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2009-2010 PROJECTS

SE ALASKA - EXHUMATION OF THE COAST MOUNTAINS BATHOLITH DURING THE GREENHOUSE TO ICEHOUSE TRANSITION IN SOUTHEAST ALASKA: A MULTIDISCIPLINARY STUDY OF THE PALEOGENE KOOTZNAHOO FM.
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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: Dr. Martha C. Eppes

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Research Advisor: Holli Frey

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

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SPATIAL VARIABLILTY OF TEPHRA SOIL ON DIFFERING GEOMORPHIC SURFACES WITHIN THE HEADWATERS OF THE DESCHUTTES RIVER, OREGON

MATTHEW HARWARD
University of North Carolina at Charlotte
Advisor: Dr. Martha C. Eppes

INTRODUCTION

Tephra (defined as fragmented volcanic ejecta, such as ash, dust, cinders and volcanic bombs (Dahlgren et al. 1999)) deposits cover a vast majority of Central Oregon. The tephra deposits in this study were resultant from the eruption of Mount Mazama, now Crater Lake, Oregon, ~7600 years before present (Zdanowiez et al., 1999). Since the eruption ~7,600 ybp the tephra deposits have been weathering at constant rates with no influences from glaciers or other major volcanic eruptions in the region. The 1980 eruption of Mount Saint Helens did not contribute tephra to this portion of Central Oregon. Also the Newberry Crater eruption of ~1500 ybp did not contribute to the tephra deposits in the study site.

The Deschutes River originates within Central Oregon and runs north into the Columbia River. The headwaters of the Deschutes River carve through these vast tephra deposits before joining the primary trunk stream of the Deschutes River. The study was intended to link the spatial variability of geomorphic features of the headwater drainage basins and the weathering of the soils forming out of these tephra deposits over the last 7,600 years. The purpose of this study is to try to better understand spatial variability and how it corresponds to the weathering of tephra based on the geomorphology within this portion of central Oregon.

The study site was situated within the drainage basins of the headwaters of the Deschutes River in Deschutes and Kalamath Counties in central Oregon. All sites were south of Three Sisters' Volcanoes and north of Mount Thielsen. The sites for study were chosen for their distinct geomorphic characteristics. The geomorphic features of interest are flood plains, hillslopes, alluvial fans, upland surfaces, and on the edges of lava flows. Each of the sites were chosen as a best representation of the geomorphic feature within the study area. The breakdown is as follows: 3 flood plain pits, 3 hillslope pits, 2 alluvial fan pits, 2 upland surface pits and 2 lava flow pits.

METHODS AND MATERIALS

At each of the 12 sites a soil pit was dug and described in detail as per the USDA standards (Soil Survey Staff, 1996) After detail field descriptions and photographic documentation of each site, samples were collected for laboratory analysis from each horizon of each pit.

After all field data was collected, each sample was first air dried then passed through a 2mm sieve. Samples were then tested for the presence of carbonates by exposing a small amount to dilute hydrochloric acid; all samples gave negative results of carbonates. Each sample was then analyzed for moist and dry color, soil texture, and moist and wet consistence (Soil Survey Laboratory Staff, 1996). Laboratory analyses were then chosen to give conclusive results as to how the spatial variability and the geomorphic features correlate due to weathering. Soil particle size was done by a modified method of Day (1965) & Jackson (1969). Total organic carbon was assessed by using a loss by ignition method, in which each sample was pulverized to a fine powder then heated to 500 ^{o}C for 1 hour. Elemental analysis was done using inductively coupled plasma mass spectrometry (ICP-MS). The ICP-MS data was converted from parts per million to percent oxide by weight for Sodium (Na_2O), Magnesium (MgO), Aluminum (Al_2O3), Potassium (K_2O), Calcium (CaO) Titanium (TiO_2), Manganese (MnO) and Iron (Fe_2O_3).

RESULTS

TiO_2 is a fairly stable compound in soil and can be used to derive a ratio between TiO_2 and the other oxides found in the soil samples. By using the idea that TiO_2 is sable within the profile and there is no loss due to weathering we can assume that the least weathered horizon contains the same amount of TiO_2 that was present at deposition, along with TiO_2 we should assume that the other oxides are at their original concentrations within this same horizon. Knowing this it is possible to divide the amount of an oxide by the amount of TiO_2 in the least weathered horizon and subtract the amount of an oxide divided by the amount of TiO_2 in a weathered horizon to get a ratio that describes the amount of weathering that has occurred:

$$(X_{\text{unweathered horizon}} / TiO_{2\ \text{unweathered horizon}}) - (X_{\text{weathered horizon}} / TiO_{2\ \text{weathered horizon}}).$$

These are weighted values based on the depth of the horizon in which the sample was taken and divided that by the total depth of the pit giving a weighted percentage of the total pit: [(Horizon Thickness/Total Pit Depth)*(ICP-MS % Weight Value)] (table 1). This gives a normalized value for comparison. With the TiO_2 ratio the closer that a value is to zero the less weathered it is. As is shown in Figure 1

Pit and Geomorphic Feature	Pit Depth (cm)	% Sand Of Total Pit (g)	% Carbon of Total Pit (g)	Na2O vs TiO2 Ratio Value	Al2O3 vs TiO2 Ratio Value	K2O vs TiO2 Ratio Value	CaO vs TiO2 Ratio Value	MnO vs TiO2 Ratio Value	Fe2O3 vs TiO2 Ratio Value	Sum Of Less Mobile Element Fe, Mn, Al	Sum of Mobile Element Na, Ca, K
Lava Flow											
Keck 01-09	120	73.80	5.09	-0.70	-8.77	-0.48	-2.74	-0.04	-2.41	-10.34	-3.92
Keck 04-09	55	72.66	2.66	0.13	2.54	0.17	0.13	0.02	0.81	4.39	0.44
Flood Plain											
Keck 02-09	72	22.73	52.35	0.71	4.56	0.37	-28.33	0.04	-2.08	2.83	-27.25
Keck 06-09	70	74.66	11.56	0.07	0.37	0.03	0.37	0.01	0.83	2.26	0.47
Keck 08-09	45	52.97	42.02	0.00	-0.33	-0.22	-0.39	0.01	-4.21	-4.05	-0.61
Alluvial Fan											
Keck 09-09	98	85.49	8.47	1.02	6.71	2.01	-1.48	0.00	-1.63	5.72	1.55
Keck 12-09	92	80.01	13.74	0.17	0.67	-0.12	1.19	-0.01	1.35	2.66	1.25
Upland Surface											
Keck 07-09	60	71.62	17.92	-0.24	-3.78	-0.59	-0.20	-0.21	0.04	-2.93	-1.03
Keck 10-09	45	56.79	17.90	0.06	-1.17	0.12	-0.19	-0.01	-0.70	-1.33	-0.02
Hillslope											
Keck 03-09	161	88.19	11.32	0.28	0.97	0.31	0.65	0.00	0.69	2.21	1.23
Keck 05-09	76	69.28	11.74	0.04	0.63	0.00	0.16	0.01	0.56	2.24	0.20
Keck 11-09	204	88.54	3.80	-1.18	-9.03	-1.24	-1.64	0.00	0.43	-8.05	-4.07

Table 1. These are the values calculated by using the formula: $(X_{\text{unweathered horizon}} / TiO_{2\ \text{unweathered horizon}}) - (X_{\text{weathered horizon}} / TiO_{2\ \text{weathered horizon}})$. These values are then used to plot figure 1, figure 2, and figure 3.

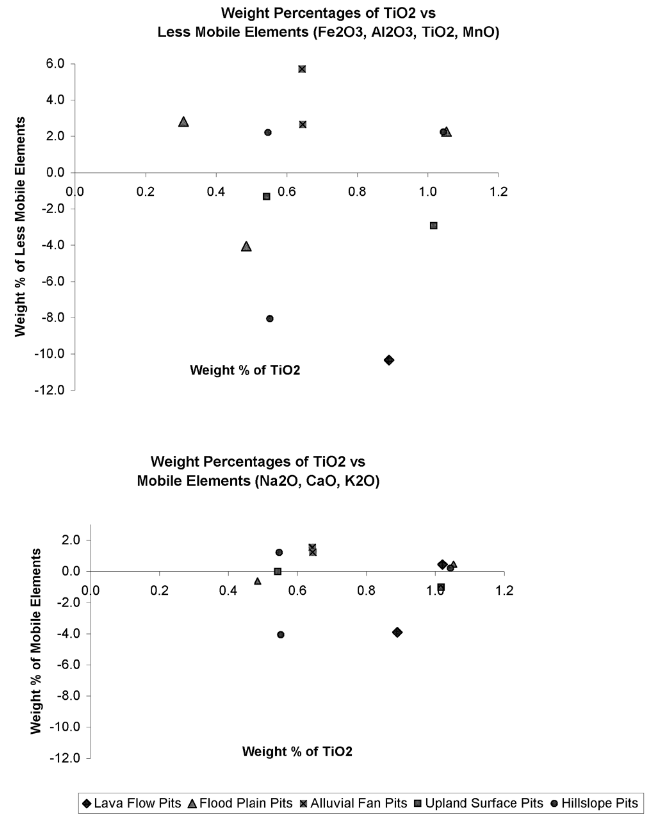

Figure 1. This is a comparison between weight percentage TiO_2 of a pit and the weight percentage of less mobile elements: Fe_2O_3, Al_2O_3, MnO, and TiO_2 combined. Along with the comparison between the weight percentage of TiO_2 of a pit and the weight percentage of mobile elements: Na_2O, CaO, and K_2O combined. These values are based on the formula of: $(X_{\text{unweathered horizon}}/TiO_{2\ \text{unweathered horizon}}) - (X_{\text{weathered horizon}}/TiO_{2\ \text{weathered horizon}})$. The resulting ratio determines the weathering of the horizon. The values are the totaled to give a weathering value of the total pit. The mobility of these compounds within the soil can be seen when comparing the two graphs and noticing the lower concentrations of the mobile elements compared to the less mobile elements.

and Figure 2, the differing geomorphic features are 'clumping' together showing that there is a correlation in the rates at which a feature is weathering out these elements.

The results of the particle size analysis shows that the majority of the samples collected were >50% sand sized particles (>67um). This indicates that the soil is immature from a developmental point, but not from a weathering perspective. The ICP-MS data shows patterns between the percentages of sand and the percentages of the elements and likewise

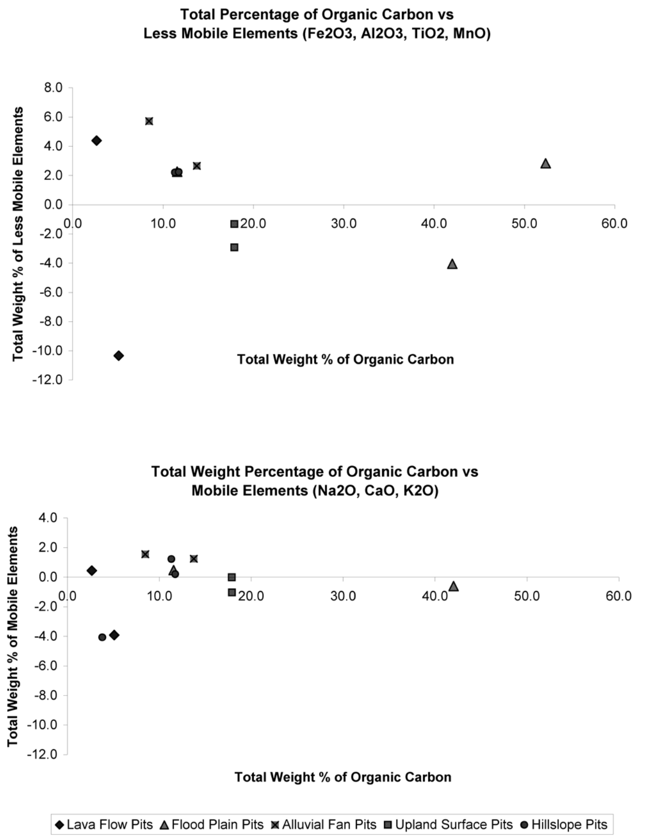

Figure 2. This is a comparison between weight percentages of organic carbon of a pit and the weight of less mobile elements: Fe_2O_3, Al_2O_3, MnO, and TiO_2 combined. Along with the weight percentage of organic carbon of a pit and the weight percentage of mobile elements: Na_2O, CaO, and K_2O combined. These values are based on the formula of:

$(X_{unweathered\ horizon}/TiO_{2\ unweathered\ horizon}) - (X_{weathered\ horizon}/TiO_{2\ weathered\ horizon})$.

The resulting ratio determines the weathering of the horizon. The values are the totaled to give a weathering value of the total pit. It can be noted that the concentrations of the mobile elements are lower than the concentrations of less mobile elements within the pits.

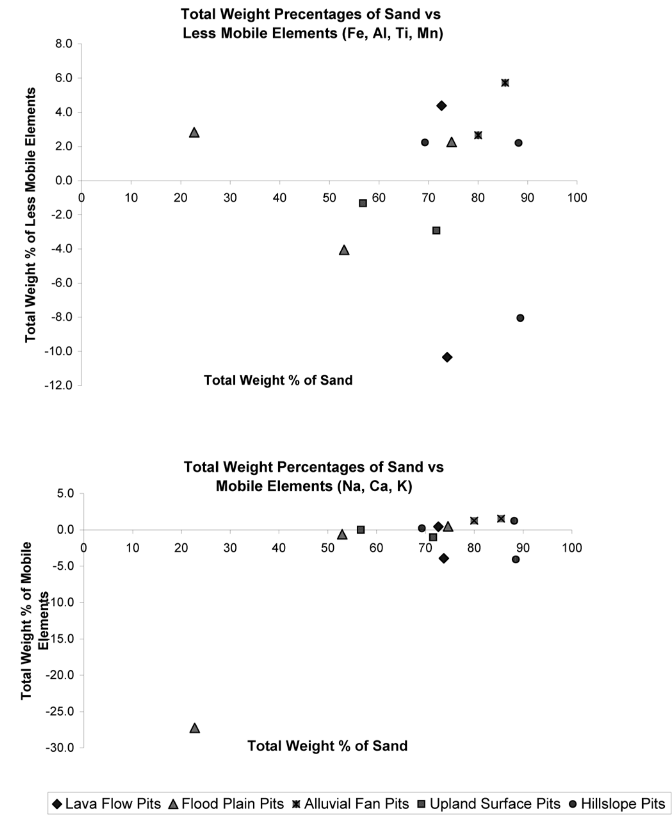

Figure 3. This is a comparison between the weight percentage of sand of a pit and the weight percentage of less mobile elements: Fe_2O_3, Al_2O_3, MnO and TiO_2 combined. Along with the comparison between the weight percentage of sand of a pit and the weight percentage of mobile elements: Na_2O, CaO, and K_2O combined. These values are based on the formula of:

$(X_{unweathered\ horizon}/TiO_{2\ unweathered\ horizon}) - (X_{weathered\ horizon}/TiO_{2\ weathered\ horizon})$

and that resulting ratio determines the weathering of the horizon. The values are the totaled to give a weathering value of the total pit.

with the depth of the soil profile and the percentages of the elements. Each geomorphic feature has its own patterns (Fig 3).

When the ICP-MS data is plotted verses depth we see that for each geomorphic feature no two features match up with their trendlines. As the elements are weathered out of the tephra and are combining with oxygen to produce these oxides one would expect to see the rates decline in concentration with depth. The data suggest that the geomorphic features such as the upland surfaces tend to be reverse of that idea and of the other geomorphic features. In most cases the trend is that the upper horizons of the soil have a higher concentration of these oxides but in the upland surface pits we actually see the opposite. Likewise Na_2O and K_2O the upland surface pits reverse and increase in concentration at the surface whereas most of the other geomorphic features decease in the upper horizons and trend towards an increasing concentration at depths. The flood plain pits seem to be the most constant in their trends.
It can be noticed that with depth almost all of the oxides are removed down to fractions of a percent in most cases. This is most likely a result of the water table moving through these lower horizons removing the oxides and flushing out into the stream. The

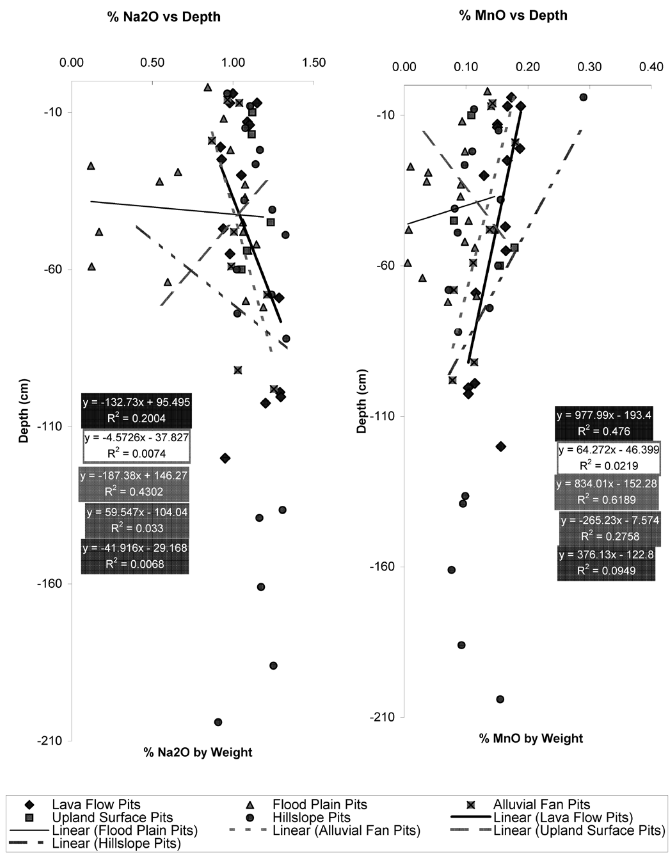

Figure 4. This is showing the weathering profiles of Na_2O and MnO as compared to depth of the pit. Each point indicates the total percentage of either Na_2O or MnO (depending on the graph) and the depth at which it was located. Na_2O is representative of mobile elements and how the geomorphic feature tends to weather. MnO is representative of a less mobile elements and how the geomorphic feature tends to weather.

O-horizons of the floodplain pits are the only place were these elements are not practically absent. The alluvial fan, hillslope, and lava flow pits fall somewhere in the middle of these two situations. The hillslope pits, next to the upland surface pits seem to be the next anomaly. With MnO and Na_2O (Fig. 4) they follow the same trend as the upland surface and deplete in the upper horizons and likewise for K_2O they are opposite from the other geomorphic features and increase in the upper horizons when the other features are being depleted. The alluvial fan pits and the lava flow pits behave in similar fashions. This suggests that the lava flow pits are being fed by the weathering of the lava flows themselves and acting much like an alluvial fan.

CONCLUSION

The results show that the microclimates due to spatial variability of the pits do not seem to be the determining factor as to the weathering rates of the soil. The geomorphic feature on which the soil is forming is the factor that influences the weathering rates of the soil. The geomorphic feature that weathers the fastest is the flood plain. The height of the water table allows the leaching of elements out of the soil profile. The upland surfaces are the most stable with the least amount of weathering. The stability of the upland surface pits is due to removal of weathered sediments from the upland surface to reveal unweathered sediments below thus giving the appearance of a soil profile that is relatively unweathered. Hillslope pits are moderately weathered features due to the fact that sediments are moving across the surface that have been moderately weathered and are being removed by gravitational forces and redepositied downslope. Alluvial fans, like hillslopes, are moderately weathered surfaces. There are horizons within the alluvial fan pits that are more weathered than horizons above and below. This is explained by knowing that sediments are constantly being weathered out from upslope and being deposited on these alluvial fans. This redeposition of the sediments is evident within the pit when looking at the TiO_2 ratios on a horizon to horizon basis. It can be noted that certain horizons seem to be more weathered than the horizon above which can only mean that it is a buried horizon. Lava flow pits seem to have some of the characteristics of the hillslope pits in that are moderately weathered and depending on which sediments are present at time of excavation determines how weathered the profile appears.

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