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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.

Faculty: Cameron Davidson (Carleton College), Karl Wirth (Macalester College), Tim White (Penn State University)

Students: Lenny Ancuta, Jordan Epstein, Nathan Evenson, Samantha Falcon, Alexander Gonzalez, Tiffany Henderson, Conor McNally, Julia Nave, Maria Princen

COLORADO – INTERDISCIPLINARY STUDIES IN THE CRITICAL ZONE, BOULDER CREEK CATCHMENT, FRONT RANGE, COLORADO.

Faculty: David Dethier (Williams) Students: Elizabeth Dengler, Evan Riddle, James Trotta

WISCONSIN - THE GEOLOGY AND ECOHYDROLOGY OF SPRINGS IN THE DRIFTLESS AREA OF SOUTHWEST WISCONSIN.

Faculty: Sue Swanson (Beloit) and Maureen Muldoon (UW-Oshkosh)

Students: Hannah Doherty, Elizabeth Forbes, Ashley Krutko, Mary Liang, Ethan Mamer, Miles Reed

OREGON - SOURCE TO SINK – WEATHERING OF VOLCANIC ROCKS AND THEIR INFLUENCE ON SOIL AND WATER CHEMISTRY IN CENTRAL OREGON.

Faculty: Holli Frey (Union) and Kathryn Szramek (Drake U.)

Students: Livia Capaldi, Matthew Harward, Matthew Kissane, Ashley Melendez, Julia Schwarz, Lauren Werckenthien

MONGOLIA - PALEOZOIC PALEOENVIRONMENTAL RECONSTRUCTION OF THE GOBI-ALTAI TERRANE, MONGOLIA.

Faculty: Connie Soja (Colgate), Paul Myrow (Colorado College), Jeff Over (SUNY-Geneseo), Chuluun Minjin (Mongolian University of Science and Technology)

Students: Uyanga Bold, Bilguun Dalaibaatar, Timothy Gibson, Badral Khurelbaatar, Madelyn Mette, Sara Oser, Adam Pellegrini, Jennifer Peteya, Munkh-Od Purevtseren, Nadine Reitman, Nicholas Sullivan, Zoe Vulgaropulos

KENAI - THE GEOMORPHOLOGY AND DATING OF HOLOCENE HIGH-WATER LEVELS ON THE KENAI PENINSULA, ALASKA

Faculty: Greg Wiles (The College of Wooster), Tom Lowell, (U. Cincinnati), Ed Berg (Kenai National Wildlife Refuge, Soldotna AK)

Students: Alena Giesche, Jessa Moser, Terry Workman

SVALBARD - HOLOCENE AND MODERN CLIMATE CHANGE IN THE HIGH ARCTIC, SVALBARD, NORWAY.

Faculty: Al Werner (Mount Holyoke College), Steve Roof (Hampshire College), Mike Retelle (Bates College)

Students: Travis Brown, Chris Coleman, Franklin Dekker, Jacalyn Gorczynski, Alice Nelson, Alexander Nereson, David Vallencourt

UNALASKA - LATE CENOZOIC VOLCANISM IN THE ALEUTIAN ARC: EXAMINING THE PRE-HOLOCENE RECORD ON UNALASKA ISLAND, AK.

Faculty: Kirsten Nicolaysen (Whitman College) and Rick Hazlett (Pomona College)

Students: Adam Curry, Allison Goldberg, Lauren Idleman, Allan Lerner, Max Siegrist, Clare Tochilin

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**Keck Geology Consortium: Projects 2009-2010
Short Contributions – OREGON**

**WEATHERING OF A VOLCANIC LANDSCAPE: THE GEOCHEMISTRY OF
THE DESCHUTES RIVER WATERSHED, CENTRAL OREGON.**

Project Faculty: *HOLLI FREY*, Union College & *KATHRYN SZRAMEK*, Drake
University

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

LIVIA CAPALDI: Oberlin College
Research Advisor: Steven Wojtal

**SPATIAL VARIABILITY OF TEPHRA SOIL ON DIFFERING GEOMORPHIC
SURFACES WITHIN THE HEADWATERS OF THE DESCHUTES RIVER,
OREGON**

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

**INCIPIENT WEATHERING IN SILICIC ROCKS INDICATED BY ENRICHMENT
OF REE AND TRACE ELEMENT CONCENTRATIONS: THE HIGH CASCADES,
OREGON**

MATTHEW KISSANE: Union College
Research Advisor: Holli Frey

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

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

**INFLUENCE OF CLIMATE AND LITHOLOGY ON SPRING CHEMISTRY IN
THE UPPER DESCHUTES RIVER, OREGON**

JULIA SCHWARZ: Carleton College
Research Advisor: Cameron Davidson

**ALKALINITY AND DISSOLVED ORGANIC CARBON IN SURFACE WATERS
OF THE DESCHUTES DRAINAGE BASIN, OREGON**

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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WEATHERING OF A VOLCANIC LANDSCAPE: THE GEOCHEMISTRY OF THE DESCHUTES RIVER WATERSHED, CENTRAL OREGON

HOLLI FREY, Union College
KATHRYN SZRAMEK, Drake University

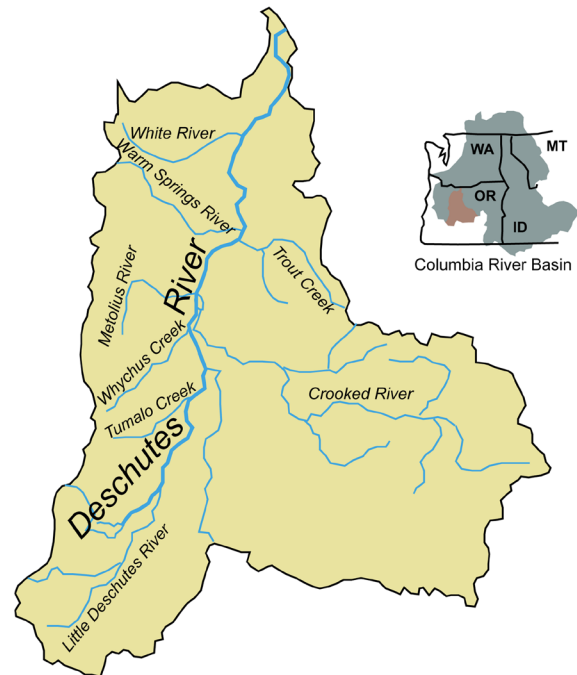
INTRODUCTION

Weathering of rock into regolith or soil is an important process that links the geosphere with the biosphere, atmosphere, and hydrosphere. The rates and mechanisms of soil formation depend on how these spheres interact and contribute to many important processes such as nutrient and carbon cycling. Integrating the rates of physical and chemical changes to bedrock over long time scales is one component of understanding the evolution of landscapes and part of recent NSF initiatives to study processes in the critical zone - “the heterogeneous, near surface environment in which complex interactions involving rock, soil, water, air, and living organisms regulate the natural habitat and determine the availability of life-sustaining resources” (National Research Council, 2001).

In order to examine these processes the project focused on the eastern side of the High Cascades and adjacent Deschutes Basin of central Oregon (Figure 1) due to the well-documented lithological diversity (e.g. Lite and Gannett, 2002) and broad range in elevation, which can act as a proxy for climate variability.

Lithology

The majority of weathering studies on volcanic rocks have focused on the breakdown of basaltic lavas (e.g. Nesbitt and Wilson, 1992; Aiuppa et al., 2000; Bendetti et al., 2003; Adot et al., 2006; Egli et al., 2008). Studies of more evolved compositions like andesite or rhyolite have focused on pyroclastic deposits from volcanic eruptions (e.g. Rasmussen et al., 2007), which differ from effusive lavas in glass content and porosity. The degree of crystallinity of basalts also affects the leaching of elements. In



Deschutes River Basin

Figure 1: The Deschutes River Watershed.

crystal-poor lavas, secondary mineralization retains Al and Fe, but the flux of Na, Si, Ca, F, and S is enhanced relative to crystal-rich lavas (Stefansson and Gislason, 2001). Geochemical changes tend to be most pronounced in the initial stages of weathering and immediately precede mineralogical changes (e.g. Price et al., 1991; Moon and Jayawardane, 2004). The secondary clay minerals produced often include allophane, halloysite, kaolinite, gibbsite, and smectite, whose more open structures are more amenable to chemical exchange.

Volcanic rock weathering is also greatly influenced by the amount of time the rocks are exposed to

the surface. Here volcanic rocks offer a substantial advantage over other types of bedrock, because the rocks are completely unweathered at the time of eruption. The rate at which soils develop affects the potential for regrowth of vegetation following volcanic eruptions. Chronosequence studies of andesitic lavas and mudflows (Nieuwenhuys et al., 2000; Lilienfein et al., 2003) demonstrate the disintegration of primary minerals into a regular sequence of clays. With increased development, soils are better able to retain nutrient thereby sustaining increased amounts and diversity of vegetation.

Climate (elevation proxy)

Climatic conditions such as increased precipitation and temperature increase the rate of chemical weathering, as evidenced by increased flux of Si and Na in granitoids (White and Blum, 1995). Similarly, in rhyolitic volcanic ash, the amount of rainfall affects which clay species develop, as composition is primarily controlled by leaching (Parfitt et al., 1983).

The utility of using elevational transects to document systematic changes in soil development affected by climate variation was demonstrated for the granitic bedrock (Dahlgren et al., 1997) and andesitic lahars (Rasmussen et al., 2007) of the central Sierra Nevadas. The range in mean annual precipitation (100 cm), temperature (13 °C), and vegetation documented in the Sierras (Dahlgren et al., 1997) is comparable to that of the central Cascades, which features a similar >2400 m elevation gradient. The parent material in our study (basalt – andesite lavas) is more vesicular and mafic than that of the Sierran studies, so the rate and type of regolith development may be substantially different.

GEOLOGIC SETTING

The eastern side of the High Cascades and adjacent Deschutes River Watershed of central Oregon, including the Ochoco Mountains (Figure 1) is described as Oregon's high desert due to the overall high elevation of the region and the location within rain shadow of the N-S trending mountains.

The High Cascades is comprised of shield volcanoes, cinder cones, and lava flows, which vary from Miocene to Quaternary in age (Figure 2). The major volcanic centers, Mount Hood, Mount Jefferson, Three Sisters, and Crater Lake range in composition from basalt to dacite, with subordinate rhyolite domes. Newberry Volcano is 65 km east of the crest of the High Cascades, but exhibits a similar range in composition. The oldest volcanic rocks in the Deschutes Basin are the John Day Fm (40 to 22 Ma), whose low permeability defines the hydrologic basement for groundwater flow (Lite and Gannett, 2002). The majority of rocks belong to the Deschutes Fm (7.5 to 4.0 Ma), a sequence of basalt-rhyolite volcanic deposits and sedimentary beds. The youngest volcanic deposits are the 1,300 year old obsidian flows at Newberry Volcano.

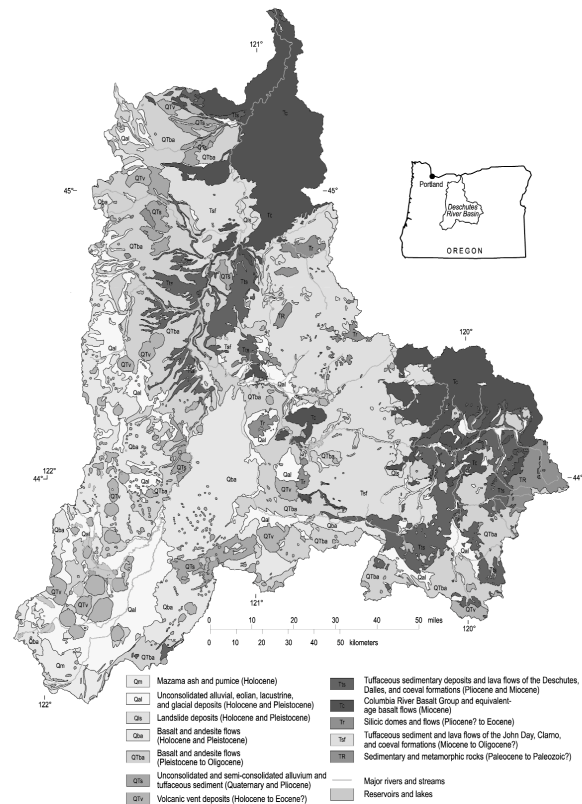


Figure 2: Generalized geologic map for the Deschutes River Watershed from O'Conner and Grant (2003).

Soils within the study area of the Deschutes Watershed are mainly developing on volcanic surfaces or reworked volcanic material that are Pliocene and younger in age. Due to the young age of the mate-



Figure 3: View from Davis Lake looking north with Mt. Bachelor and the Three Sisters to the north and the crest of the Cascades to the west.

rials, the nature of tephra deposits and the colder soil temperatures the soils tend to have weak horizon development. In the La Pine Basin (the upper section of the Deschutes watershed south of Bend, Oregon) soils are formed mainly of pumice and ash deposits from the eruption of Mt. Mazama and tend to only have weakly developed A horizons and often limited B horizon development (Myhrum, R. and Ferry, W., 1999).

Due to their high elevation (>3000 m), the volcanic peaks in the Cascades act as an orographic barrier, inhibiting rainfall to the east of the range. The greatest annual precipitation (400 cm) occurs at the highest elevations and decreases downslope to <40 cm in the Deschutes Basin, within 30 kilometers of the crest of the range (Taylor, 1993). Temperature also varies from the ridge crest to the valley. In January, the mean daily minimum and maximum temperatures at Santiam Pass in the Cascades range from -6 and 1 °C, whereas the temperatures in the valley, measured at Bend, range from -5.5 and 5.5 °C (Oregon Climate Service, 1999). A similar disparity is seen in July, with minimum and maximum temperatures of 6 and 23 °C at Santiam Pass and 7 and 27 °C in Bend (Oregon Climate Service, 1999). Evapotranspiration also varies greatly across the study area with yearly pan evaporation difference of at least half a meter with higher evaporation rates to the East and at lower elevations within the basin (Western Regional Climate Center, 2010).

The Deschutes River flows north until it joins the

Columbia River and drains approximately 27,195 km² with an average discharge of 5816 cfs (United State Geological Survey, 2010). The project focuses on the Upper Deschutes watershed, which mainly drains the eastern High Cascades to the west (Figure 3) and the Crooked River watershed (Figure 4), which drains area to the east and the Ochoco Mountains. Land use within the watershed is mainly federal managed forests (Deschutes and Ochoco NF) and federally managed Grasslands (e.g. Crooked River National Grassland) watershed, along with extensive irrigated crop and rangeland in the east portion of basin. Pine forests dominate the upland regions while sagebrush, grasses, and juniper are the dominant vegetation in the low land regions. The main population centers in the region include the areas surrounding Bend, Redmond, and Prineville, however the region has a relatively low population density of fewer than 25 persons per square mile.



Figure 4: South Fork of the Crooked River. Notice the sparse vegetation on the slopes away from the riparian zone.

RESEARCH APPROACH

The project took place from June 22nd to July 18th 2010. The project was divided into two main components, with roughly two thirds of the time spent in the field location collecting samples of rock, soil and water for later analysis and a third of the time working at Union College prepping samples for analysis, compiling field data into databases and creating a Google Earth database of all sample locations and descriptions.

Based on interest, the Oregon Keck participants divided into two main groups, those working on rocks and soil and those working on water. Each group developed a sampling campaign based on the geologic and topographic maps available and altered them based on the actual field conditions. Each group tried to obtain a range of samples that covered the diversity of lithology, including streams draining various lithology and regional coverage to account for climate variability.

In order to characterize the bedrock volcanic lithology and a primary source of elemental flux in the Deschutes Watershed, the students collected >75 lava samples, ranging from basalt to rhyolite in composition. The sampling sites were based on the geologic map of Sherrod and Smith (2000) to collect a sample from each unique vent or lava flow unit. At each site, a weathered surficial sample and a more pristine “fresh” sample were collected for physical and chemical comparison.

In order to trace the elemental flux out of the volcanic rocks and into the water, soil pits were dug in twelve different locations in the basin. In the field, the pits were described using USDA standards (Figure 5) and a sample was collected from each horizon for further analysis, including texture, moisture, carbonate content, organic content, and major element geochemistry via ICP-MS.

Surface and groundwaters within the Deschutes watershed were sampled to capture the diversity in lithology, climate and landuse. Students chose



Figure 5: Typical soil pit for the study region.

sample sites based on access to site, the lithology and landuse of the sub drainage and the locations of tributaries. In the field, waters were measured for pH, water temperature, conductivity and samples were collected for later analysis for alkalinity, cation, anion and trace elements Selected sites were collected for DOC and CFC analysis.

At Union College the students performed a majority of the preliminary analytical work: made thin section chips, powdered samples for major and trace element geochemical analysis, photographed samples, and conducted bulk density measurements. Students analyzed trace element concentrations in both water and rock samples using the ICP-MS at Union. Analysis of oxide components in the soils was done at UNC Charlotte by Harwood. Microprobe analyses of plagioclase phenocrysts were done at UCLA by Melendez. Anion components were done via ion chromatography at University of Arizona. Dissolved organic carbon and ICP-OES was done at the University of Michigan. Major element analyses of rock and soil samples were done at AcmeLabs. Chloro-fluorocarbon analysis was performed at the Tritium Lab at the University of Miami.

STUDENT PROJECTS

Rocks and Soils

Matthew Kissane (Union College) analyzed the bulk major and trace element geochemistry of the silicic volcanic rocks (andesites and dacites) within the watershed. He was interested in element mobility as the rocks weather and how different factors, such as silica content, age, and porosity affect mobility. In the pairs of lavas studied, there was a decrease in density from the fresh to weathered samples, along with subtle petrographic indications of volcanic glass and mineral alteration and breakdown. There was little variation among major elements in fresh and weathered samples, whereas all Quaternary weathered samples showed enrichment in trace element concentrations. Trace elements are thus a more suitable proxy for recording incipient weathering and are significantly affected before major elements or mineral phases.

Ashley Melendez (CSU Fullerton) investigated the plagioclase geochemistry within the volcanic rocks in the basin and how distance from vesicles may affect the weathering and breakdown of major mineral phases. Despite some textural evidence of plagioclase weathering (decrease in birefringence, yellowish brown discoloration, scalloped rims on individual phenocrysts, dusty textures within crystals, etc.), there was no discernible difference in major element plagioclase composition with respect to distance from pore spaces. Because Ca and Na are typically among the more mobile elements during weathering, their lack of depletion suggests that the plagioclase has not yet begun to break down into clay minerals.

Matthew Harward (UNC Charlotte) collected soil samples forming on a variety of geomorphic surfaces in order to investigate the geochemistry of the soils developing over the volcanic rocks within the basin. The geomorphic features investigated include flood plains, hillslopes, alluvial fans, upland surfaces, and lava flows. Developmentally, the soils are relatively immature (>50% sand-sized fraction), but have nonetheless experienced chemical weather-

ing. Plot of oxide components normalized to TiO_2 concentration (assumed immobile) relative to depth, show general trends of elemental increasing with depth, with the exception of the upland surfaces. The elemental depletion at depth is attributed to interaction with the water table.

Water

Livia Capaldi (Oberlin College) investigated the controls on solutes within the Deschutes River Watershed. She created a GIS map of the region where she was able to better determine the physiographic characteristics of the watershed and sub-watersheds. She then linked the stream geochemistry to physical aspects of the drainage basin such as drainage area, slope and length of stream to determine the possible relationships between the various characteristics. She determined that within the Deschutes watershed drainage basin area is linked to the total concentration of solutes, but did not observe a link between chemistry and slope or length of stream.

Julia Schwarz (Carleton College) investigated springs within the basin using trace element and rare earth element (REE) geochemical data along with residence times developed from chlorofluorocarbon (CFC) dating to better understand the processes influencing the geochemistry of regional groundwaters, such as residence time and lithology. She notes marked geochemical differences between springs draining the western and eastern edges of the basin, however the CFC age range for the springs were small therefore indicating that other processes such as climate or lithology controlling the differences within the springs not residence time.

Lauren Werckenthien (DePauw University) examined inorganic and organic carbon within the Deschutes watershed focusing on how HCO_3^- and DOC (dissolved organic carbon) vary with lithology, landuse, the dissolved load of the streams and the links between carbon and mineral weathering. Her results link older lithologies to higher HCO_3^- concentration within the basin.

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