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Andrew P. de Wet
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Keck Geology Consortium
Franklin & Marshall College
PO Box 3003, Lanc. Pa, 17604

Lara Heister
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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: Steven Wojtal

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

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Keck Geology Consortium
Franklin & Marshall College
PO Box 3003, Lancaster Pa, 17603
Keckgeology.org

CHEMICAL WEATHERING IN THE DESCHUTES BASIN: HOW WATERSHED FEATURES EFFECT CATION CONCENTRATIONS IN WATER CHEMISTRY

LIVIA CAPALDI
Oberlin College
Steven Wojtal

INTRODUCTION

One of the most important factors controlling stream chemistry is the bedrock geology of the region; however there is not a quantitative way to predict chemistry based on geology alone (O'brien et al. 1997). There are many factors that can affect the constituents in the water chemistry such as geology, slope, rainfall, and land use. In the Deschutes Basin in central Oregon there is a range in all of the factors listed. The western part of the basin drains the eastern side of the Cascade Mountains, and is largely covered in federally managed forests, with less commercial agriculture and more precipitation than the eastern regions of the basin which mainly drain areas with irrigated crop and grazing land with an overall drier climate. Do these factors contribute to the chemical difference in the east and west equally or are there some factors that should be weighted more heavily when predicting the water chemistry of a region. This is very important in determining the effect that rock chemistry and other factors will have on water chemistry, and it can also give some insight into how water chemistry can affect rock weathering.

The Deschutes Basin is mostly comprised of volcanic material and unconsolidated silicate sediments (Ludington et al. 2006). The water travels through all of these areas, but the groundwater can have different residence times due to climate and slope of the region (Tanaka and Suzuki 2008). The average annual rainfall for most of the Crooked River catchment is less than 40 inches per year, while the lower part of the Deschutes basin receives over 50 inches a year in most places and some regions in the mountains exceed 150 inches per year.

METHODOLOGY

The study area provides an excellent location to compare the weathering of silicate rocks in two different climatic and land use settings. As seen in previous studies when there are carbonate rocks in a system they tend to dominate the chemical weathering and a good signal cannot be gathered from the silicate weathering (Douglas 2006).

Samples were collected at 52 stream samples around the Deschutes basin (fig. 1). These samples were analyzed for major and minor element chemistry. Conductivity and pH were tested on site and alkalinity was calculated using titrations in the field. Assessing the differences between the two regions was done using GIS to map and compare the topography, precipitation, watershed size, and stream length. The regions can be easily split based on the separation between the Deschutes River catchment and the Crooked River catchment, a major tributary to the Deschutes River that drains the eastern part of the basin. Due to distance and access the eastern region was sampled less and there are only six samples from the Crooked River catchment, but they are statistically different from the forty-seven samples taken in the western region. There was little to no rain for the entirety of the sampling dates so it is unlikely that a particular stream was extremely diluted or concentrated on any one day.

The Deschutes watershed was broken down into over 300 smaller watersheds, based on state specifications to more accurately assess the contribution of watershed size to the water chemistry. Using this data the area draining to each sample was calculated. These watersheds were further broken down

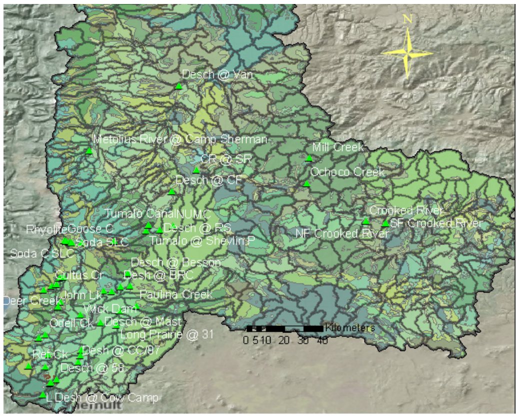

Fig.1 Map of region created using GIS showing lithology units and watershed boundaries. Crooked River catchment samples are CR@SR, NF Crooked River, SF Crooked River, Crooked River, Mill Creek, and Ochoco Creek.

Cation		East	West
	# of samp	46	6
Ca	Mean	0.11163	0.874917
	Variance	0.011217	0.120403
K	Mean	0.012209	0.07655
	Variance	0.000359	0.004881
Mg	Mean	0.122909	0.689133
	Variance	0.077056	0.116962
Na	Mean	0.101917	1.054117
	Variance	0.071445	1.051049
Si	Mean	0.46255	0.605267
	Variance	0.024409	0.032234

Fig 2 Means and variances of east and west cation concentrations, units in mM, show a significant difference in the cation concentration between the samples of the Crooked River catchment in the east and the Deschutes River in the west.

into geologic units to determine the total area of a single unit that was draining to a sample and also the percentage of the total watershed that a particular unit represents. The stream length leading to a sample location was also calculated.

RESULTS

The watersheds of the six Crooked River samples average an annual rainfall of 42.91 inches per year, whereas the Deschutes River watershed samples average 92.9 inches per year. The elevation in the west is generally higher, with an average elevation of 1377 m, and the Crooked River catchments have an average elevation of 1150 m. The average slope of the western watersheds is less than the eastern watersheds, with averages of 32 and 43 degrees respectively. Based on numerous studies climate and topography are the major secondary controls on how rocks weather, the rates are largely based on temperature, precipitation, elevation, slope, and runoff (Gislason et al 2008 and Noh et al. 2009).

Chemical analysis showed that the samples in the east had significantly higher cation concentrations. The means and variances are listed in figure 2, which shows that all cation concentration means were greater in the east. There were some anomalies in the Deschutes basin, such as Paulina Creek in the southeastern part of the Deschutes catchment. The samples show that calcium and magnesium are the most abundant cations. The least abundant is potassium. The cation concentration distribution shows a clear increase in calcium concentration in the samples in the eastern region (fig 3). The magnesium distribution also shows a clear trend of much higher concentrations in the east. The samples tend to reflect each other in cation concentrations, so that a sample with high levels of one cation will tend to have high levels of the other cations as well.

Combining these small watersheds and raster data, the average slope, mean elevation, and precipitation were all calculated for the area draining into a sample. The correlation of annual precipitation to cation concentrations is a weak negative relationship for all cations, except for Mg, which has a weak positive correlation. The correlation is strongest for calcium, but still only with an r^2 value of less than 0.15. Despite previous studies (Tanaka and Suzuki 2009) observing a strong correlation between both mean elevation and slope within a watershed and cation concentration, this data exhibits only very weak trends (see fig. 4). The elevation and slope related to cation concentrations both have a very weak correlation with a trend line that has a slope close to 0.

The only relatively strong correlation between a physical characteristic and the cation concentration is to the area of the watershed. The relationship of

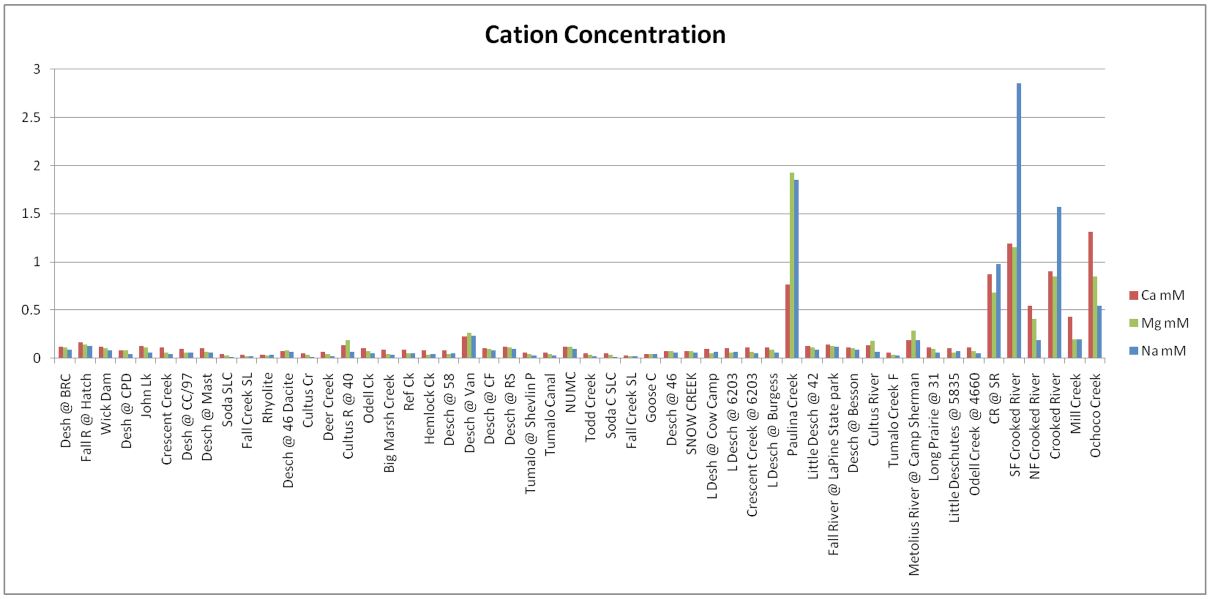

Fig. 3 Graph of cation concentrations for each sample, the six samples on the right side of the graph are the samples from the Crooked River catchment. These six samples consistently have the highest cation concentration. Paulina Creek is in the Deschutes River basin, but has similar lithology to the Crooked River catchment.

the sodium calcium ratio to total watershed area is a relatively strong positive correlation (see fig. 5), greater areas yield higher ratios. There is also some correlation between the individual cation concentrations and stream length but the trendlines for these relationships are nearly horizontal and just show that the concentrations of potassium, magnesium, and sodium do not vary much as stream length changes.

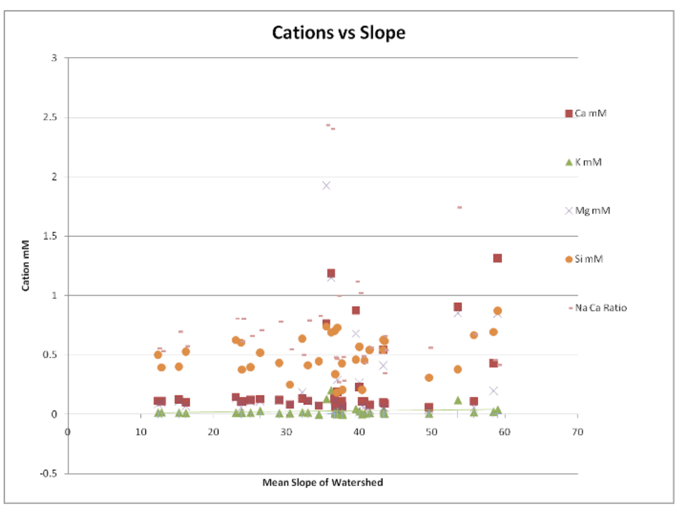

Fig. 4 Graph modeled off of Tanaka and Suzuki (2008), comparing watershed mean slope to cation concentration, all trendlines have a small r2 value. There is a weak correlation between slope and cation concentration in this sample area.

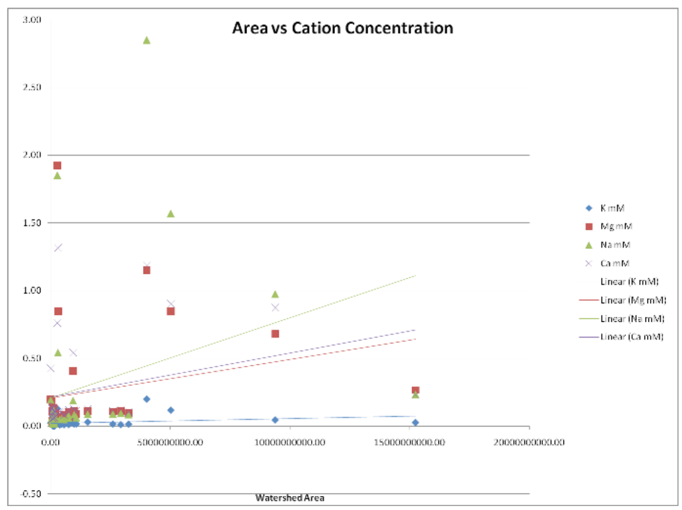

Fig. 5 Graph of watershed area and cation concentration for Calcium, potassium, magnesium, and sodium. Watershed size has relatively strong correlation to cation concentration for all of the individual cations.

DISCUSSION AND CONCLUSION

All of the cations respond to the difference in physical properties in a similar way, with the eastern regions experiencing an increase in concentration across all of the cations, although there is an extreme increase in calcium in the South Fork Crooked River sample. This probably means that there is not an outside source input, such as agriculture because there is no one cation that is generally more abundant in the east. Another possibility is that there is a constant pollution source across the entire Deschutes watershed that is affecting everything equally. The total concentrations are what is changing, not the relative abundances, which could be a result of less precipitation, greater evaporation, an increase in weathering rates, or some other factor. The lack of direct correlations of one characteristic to any of the cations among the data shows that none of the factors considered have a dominant control over the water chemistry in the Deschutes Basin. The data does not show a predictable trend for water chemistries within a watershed. It is clear that the conditions in the east and west are quite different in terms of climate and topography; however there is no conclusive evidence that either of these things is driving the difference in cation concentrations. The most significant predictor of the relationship between the water chemistries within the watershed is the total area that is draining to that point. This makes sense since there is more time for interaction between the water and rock to allow for chemical weathering. In general the cation concentration increased with watershed area, the major anomaly in this correlation is Paulina Creek, which has a similar cation concentration to the samples from the east. Paulina Creek watershed has a similar lithology to the watersheds of the east, which could be the reason that it more closely resembles those samples.

Factors that could also be affecting the way the rock weathers and changes water chemistry are vegetation, rock fracturing, and residence time. Although residence time is a major consideration in how slope effects weathering there are hydrogeologic factors such as porosity, and biologic factors such as vegetation cover.

Comparing the east and west of the Deschutes Basin shows that there is no clear cut recipe that can be followed to determine water chemistry. Trends that were expected based on studies in small volcanic watersheds in different places did not prove true in the study area, the mean slope of the watershed did not yield a correlation similar to that found by Tanaka and Suzuki (2009) and precipitation did not give a strong correlation either.

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