Research Proposal

Geomorphic Analysis of Late Quaternary Cinder Cones at Newberry Volcano, Central Oregon: Landform Evolution and Eruptive History in a Back-Arc Setting

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INTRODUCTION

Newberry Volcano is located in central Oregon, about 60 km east of the High Cascades, near the cities of Bend and LaPine (Figure 1, p. 8). It is tectonically positioned in a complex, back-arc setting that lies at the intersection of the Basin and Range, High Lava Plains, and Cascade Volcanic Arc provinces. With an area covering greater than 1600 km^2, Newberry is one of the largest shield volcanoes in the contiguous United States and is associated with bimodal volcanism that has produced over 400 basaltic cinder cones and fissure vents (Jensen, 2002; Figure 2, p. 9). While the earliest eruptions are estimated to date back 600,000 years (Sherrod et al., 1997), exposed cinder cones are generally middle Pleistocene to Holocene in age (<300,000 yrs; Jensen, 2000).

The purpose of this proposal is to garner support to conduct a geomorphic field investigation of the basaltic cones and refine a DEM-based morphometric model developed by Taylor et al. (2003). The large sample size provides a robust data set from which to evaluate existing landform evolution models and examine controls on magma emplacement processes over time.

SETTING

Central Oregon is characterized by an arid to semi-arid climate that is controlled by rainshadow effects on the lee side of the Cascade Range (Taylor and Hannan, 1999). Newberry site elevations range from 1150 m to 2433 m with corresponding increases in average annual precipitation from 380 mm to 760 mm, respectively. The regional landscape is forested predominantly by Ponderosa (*Pinus ponderosa*) and Lodgepole (*Pinus contorta*) pine, with lesser amounts of Mountain Hemlock (*Tsuga mertensiana*) and True Fir (*Abies amabilis*) occurring at higher elevations (Franklin and Dyrness, 1988).

Newberry is a broad shield volcano with a 5 to 7 km wide caldera at the summit (Figure 2). It is situated at the intersection of three major fracture systems including the Brothers (west-northwest trending), Tumalo (north-northwest), and Walker Rim (northeast) fault zones (Figure 1; MacLeod et al., 1981; MacLeod and Sherrod, 1988). The flanks are covered mostly by basaltic andesite flows (54-55 wt.% SiO_2) with subordinate amounts of basalt and andesite (Figure 2). Compositional characteristics are similar to calc-alkaline flows in the Cascade Range (MacLeod and Sherrod, 1988). Newberry is uniquely positioned at the younger end of a sequence of rhyolitic domes and ash-flow tuffs that decrease in age from 10 m.y. in southeastern Oregon to less than 1 m.y. near the present caldera (Figure 1) (Walker, 1974; Jordan et al., 2004). This westward-younging sequence of silicic volcanics approximately mirrors those of the northeast-trending Yellowstone hotspot track, making Newberry one of the most tectonically intriguing and enigmatic volcanic features in the western U.S. (Rowe et al., 2003; Jordan et al., 2004; Xue and Allen, 2006).

PREVIOUS WORK

The fundamental geologic framework of Newberry Volcano was documented by Higgins (1973), MacLeod et al. (1995), Sherrod et al. (1997), and Jensen and Chitwood (2000); however details of the stratigraphy, petrogenetic history, and magmatic evolution are a work in progress. Advancements were recently made with regard to the silicic-phase volcanism (e.g., Templeton, 2004; Kuehn and Foit, 2006); but less is known about the basaltic modes, particularly magma emplacement mechanisms and timing of cinder cone eruptions (Jensen and Chitwood, 2000; Donnelly-Nolan et al., 2000). Of the nearly 400 basaltic cinder cones, fissure vent deposits, and related lava flows mapped at Newberry (MacLeod et al., 1995); only 12 were numerically dated with radiometric techniques (C-14, K-Ar, Ar-Ar) (Jensen, 2000). Age dating of the voluminous amount of cinder cone deposits and complexly interbedded (buried) flows is problematic, and proves to be an elusive facet of Newberry geology. MacLeod and Sherrod (1988) observed that the curvilinear distribution of cinder cones and fissure vents on the flanks of Newberry trend approximately parallel to the Walker Rim and Tumalo fault zones, suggesting that these structures may form a single arc-shaped fracture zone at depth and likely serve as conduits that guide magma emplacement (Figures 1 and 2). MacLeod and Sherrod (1988) also suggested that north-northwest trending cones and fissure vents are relatively younger than those trending north-northeast.

To quantitatively test these hypotheses, Taylor et al. (2003, 2005, 2007) conducted preliminary morphometric and geospatial analyses of ~300 cinder cones distributed across the north and south flanks of Newberry Volcano. These studies employed Geographic Information Systems (GIS) techniques to analyze cinder cone data derived from digital geologic maps (Giles et al., 2003) and USGS 10-m digital elevation models. Measurements included cone volume, cone-shape (cone slope, relief, height-to-width ratios), and trend analyses of cone-point alignment patterns. The exploratory GIS work by Taylor et al. (2003) revealed two statistically-distinct, morphometric cone classes: Group I (n = 42) characterized by higher relief and steeper slope profiles (i.e., relatively "young" morphology) and Group II (n = 140) of lower relief and gentler slopes (i.e., relatively "old" morphology) (Figure 3). Geospatial analysis revealed strong cone lineaments parallel to the Brothers and Tumalo fault zones (Taylor et al., 2005); supporting the concept that faulting and regional tectonic stress fields structurally control magma emplacement at Newberry (MacLeod and Sherrod, 1998).

Based on preliminary comparison with the dozen numerically-dated cinder cones and basaltic flows at Newberry (Jensen, 2000), it is uncertain whether the morphometric groupings of Taylor et al. (2003) are a function of age differences and degradation state, or a combination of other variables such as magma composition, ejecta volume and rate, degree of agglutination, lava breaching, post-eruptive cone burial, or cryogenic modification. Donnelly-Nolan et al. (2004) speculated that late Pleistocene glaciation at Newberry may have been more extensive than the limited occurrence of cirque glaciers near the caldera summit, as originally suggested by MacLeod et al. (1995) and Osborn and Bevis (2001). Given the 1100 m of relief and elevation range at Newberry (1150 m to 2433 m), late Quaternary climate change has certainly influenced post-eruptive cone degradation processes; however the documented evidence for widespread glacial erosion is poorly constrained. Evidence for glacial modification was not detected in the DEM work by Taylor et al. (2003), but it is reasonable to consider the likelihood of periglacial conditions at higher flank elevations during the Pleistocene. Regardless of which combination of post-eruptive surface processes have modified primary cinder cone morphology at Newberry, systematic field studies are required to definitively decipher the factors controlling the two morphometric groupings identified by Taylor et al. (2003). The large number of cinder cones provides a statistically viable sample population on which to test well-established relative dating and geomorphic techniques.

RESEARCH OBJECTIVES

Cinder cones degrade over time by both diffusive and advective erosion processes, with mass transfer from hillslope to debris apron and loss of crater definition. Existing cone degradation models posit that as cone age increases, side-slope gradients, relief, and height-to-width ratio decrease, while drainage density increases (e.g., Scott and Trask, 1971; Porter, 1972; Dowrenwend et al., 1986; Hooper and Sheridan, 1998; Wood 1980). Such cone degradation models have formed the basis of oft-cited geomorphic dating studies in volcanic regions of the southwestern U.S. (e.g., Dohrenwend et al., 1986; Wells et al., 1990).

The central research questions for the Newberry cinder cone project are framed as follows: (1) Do the cone-morphology models developed for the southwestern U.S. apply to arid back-arc landscapes at more northerly latitudes in the Pacific Northwest? (2) How do variable climate regimes influence the morphologic evolution of cinder cones over time? (3) What are the ages of cinder cones and how are they spatially distributed? (4) Given answers to the above, what tectonic factors control small-volume magma emplacement at Newberry cone fields?

While the initial Phase I work by Taylor et al. (2003) identified two morphologically distinct cone populations at Newberry (Figure 3), no supporting field work has been conducted to validate these DEM-based observations. The purpose of this proposal is to garner funds to conduct a Phase II geomorphic field investigation. The objectives of this work are to: (1) collect field observations on Newberry cinder cones to test and refine the preliminary morphometric models of Taylor et al. (2003); (2) apply established field-based geomorphic techniques developed in other volcanic fields; (3) develop regional landform evolution models founded on empirical geomorphic observation; and (4) utilize the results of this study to contribute to the understanding of the eruptive history and magmatic processes at Newberry Volcano.

METHODOLOGY

Collection and analysis of geomorphic data will follow field techniques described by Wood (1980), Dohrenwend et al. (1986), Wells et al. (1990), and Valentine et al. (2006). Geomorphic field surveys will be completed on 25 to 30 cinder cones from each of the two morphology groups delineated by Taylor et al. (2003). Cone subsets will be selected on the basis of the following criteria: (1) subequal distribution across the north and south flanks of the shield volcano; (2) distribution across a range of elevations from lower flanks to summit caldera; and (3) inclusion of the 12 numerically-dated cones tabulated by Jensen (2000).

Field observations and measurements will include: (1) large-scale mapping of cone features, crater morphology, composition, debris-apron morphology, and outcrop localities; (2) morphometric parameters such as cone-slope gradients, apron dimensions, and apron slopes ; (3) field measurement of drainage density (gullies, channels); and (4) excavation of reconnaissance test pits with observations on soil thickness, stratigraphy, and degree of pedogenic development. The numerically-dated cones of Jensen (2000) will be used for chronometric calibration of landform features. Additional cones will be identified for numerical-dating applications as the project advances. Comparative statistical analyses of field data will be subsequently used to validate and refine the DEM-based morphometric models of Taylor et al. (2003), thus providing a framework from which to derive regional landform evolution models.

PROJECT TIMELINE

Field work will be conducted over two summer seasons in 2008 and 2009, with 15 field days and 2 travel days per year. Data will be compiled and analyzed throughout the project period with a final report completed by December 31, 2009. Results will be presented at the 2009 Annual Meeting of the Geological Society of America meeting in Portland, Oregon.

The two-year time frame for the project is necessary to accommodate the PI's existing teaching and service commitments at Western Oregon University (WOU), a four-year undergraduate institution that forms part of the Oregon University System. The institutional emphasis on quality teaching and high levels of faculty-student contact (36 credit hours per year) requires an expanded project timeline to accommodate off-campus research.

PROPOSED BUDGET

Year 1 (Summer 2008 – Spring 2009)		
Faculty Summer Salary	$2330	(includes other personnel expenses "OPE")
Student Assistant(s) Salary	$2450	(includes OPE)
Travel Expenses	$1750	
Misc. Supplies	$300	
Subtotal	**$6830**	
Year 2 (Summer – Fall 2009)		
Faculty Summer Salary	$2330	(includes OPE)
Student Assistant(s) Salary	$1750	(includes OPE)
Travel Expenses	$1750	
Misc. Supplies	$300	
Subtotal	**$6130**	
Total Direct Costs	**$12,960**	
Indirect Costs	**N/A**	

Budget Explanation

I. Faculty Salary

Summer 2008 Salary 0.19 FTE x 0.18 x $52,391 annual =	$1792	
Summer 2008 30% OPE =	$538	
Year 1 Subtotal=		**$2330**
Summer 2008 Salary 0.19 FTE x 0.18 x $52,391 annual =	$1792	
Summer 2008 30% OPE =	$538	
Year 2 Subtotal=		**$2330**

***According to collective bargaining agreements; faculty summer salary at Western Oregon University is 18% of annual multiplied by the fraction of full-time equivalent. PI is planning on 17 project days for summer session which is equivalent to 0.19 FTE.*

II. Student Assistant Wages

Summer 2008 = 20 days x 8 hr / day x $8.75/hr (incl. OPE) =	$1400	
Fall Term 2008 = 10 wks x 4 hrs/wk x $8.75/hr (incl. OPE) =	$350	
Winter Term 2009 = 10 wks x 4 hrs/wk x $8.75/hr (incl. OPE) =	$350	
Spring Term 2009 = 10 wks x 4 hrs/wk x $8.75/hr (incl. OPE) =	$350	
Year 1 Subtotal =		**$2450**
Summer 2009 = 20 days x 8 hr / day x $8.75/hr (incl OPE) =	$1400	
Fall Term 2009 = 10 wks x 4 hrs/wk x $8.75/hr (incl. OPE) =	$350	
Year 2 Subtotal =		**$1750**

***Depending on availability and enrollment levels, two to three undergraduate students from Western Oregon University will be engaged as research assistants throughout the duration of the project.*

III. Travel Expenses:

Summer 2008		
4-wd vehicle rental and mileage		
Vehicle Rental (1-month rate) =	$390	
Mobilization Mileage $0.30/mi x 385 mi RT =	$115	
In-field Mileage $0.30/mi x 50 mi/day x 15 day =	$225	
Vehicle Subtotal=	**$730**	
Per Diem		
PI: 17 days x $30/day (15 field days + 2 travel days) =	$510	
Student Assistant: 17 days x $30/day =	$510	
Per Diem Subtotal=	**$1020**	
Year 1 Travel Expenses=		**$1750**
Summer 2009		
4-wd vehicle rental and mileage		
Vehicle Rental (1-month rate) =	$390	
Mobilization Mileage $0.30/mi x 385 mi RT =	$115	
In-field Mileage $0.30/mi x 50 mi/day x 15 day =	$225	
Vehicle Subtotal=	**$730**	
Per Diem		
PI: 17 days x $30/day (15 field days + 2 travel days) =	$510	
Student Assistant: 17 days x $30/day =	$510	
Per Diem Subtotal=	**$1020**	
Year 2 Travel Expenses=		**$1750**

***A 4-WD vehicle will be required for field travel on rugged forest roads around Newberry Volcano. Field vehicles will be rented through motorpool services at Oregon State University.*

IV. Miscellaneous Supply Expenses

$300 per year is budgeted for miscellaneous field supplies necessary to accomplish stated objectives. Examples of supply purchases include base maps, aerial photos, field notebooks, and reproduction costs.

PENDING GRANTS AND FINANCIAL SUPPORT

No other proposals or secured funds are currently pending or available for the Newberry cinder cone project. The GIS-based analyses of Taylor et al. (2003, 2005, 2007) were supported primarily by internal resources at WOU, with the bulk of work completed as undergraduate independent study projects in the Earth Science program. If awarded, Cole Memorial funds from the Geological Society of America will cover 71% of the proposed project costs. It is anticipated that the balance of funds will be obtained from the WOU Faculty Development Fund.

PROJECT JUSTIFICATION

The results of this project will make a significant contribution towards understanding the geologic history of the Cascadia back-arc and development of landform evolution models in volcanic landscapes of the Pacific Northwest. Although such models have been derived in other volcanic fields (e.g., Lathrop Wells, Cima, Springerville), no systematic field investigations of cone morphology have been conducted at Newberry Volcano. Given the large number of late Quaternary cinder cones preserved on the landscape (n ~400), the site represents an important geologic framework from which to conduct morphometric analyses, test landform evolution models, and decipher controls on magma emplacement processes over time. As central Oregon has one of the highest population growth rates in the United States (annual avg. growth = 21%; U.S. Census Bureau, 2003), this study will also have important implications for volcanic hazards assessment in the region (after Sherrod et al., 1997). Results will be directly applicable to the understanding of other volcanically-active regions around the world.

The proposed work is a necessary step leading towards design of a comprehensive sampling plan to examine rock and soil geochemistry at Newberry cinder cones. Completion of a thorough Phase II field campaign will be critical prior to implementation of more costly geochemical and soil sampling strategies. Future Phase III project work will focus on soil development (e.g., Rech et al., 2001), derivation of numerical cone-degradation models (e.g., Hooper and Sheridan, 1998), and analysis of cone geochemistry (e.g., Strong and Wolff, 2003).

In addition to its scientific value, this work will directly promote teaching and research at a predominantly four-year, undergraduate institution in the Pacific Northwest. Newberry Volcano represents an ideal natural laboratory for student application of quantitative techniques to multivariate systems with interdependent process-response mechanisms. As such, the proposed budget will support training of 2 to 3 undergraduate Earth Science majors at Western Oregon University. Project results will be integrated into the curriculum as contextual learning modules in several upper division courses (e.g., ES322 Geomorphology, ES406 Independent Study, ES473 Environmental Geology). This work directly supports the advancement of geoscience education, environmental management, and hazards mitigation in the Pacific Northwest and beyond. In sum, the project offers significant return on investment of Cole Memorial Funds.

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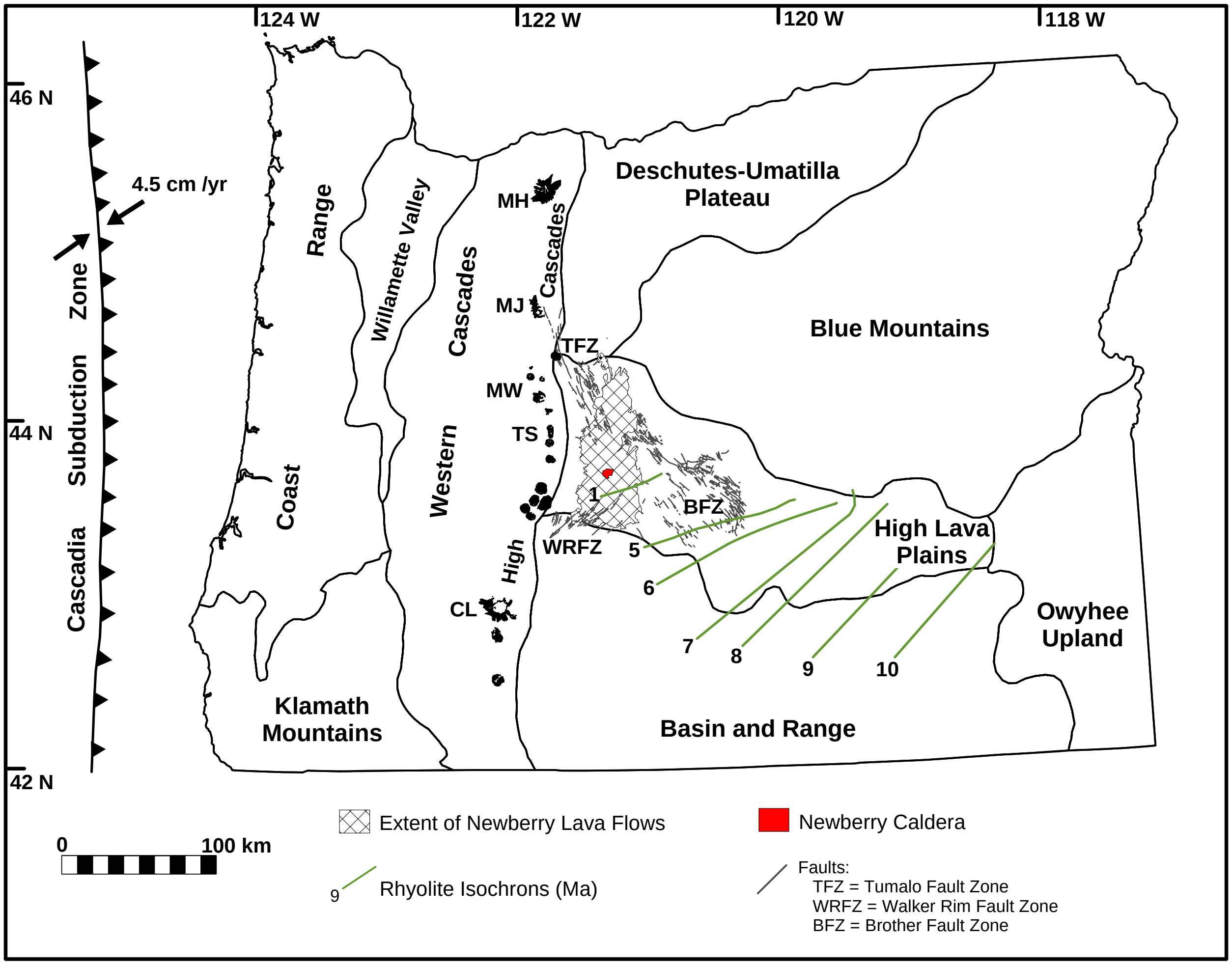

Figure 1. Generalized map of Oregon emphasizing the regional geologic, physiographic, and tectonic framework of Newberry Volcano. (After Walker and MacLeod, 1991). Locations of High Cascade volcanoes are identified as follows: MH = Mt. Hood, MJ = Mt. Jefferson, MW = Mt. Washington, TS = Three Sisters, CL = Crater Lake.

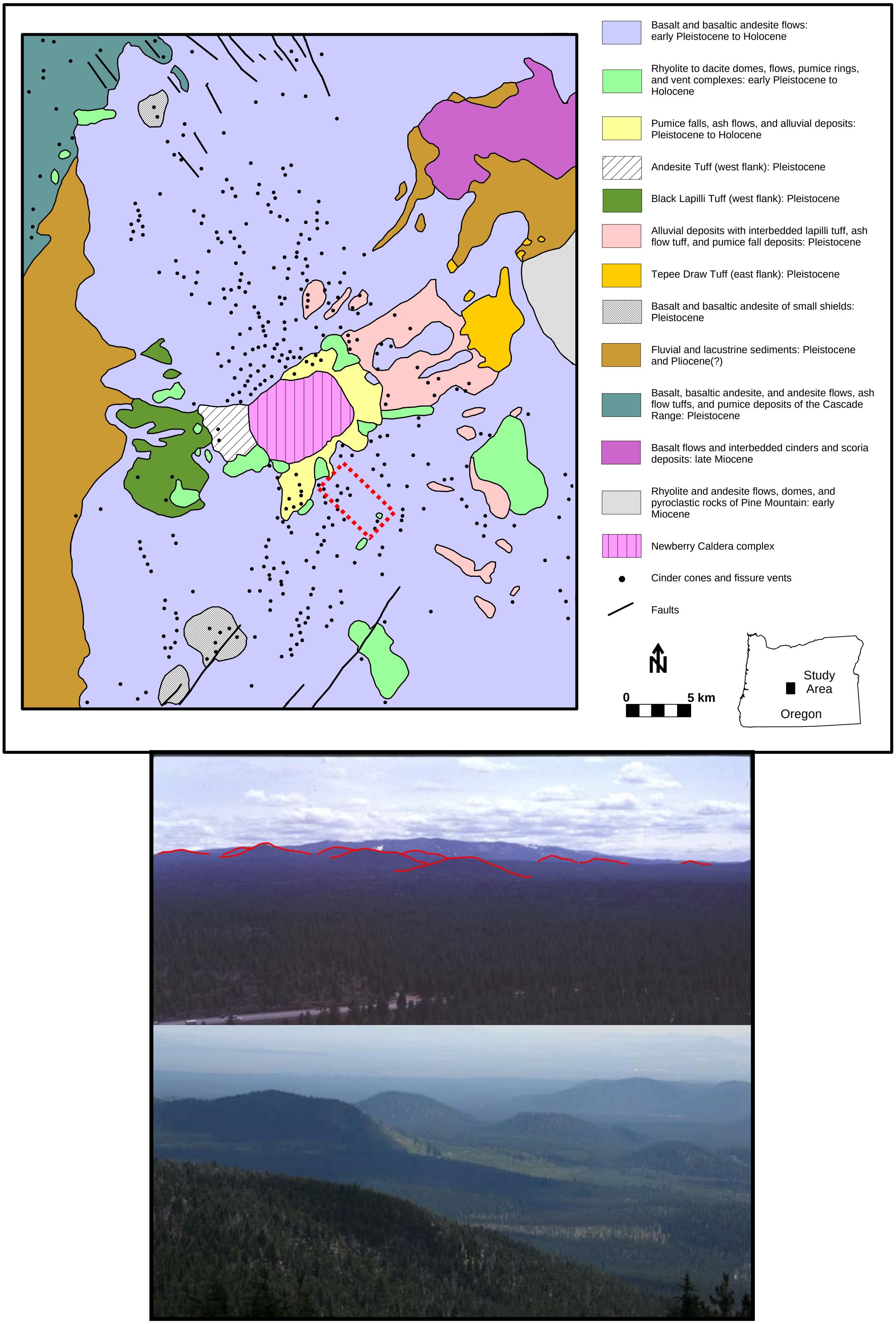

Figure 2. Generalized geologic map and photographic overview of Newberry Volcano (after Jensen, 2000). Top photo shows central caldera region and related cinder-cone field in foreground (red outlines). Bottom photo is an aerial view of the southeast cinder cone field (dashed box on map).

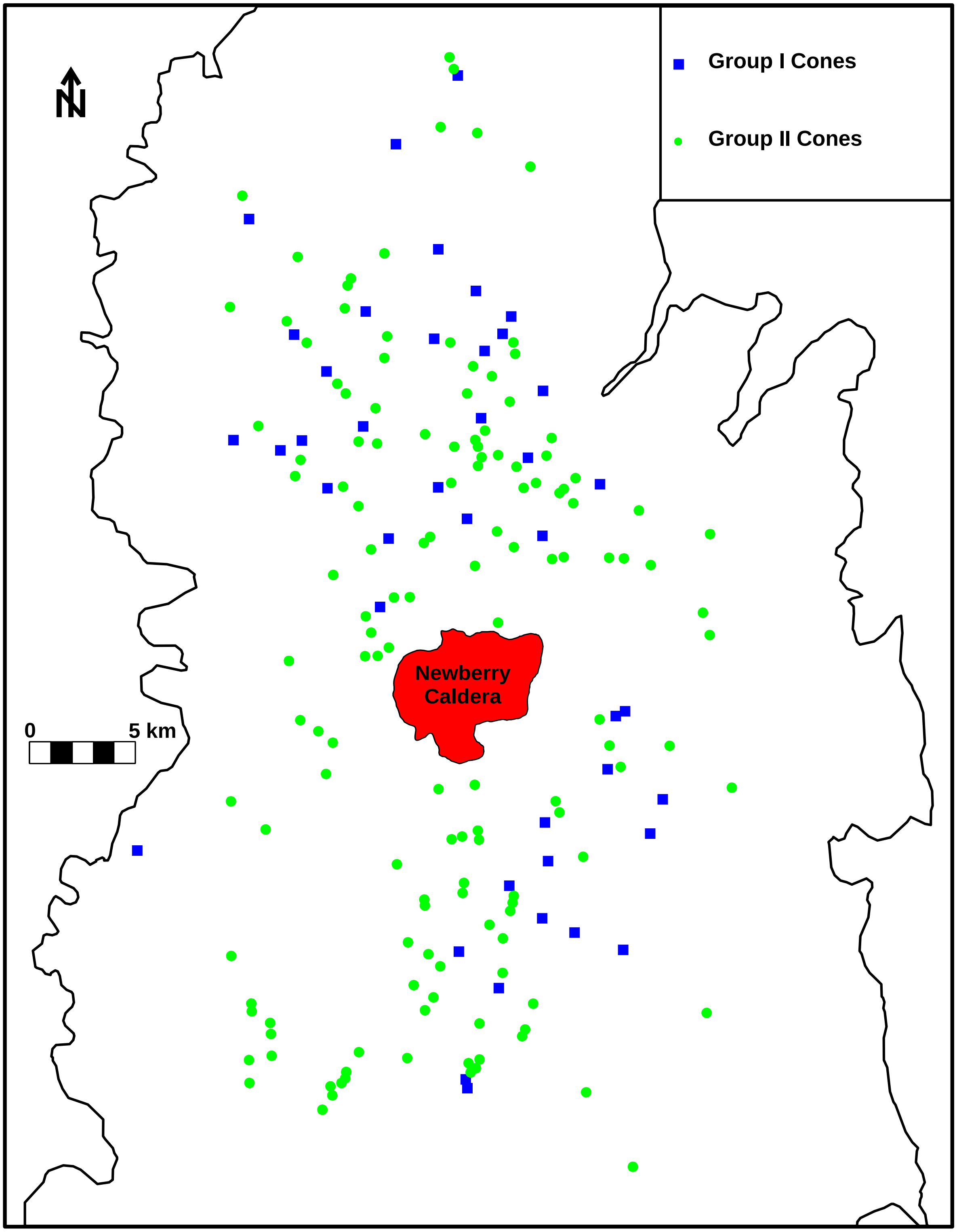

Figure 3. Map showing distribution of the two morphometric classes of cinder cones identified by Taylor et al. (2003), as derived by analysis of 10-m digital elevation models. Group I cones ("younger"; n = 42) are statistically characterized by the following: avg. cone slope = 18.7^{o}, avg. cone height = 127.7 m, and avg. cone height-to-width ratio = 0.19. Group II cones ("older"; n = 140) are characterized by: avg. cone slope = 12.8^{o}, avg. cone height = 66.1 m, and avg. cone height-to-width ratio = 0.14. Morphometric differences between cone classes are statistically significant at the 95% confidence interval. Refer to Taylor et al. (2003) for an overview of techniques and results.

QUALIFICATIONS OF THE PRINCIPAL INVESTIGATOR

Appointments and Professional History

- Associate Professor of Geology, Western Oregon University, 2004-present.
- Visiting Scientist, H.J. Andrews Experimental Forest / Oregon State University, 2007
- Visiting Professor of Environmental Geology, Willamette University, 2005.
- Visiting Professor of Geography, University of Oregon, 2001.
- Assistant Professor of Geology, Western Oregon University, 1999-2004.
- Project Geologist, U.S. Filter - Chester Engineers, Inc., Pittsburgh, PA, 1999.
- Research Assistant, Geology, West Virginia University, 1997-1999.
- Instructor, Earth Science, California University of Pennsylvania, 1993-1997.
- Instructor, Geology/Geography, Westmoreland County Community College, 1990-1995.
- Hydrogeologist, Anderson Geological Services, Washington, PA, 1990-1994.
- Hydrogeologist, Geraghty and Miller, Inc., Washington, PA, 1989-1990.
- Research Assistant, Geology, University of New Mexico, 1988-1989.
- Project Scientist, Agronomy and Soils, Washington State University, 1986-1987.
- Geophysics Technician, Practical Geophysics, Inc., Salt Lake City, UT, 1985.
- Teaching/Research Assistant, Geology, Washington State University, 1983-1985.

Recent Publications and Abstracts

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Taylor, S.B., 2002, Bedrock control on slope gradients in the Luckiamute Watershed, Central Coast Range, Oregon: Implications for sediment transport and storage: American Geophysical Union Abs. with Prog. 83(47): H21C-0842.

Taylor, S.B., Dutton, B.E., and Poston, P.E., 2002, Luckiamute River Watershed, Upper Willamette Basin, Oregon – An Integrated Environmental Study, in Moore, G.W., ed., Field Guide to Geologic Processes in Cascadia: Oregon Department of Geology and Mineral Industries Special Paper 36, p. 167-186.

Taylor, S.B., Madarish, D., and Kite, J.S., 2001, Gravel distribution analysis of three channel systems in the central Appalachians: Comparative evaluation of sediment-transport efficiency and valley-erosion dynamics: Abstracts with Program, Binghamton Symposium, Mountain Geomorphology: Integrating Earth Systems, University of North Carolina, Chapel Hill, North Carolina, p. 49-50.

Grants and Awards

2007-2008	National Science Foundation-Research Opportunity Award ($13,000); “Decadal-Scale Sediment Yield in Forested Watersheds at H.J. Andrews Experimental Forest”
2007-2008	Western Oregon University Faculty Professional Development Grant ($2100); “Decadal-Scale Sediment Yield in Forested Watersheds at H.J. Andrews Experimental Forest”
2005-2006	Northwest Invasive Weed Management Partnership ($2000); “Japanese Knotweed Distribution in the Riparian Zone of the Luckiamute River, Central Oregon Coast Range”
2005-2006	Oregon Community Foundation Grant ($5000); “Grant Supplement: Geomorphic and Anthropogenic Controls on Invasive Plant Distribution in the Luckiamute River Basin”
2004-2006	Center for Water and Env. Sustainability / U.S. Geological Survey ($15,000); “Hydro-geomorphic Analysis of the Luckiamute Watershed, Central Oregon Coast Range”
2004-2005	Western Oregon University Foundation Grant ($1000); “Hydrogeomorphic Analysis of the Luckiamute Watershed, Central Oregon Coast Range”
2004-2005	WOU Center for Teaching and Learning Undergraduate Research Grant ($800); “Cinder Cone Analysis at Newberry Volcano”
2004-2005	Western Oregon University Faculty Development Grant ($6000); “Geomorphic and Anthropogenic Controls on Invasive Plant Distribution in the Luckiamute River Basin”
2003-2004	Oregon Community Foundation Grant ($7000); “Geomorphic and Anthropogenic Controls on Invasive Plant Distribution in the Luckiamute River Basin”
2002	Western Oregon University, Student Technology Fund ($150,000); “Infusing Technology Across the Science Curriculum - Division of Natural Sciences and Mathematics”
2002	Western Oregon University, Faculty Professional Development Grant ($3000); “Geospatial Analysis of Cinder Cones at Newberry Volcano, Central Oregon”
2002	Western Oregon University, PT3 (U.S. Dept. of Education) Faculty Grant ($7000); “Inquiry-Based Technology Applications for the Earth System Science Curricula”
2002	Murdock Trust Partners in Science Extension Grant ($2000); “Geomorphic Hazards Analysis in Western Oregon”
2001	Western Oregon University, Faculty Professional Development Grant ($3000)
2001	Western Oregon University, PT3 (U.S. Dept. of Ed.) Faculty Grant ($10,000); “GIS Applications in the Earth Science Curricula at Western Oregon University”
2000-2001	Murdock Trust Partners in Science Research Grant ($15,000); “Geomorphic Hazards Analysis in Western Oregon”
2000-2001	Oregon Collaborative for Teacher Preparation Faculty Fellowship ($1000); “Development of an Earth System Science Curricula at Western Oregon University”
2000	ESRI University GIS Software Donation Award ($10,000)

1999	Western Oregon University, Faculty Professional Development Grant ($3000); "Analysis of Geomorphic Hazards in Western Oregon"
1997-1999	NASA Earth System Science Fellowship (ESS/97-0080) ($70,000); "Geomorphic Controls on Sediment-Transport Efficiency in the Central Appalachians"
1997	U.S. Geological Survey - EDMAP Program (1434-HQ-97-AG-01782) ($10,000); "Surficial Mapping of the Little River Basin, Augusta County, Virginia"
1996	The Vehse Award for Travel and Research, West Virginia University ($500) "Geomorphic Controls on Sediment Transport Efficiency in the Central Appalachians"
1996	Sigma Xi Society for Scientific Research - Research Grants ($300) "Geomorphic Controls on Sediment Transport Efficiency in the Central Appalachians"
1996	Geological Society of America - Research Grants ($1500) "Geomorphic Controls on Sediment Transport Efficiency in the Central Appalachians"
1996	Office of Academic Affairs and Research, West Virginia University ($800) "Geomorphic Controls on Sediment Transport Efficiency in the Central Appalachians"
1996	U.S. Geological Survey - EDMAP Program (1434-HQ-96-AG-01561) ($15,000); "Surficial Mapping of the North Fork Basin, Pocahontas County, West Virginia"
1989	Student Research Allocation Committee, University of New Mexico ($800); "Stratigraphy and Sedimentology of the East Pisco Basin, Central Peru"
1989	The Geological Society of America - Research Grants ($2000); "Stratigraphy and Sedimentology of the East Pisco Basin, Central Peru"
1984	Student Travel Award, The Graduate School, Washington State University ($800); "Stratigraphy and Sedimentology of the Eocene Swauk Formation, Central Washington"
1983	Shell Oil Company, Western Exploration and Production ($2000); "Stratigraphy and Sedimentology of the Eocene Swauk Formation, Central Washington"

Professional Affiliations and Service

- Present; Earth Science Advisor, K-12 Science Standards Review Panel, Oregon Department of Education, Salem, Oregon.
- 2005-Present; Member and Chair, Oregon Board of Geologist Examiners, Salem, OR.
- 2005-Present; Member, Council of Examiners, National Association of State Boards of Geology, Columbia, South Carolina.
- 2002-Present; Member, State Geologic Mapping Advisory Committee, Oregon Dept. of Geology and Mineral Industries, Portland, Oregon.
- 2000-2003; Project Coordinator, Preparing Tomorrow's Teachers to Use Technology (PT3), Western Oregon University, under contract with U.S. Dept. of Education.
- 1996-Present; Member American Geophysical Union.
- 1989-Present; Member Geological Society of America.