How does the mantle beneath the Ring of Fire change through time?: a trace element study of primitive basalts erupted in a small area in the Southern Cascades

Abstract

I will test the hypothesis that spatially related but temporally different primitive basalts associated with Lassen Volcanic Center, northern California, are genetically and chemically related. This project proposes to use trace- and rare-earth elements of seven basalt flows that have well characterized temporal relationships to better understand the evolution of the mantle beneath the Southern Cascades. Major element data for these rock units suggest that they may be derived by multiple episodes of incongruently melting the mantle, significantly changing the composition with each melt extraction. Although detailed major earth element studies have been performed on the both of these rock units, their trace and rare earth elements are poorly characterized. Because trace elements are more sensitive to mantle modification processes, collection of this data will contribute significantly to our understanding of the nature of mantle sources that contribute to the development of primitive basalts in the volcanoes that make up the Ring of Fire.

This proposal will provide a unique opportunity for me as a first-generation college student to explore the scientific method with a research problem of my own. The questions addressed with this project fit into a larger research project by my mentor regarding the nature of the mantle. My experience as a geology major and the work I have done with my mentor make me uniquely qualified to carry out this project.

Project Description

I will test the hypothesis that spatially related but temporally different volcanic rocks in the Poison Lake area, near Lassen Volcanic National Park, are genetically and chemically related. This project will focus on three mantle-like compositions – the 200,000 year old Cone Lake sequence and the 100,000 year old Stephens Campground, and Cone Lake Road units (Muffler et al., *in review*) – that overlap in a small area (<15 km^2) just outside Lassen Volcanic National Park. The eruptive relationship of these three suites suggests that the Cone Lake sequence erupted first, followed by Stephens Campground, and then Cone Lake Road. Major element compositions of the rocks suggest that they could be derived by multiple partial melting events in the mantle (Wenner et al., 2009). Since these rocks are chemically and spatially related but temporally different, this study will help us to understand heterogeneity in the mantle through time and will lead to a better understanding of complex mantle compositions beneath the Lassen Volcanic Center and surrounding Cascade region.

A detailed study of a portion of the Poison Lake Chain (100ka) shows significant spatial variations in both isotopes and trace elements, suggesting mantle variation on a small scale (Wenner and Teasdale, 2009). Stephens Campground and Chain Lake Road are a part of the Poison Lake Chain (Clynne and Muffler, *in press*) but detailed trace- and rare earth element studies have not been performed. In addition, even less is known about the trace element geochemistry of the older Cone Lake sequence (200ka). Major element signatures for this unit show variation among them and suggest that these magmas ascended fast and were not modified by the crust or by each other (Wenner and Teasdale, 2009). The major elements also show that the youngest rocks are the most primitive and these variations are consistent with multiple episodes of partial melting of the mantle leading to modification by extracting melts.

The proposed trace and rare earth element studies on seven units (two from the Cone Lake sequence, two from Cone Lake Road, and three from Stephens Campground) will help to confirm my hypothesis that volcanic rocks in the Poison Lake area are genetically and chemically related. Since trace and rare elements are more sensitive to modification processes than major elements, they can be used to significantly contribute to the study of geochemical processes inside the Lassen Volcanic Center. This trace and rare earth element analyses will also help to better understand the nature of the mantle sources that contribute to the development of primitive magmas in the volcanoes that make up the Ring of Fire.

Methodology

This project will involve several research techniques, including library research, fieldwork and preparation of samples in the laboratory. Library research will include searching the literature for information and data for similar aged rocks in the area. A large portion of this project will be spent completing fieldwork in Northern California, just outside of Lassen Volcanic National Park. Fieldwork for this project includes collecting multiple samples from each of the identified seven units, some geologic mapping (detailed maps of the rock types present in an area), and use of Global Positioning Satellite (GPS) units to mark sample locations. Because trace element compositions are very sensitive to processes, including weathering, we will use proven field techniques to obtain the freshest samples possible. We plan to collect multiple samples of each individual lava flow to see how the magma changed over the duration of a single eruption.

Laboratory work will consist of preparing and examining thin sections under a petrographic microscope which will help us choose appropriate rock samples for geochemical analysis. Once appropriate samples are identified, laboratory work will include the crushing and

powdering of samples that will be sent to Washington State University for trace-element analysis by inductively coupled plasma-mass spectrometry (ICP-MS). ICP-MS has been chosen because it is the most sensitive and accurate way to measure rare-earth elements and the trace element s of interest. Trace- and rare-earth element compositions can help us to recognize and identify the modification processes that influenced the mantle in this area.

Student Motivation and Background

The chance to pursue this research project opens an opportunity to participate in a collaborative faculty-undergraduate research project that gives me research experience and prepares me for graduate school and professional life in volcanology and geochemistry. Learning about the interior of earth truly excites me, and volcanology and geochemistry provide me with an opportunity to better understand the system under the crust of Earth. Characterization of mantle composition distributions and different sources of magmas could help scientists recognize more about how a volcano will erupt. This project may help volcanologists to develop better hazard plans that could save more lives in the case of future volcanic eruptions.

I come from a working class family with no college background, and as a first generation college student I want nothing more than to succeed as an undergraduate student in geology and be passionate about what I do. The process of designing and executing an exciting research project with the help of my mentor will only better my chances for success. My geology and other science classes will provide academic support for the project. I have also participated in several geology field trips that increased my interest in field work and provide me with an appropriate background for this type of field-laboratory study. So far in my career, I have taken Physical Geology, Evolution of the Earth, Mineralogy, two semesters of Chemistry, and a field course in geology in Missouri at the St. Francois Mountains. I am currently taking Lithology,

Introduction to Field Methods, and am participating in a field course in geology in West Texas and Big Bend National Park during the spring 2010 term. Besides the field courses, many of my geology courses have a field trip associated with them. I have also been working with Dr. Jennifer Wenner, who was my Mineralogy professor, reading articles about previous research in the area of interest for the second half of my fall 2009 semester and will continue to do so during spring 2010.

The role of Dr. Wenner, as mentor, will be to provide guidance in all aspects of this project while allowing me some autonomy to creatively explore the scientific method through this project. Although this project represents a small piece of Dr. Wenner's larger project at Lassen, the ideas for this project resulted from multiple conversations with her and from my own creativity, and I will be the primary researcher. Dr. Wenner will supervise field and laboratory work as well as serve as consultant on field, geochemical and volcanological aspects of the project.

Location and Timeline

Research for this project will be conducted in Northern California just outside Lassen Volcanic National Park in the Poison Lake Chain. Samples collected will be sent to Washington State University for trace element analysis using their ICP-MS. Additional laboratory work and research will be completed at the University of Wisconsin-Oshkosh.

For this research project, I will spend sixty hours in early summer of 2010 at the University of Wisconsin-Oshkosh doing library research and going through previously collected thin sections to make sampling plans for upcoming fieldwork. During the middle of the summer, my mentor and I will travel to Northern California to the Lassen Volcanic Center to conduct the necessary fieldwork for seven to ten days. Because fieldwork is intensive and we often spend

ten to twelve hours working in the field, I anticipate spending 80-120 hours in the field. Upon returning to Oshkosh, I will spend approximately 40-60 hours preparing thin sections, determining appropriate samples and preparing those samples to be sent to WSU. When data is returned, I will spend the remaining time analyzing data and preparing a poster for presentation at Celebration of Scholarship.

Outcomes

This project has several tangible and intangible outcomes. Tangible outcomes include:

- a complete data set of trace element compositions for the units sampled
- a set of field notes and a geologic map of the units sampled
- A model for the processes that modified the mantle and magmas erupted in the Poison Lake Chain
- Submission of an abstract and presentation of my results at a professional meeting such as American Geophysical Union (AGU) in December 2010.
- Presentation of results at the Celebration of Scholarships at the University of Wisconsin-Oshkosh in Spring 2011

Intangible outcomes include a new circle of colleagues from numerous institutions (WSU, USGS, CSU-Chico), new knowledge and skill in the area of igneous geochemistry and volcanology research and the experience of presenting work to my peers in the field. Each of these expected outcomes add to the priceless educational experience that I will gain by completing this project.

Budget

This project requires only a plane ticket, and funds for analysis. WSU charges $50-75 per sample and we will analyze 7-10 samples. The Geology Department has limited funds to help with a plane ticket, so funds from this grant will be used for geochemical analysis.

References Cited

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Wenner, J. M., and Teasdale, R., 2009, Small Scale Heterogeneity in the Mantle Beneath the Southern Cascades: Isotope and Trace-Element Geochemistry of Primitive Basalts in the Poison Lake Chain Eos, Transactions, American Geophysical Union, v. 90, no. 52, Fall Meet. Suppl., Abstract V21C-2001.

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Monday, February 8, 2010

Student/Faculty Collaborative Research Program
Review Board
University of Wisconsin Oshkosh
Office of Grants and Faculty Development
Oshkosh, WI 54901

Dear Review Board,

I am writing in support of Kyle Colburn's proposal entitled "How does the mantle beneath the Ring of Fire change through time?" Kyle's proposed project represents a part of one of my larger undertakings in the Poison Lake area of the Southern Cascades; therefore, I am extremely eager to have Kyle complete this project. The proposed project resulted from Kyle's own exploration of the geology in the Poison Lake chain toward the end of last semester and this eventually developed into the proposal you see here. He outlined and wrote the proposal himself.

Kyle's drive and dedication to the field of geology is evident in the work that he does. He initiated work on the Poison Lake basalts last semester, asking to explore the question of mantle composition by reading and discussing appropriate articles. Although Kyle is in the midst of the sequence of core courses for the geology major, he has shown a commendable intellectual capacity for igneous petrology and geochemistry. In addition to completing the core courses in geology by the summer, Kyle will also have participated in many field trips. These two factors will give him ample field and geology experience to complete this project. Throughout the design of this project, Kyle has been an active participant, driving the research question with his curiosity and interest in volcanology. He is hard working and dedicated and is certainly capable of completing a project such as this one in the eight week summer term.

I am fully capable of supervising this project as I have mentored over 15 students in similar projects in the past 10 years at Oshkosh. Projects with intense fieldwork and laboratory work dominate the kinds of projects that my students design. I have trained students in field and lab techniques and many have gone on to graduate school. Almost all of them end up presenting their work at professional meetings or co-authoring publications. My role as mentor in this particular project will be to serve as consultant and teacher, training Kyle in field and lab techniques and providing guidance and direction for his research while allowing him freedom to explore his research question. I will also be present in the field to serve as guide for appropriate sampling, mapping and volcanological techniques. I look forward to Kyle's successful completion of this interesting and challenging research problem.

Kindest regards,

Jennifer M. Wenner, Assistant Professor of Geology

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