathering rate is expected to increase with An content of the plagioclase crystal (White and Brantley, 2003). This correlation was not detected at all. There was no correlation between An content in a plagioclase phenocryst and distance to a void found in these rocks. Backscatter electron (BSE) images also indicate little weathering of plagioclase crystals. Plagioclase crystals examined using BSE images exhibit little deterioration along edges of phenocrysts either near or some distance from a void space.

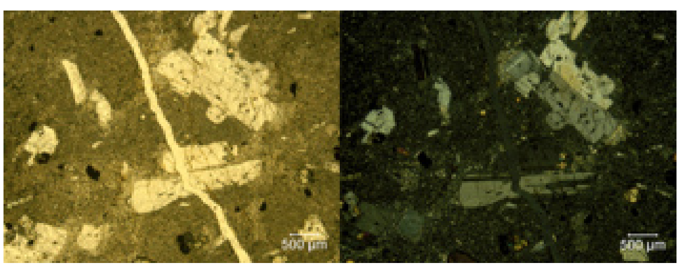

Figure 3: Photomicrographs in plane and crossed- polarized light of Plagioclase phenocrysts in dacite. Notice the fracture passes directly through phenocryst without any apparent weathering.

The ICP-OES analysis results indicated that the rocks range in composition from basalt to rhyolite. The bulk rock compositions of the samples do not indicate any significant weathering of plagioclase.

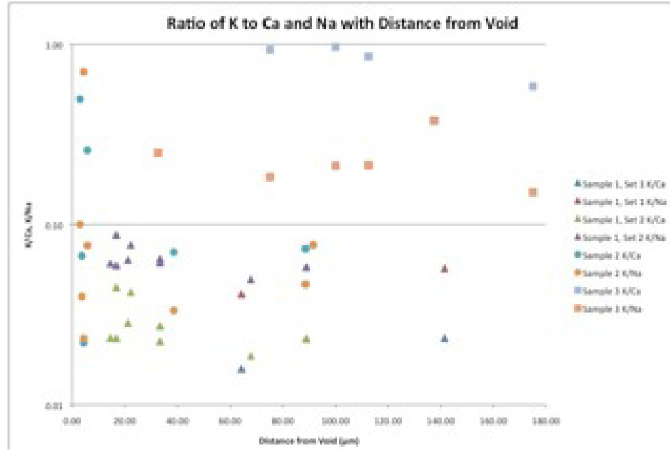

Figure 4: Graph of the ratio of K to Ca and Na with distance from a void in a basalt, andesite and rhyolite.

DISCUSSION

The composition of streams and rivers is dependent on the decomposition of rock in the area. Throughout a watershed, especially one as large as the Deschutes Basin, many, many streams and rivers are collecting ions from the rocks they pass over and through. The water chemistry may indicate a relationship with elements associated with volcanic rock (Na, Ca, K, Al, Ti, Mg, Fe), but it is not likely that the majority of these elemental traces are sourced from the plagioclase in the samples collected in this study. While the rock samples exhibit evidence for the initial stages of alteration as described above, the elemental evidence gathered through electron microprobe analysis does not support plagioclase from these rocks as the dominant source of ions in stream water.

The rocks appear to be weathered in general in hand sample, but plagioclase is not one of the first minerals to weather from a rock, it has not undergone a great degree of weathering in these rocks. The rocks sampled in this study have just begun to enter the initial stages of weathering but have not yet begun to significantly weather the plagioclase. The dry climate of the field area, combined with the silicic composition of some of the rocks and the relatively young age of all of the rocks has not allowed for any significant weathering of the plagioclase.

Electron Microprobe Analysis of Volcanic Rocks of Deschutes Basin, Central Oregon

Sample	1-1	1-1	1-2	1-2	1-2	1-2	1-2	1-2
Data Point	1	2	3	4	5	6	7	8
TiO2	0.080	0.060	0.094	0.146	0.136	0.069	0.123	0.109
SiO2	53.060	53.610	52.864	55.365	54.046	52.945	53.812	53.305
Al2O3	29.320	28.800	29.274	27.216	28.604	29.037	28.406	28.844
FeO	0.620	0.860	0.770	1.094	0.691	1.027	0.936	0.864
MnO	0	0.010	0.039	0	0.051	0.008	0	0.017
MgO	0.200	0.170	0.160	0.188	0.140	0.166	0.133	0.198
CaO	12.020	11.630	12.177	10.232	11.211	12.027	11.382	11.814
Na2O	4.450	4.600	4.411	5.388	4.824	4.477	4.875	4.564
K2O	0.160	0.240	0.196	0.372	0.274	0.244	0.268	0.237
SO3	0.080	0.010	0.015	0	0.024	0	0.064	0.047
TOTAL	100	100	100	100	100	100	100	100

Sample	1-2	1-2	1-2	1-2	1-2	2	2	2
Data Point	9	10	11	12	13	14	15	16
TiO2	0.074	0.160	0.341	0.094	0.146	0.408	0.037	0.119
SiO2	52.541	53.140	54.942	52.864	55.365	67.671	63.141	65.563
Al2O3	29.493	28.870	26.896	29.274	27.216	19.758	23.063	19.768
FeO	0.804	0.938	1.523	0.770	1.094	0.771	0.483	0.480
MnO	0.015	0	0.036	0.039	0	0.027	0	0
MgO	0.147	0.149	0.304	0.160	0.188	0.440	0.001	0.008
CaO	12.492	11.957	10.416	12.177	10.232	1.752	2.965	0.485
Na2O	4.191	4.544	5.123	4.411	5.388	8.364	9.628	8.311
K2O	0.242	0.241	0.402	0.196	0.372	0.748	0.659	5.220
SO3	0	0	0.018	0.015	0	0.061	0.024	0.045
TOTAL	100	100	100	100	100	100	100	100

Sample	2	2	2	2	2	2	3	3
Data Point	17	18	19	20	21	22	23	24
TiO2	0.086	0.085	0.079	0.126	0.127	0.130	0.041	0.018
SiO2	55.601	59.829	66.030	60.233	60.314	58.255	65.097	65.200
Al2O3	27.989	24.987	19.027	24.665	24.355	25.923	21.782	21.613
FeO	0.703	0.847	0.507	0.698	0.784	0.793	0.237	0.307
MnO	0.045	0	0.031	0	0	0.031	0.018	0
MgO	0	0.025	0.004	0.004	0.018	0.035	0.021	0
CaO	8.065	5.280	0.145	4.612	5.559	7.283	2.439	2.053
Na2O	7.357	8.552	5.993	9.363	8.428	6.984	9.067	9.035
K2O	0.153	0.305	8.139	0.279	0.351	0.482	1.225	1.708
SO3	0	0.090	0.044	0.021	0.064	0.085	0.074	0.067
TOTAL	100	100	100	100	100	100	100	100

Sample	3	3	3	3
Data Point	25	26	27	28
TiO2	0.033	0.056	0	0.077
SiO2	68.429	65.643	65.969	70.249
Al2O3	19.805	21.653	21.152	18.467
FeO	0.268	0.525	0.310	0.436
MnO	0.010	0.214	0	0.013
MgO	0.020	0.024	0	0.003
CaO	0.998	2.117	1.864	1.158
Na2O	8.531	8.206	9.163	7.169
K2O	1.904	1.562	1.499	2.416
SO3	0	0	0.043	0.011
TOTAL	100	100	100	100

Table 1: Table of elemental percentages in a basalt, andesite and rhyolite. Note that these values are normalized.

CONCLUSION AND FUTURE WORK

Since it would follow that the source of elemental traces found in streams in the Deschutes Basin is not the plagioclase from the quaternary volcanic rock studied here, an interesting extension to this project would be to compare rocks of the dry Deschutes Basin to rocks of similar composition to from the wet climate of the western part of Oregon. Would significant weathering of the rocks of the same composition and age occur in an environment receiving more precipitation? Plagioclase is slow to begin weathering. It will not begin weathering until most of the other minerals have undergone some degree of weathering. This is the reason that there is very little EMP evidence for weathering. The rocks are too young. Would older rocks from the same area in the Deschutes Basin exhibit a greater degree of weathering than the rocks studied here? The results of this study provide an initial position for more investigation of weathering of plagioclase in young rocks of a dry climate.

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