Prepared in cooperation with the National Park Service

Living with a Volcano in Your Backyard

An Educator's Guide with Emphasis on Mount Rainier

General Information Product 19
Version 2.0, December 2014

U.S. Department of the Interior
U.S. Geological Survey

This page left intentionally blank

Living with a Volcano in Your Backyard—An Educator's Guide with Emphasis on Mount Rainier

Coordinated by Carolyn Driedger, Anne Doherty, Cheryl Dixon, and Lisa Faust

Prepared in cooperation with the National Park Service

General Information Product 19
Version 2.0, December 2014

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
GALE A. NORTON, Secretary

U.S. Geological Survey
P. Patrick Leahy, Acting Director

U.S. Geological Survey, Reston, Virginia
First release: 2005, online
Revised: December 2014 (ver. 2.0), online

For product and ordering information: World Wide Web: http://www.usgs.gov/pubprod
Telephone: 1-888-ASK-USGS

For more information on the USGS—the Federal source for science about the Earth,
its natural and living resources, natural hazards, and the environment:
World Wide Web: http://www.usgs.gov
Telephone: 1-888-ASK-USGS

Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Although this information product, for the most part, is in the public domain, it also may contain copyrighted materials as noted in the text. Permission to reproduce copyrighted items must be secured from the copyright owner.

Part or all of this report is presented is Portable Document Format (PDF). For best results viewing and printing PDF documents, it is recommended that you download the documents to your computer and open them with Adobe Reader. PDF documents opened from your browser may not display or print as intended. Download the latest version of Adobe Reader, free of charge.

Suggested citation:
Driedger, C., Doherty, A., Dixon, C., and Faust, L., coordinators, 2005, Living with a volcano in your backyard—An educator's guide with emphasis on Mount Rainier (ver. 2.0, December 2014): U.S. Geological Survey General Information Product 19, 716 p., *http://dx.doi.org/10.3133/gip19*.

ISSN 2332-0354X (online)

CONTENTS

Introduction

Credits

Acknowledgments

How to Use the Guide

Key Concepts

Activity Overview

Explanation of Activity Format and Fonts

Recommended Activity Sequencing

Conversion Factors

Educator Standards Matrix

Chapter 1. What the Past Tells Us

Chapter 2. Today's Discoveries Unlock the Past

Chapter 3. Don't Be Scared—Be Prepared!

Appendixes

I Volcanism in a Plate Tectonics Perspective

II A Short History of Mount Rainier

III Journey Back in Time—Field Guide

IV Internet Resources

V Glossary

This page left intentionally blank

Living with a Volcano in Your Backyard—
An Educator's Guide with Emphasis on Mount Rainier

Coordinated by: Carolyn Driedger[1], Anne Doherty[2], Cheryl Dixon[2], and Lisa Faust[1]

INTRODUCTION

Today's residents, as well as residents of centuries past consider Mount Rainier "the spiritual and cultural icon of the Pacific Northwest." As a backdrop for many of the State's residents, Mount Rainier offers beauty, solace, inspiration, and challenge. The mountain sets the daily mood for thousands of people who gaze at and respect it. There is no mistaking this object of admiration when people smile and remark that, "the mountain is out!"

Yet, the origin of Mount Rainier, formed by volcanic processes and now heavily laden with snow and ice, remains an enigma to many admirers. During the 1980s, volcanologists from around the world voted Mount Rainier as one of 17 volcanoes most worthy of additional study because of the hazard potential to large population centers nearby. Subsequent research indicates that Mount Rainier, though quiet since the nineteenth century, is very much an "active volcano" with potential to erupt again and disrupt the life of Pacific Northwest residents. Following days to months or more of warning, Mount Rainier could erupt lava and ash and melt snow and ice to form lahars (volcanic mudflows). Or, Mount Rainier could simply warm up briefly, jolt us from our apathy, and then return to slumber for many more years.

Until such time, the mountain is ours to explore. **Living with a Volcano in Your Backyard—An Educator's Guide with Emphasis on Mount Rainier** invites educators and their students to learn what scientists are discovering about Mount Rainier's past; to explore its slopes during this period of quiescence; and to plan future responses to volcanic unrest.

Mount Rainier National Park is a unique classroom, rich in resources for observing geologic change. The park staff encourages safe and knowledgeable use by educators and students and their families.

[1] U.S. Geological Survey; [2] National Park Service

Activity last modified: September 7, 2014

The National Park Service and the U.S. Geological Survey's Volcano Hazards Program (USGS-VHP) support development and publication of this educator's guide as part of their mission to educate the public about volcanoes. The USGS-VHP studies the dynamics of volcanoes, investigates eruption histories, develops hazard assessments, monitors volcano-related activity, and collaborates with local officials to lower the risk of disruption when volcanoes become restless.

CREDITS

Project Coordinators

Carolyn Driedger, Anne Doherty, Cheryl Dixon, and Lisa Faust

The National Park Service and U.S. Geological Survey wish to acknowledge the insights, contributions, and dedication of all of the teachers, emergency managers, and scientists who developed and supported this educator's guide.

Contributing Agencies

U.S. Geological Survey
Mount Rainier Volcano Hazard Workgroup
Pierce County Emergency Management Division
Orting School District
Eatonville School District
Bethel School District
Washington Emergency Management Division
National Park Service
Yelm School District
Tacoma School District

Primary Activity Developers and Writers

Brit Argow
Anne Doherty
Cheryl Dixon
Carolyn Driedger
Colleen Riley

Contributing Activity Developers and Writers

Jenny Anderson
Lisa Anjozian
Julie Benkovich
Mary Henterly
Kathy Johnstone
Chris Maun
Jane Poole
Mike Roylance
Tom Sisson
Nina Shields
Bob Smith
Marianne Smith
Kim Strassburg
Liz Westby
Debra Wood

Graphics and Illustrations, Design and Layout

Lisa Faust (U.S. Geological Survey)

Reviewers

Activity Technical Reviewers

Cynthia Gardner
Larry Mastin
Bobbie Myers
Tom Pierson
Tom Sisson
Kevin Scott
Willie Scott
Robert Tilling
James Vallance
Jody Woodcock

Educator Reviewers

Jenny Anderson
Britt Argow
Bonnie Beaudoin
Julie Benkovich
Barry Bloch
Ellen Bratcovich
Penny Davis
Dawn Ellis
Ken Fidler
Olga Haider
Rick Haughee
Annette Heffron
Mary Henterly
Steven Hoden
Jeff Houck
David Jacobson
Kathy Johnstone
Laura Kraig
Mathew Kwartin
Jim Lazzarrni
Chris Maun
Katie Mettler
Richard Muse
Jane Poole
Shirley Reboin
Richard Schroedel
Marianne Smith
Ted Stout
Kim Strassburg
Eric Temple
Brett Thomsen
Liz Westby
Debra Wood
Kristy Worley

Editorial Reviews

Jaclyn Richardson LaRue (National Park Service)
Robert Tilling (U.S. Geological Survey)
Christine Janda (U.S. Geological Survey)

Publication Support

U.S. Geological Survey
National Park Service
Washington Emergency Management Division

ACKNOWLEDGMENTS

The Mount Rainier Volcano Hazards Work Group is a coalition of emergency and land-use managers, educators, public officials, community leaders, and scientists dedicated to mitigating the effects of volcanic activity at Mount Rainier. Since 1996, the work group has met regularly to plan responses to future volcanic unrest at Mount Rainier. These measures include developing a Volcano Response Plan that defines the role of each contributing agency during volcanic unrest, practicing the plan, training emergency management staff about volcano matters, and supporting development of a lahar detection system and accompanying notification system. Member agencies provide grass roots community outreach regarding volcanic hazards. Their effort encouraged the writing of **Living with a**

HOW TO USE THIS GUIDE

Living with a Volcano in Your Backyard—An Educator's Guide with Emphasis on Mount Rainier is a three-unit guide that provides science content and inquiry-based activities about volcanoes of the Cascade Range, with emphasis placed on Mount Rainier. Activities are designed for middle school students. Adaptations and extensions offer opportunities for students in higher and lower grade levels. Background sections provide more in-depth information. This guide includes more than 30 activities, a field guide to geological sites of interest in Mount Rainier National Park, glossary, list of Internet resources, and supplementary information.

The principal purpose of this guide is to familiarize students with the geologic and hydrologic processes that shaped Mount Rainier. The authors wish to show how present populations can enjoy the mountain safely and responsibly while recognizing these natural processes as hazards. Materials in the guide enable broad instruction about volcanoes of the Cascade Range, and focused instruction about Mount Rainier volcano. Science content and activities are usable alone or as augmentation for other curricula.

KEY CONCEPTS

Many Volcanoes of the Cascade Range are Historically and Presently Active

- Mount Rainier is one of thousands of volcanoes located in a circum-Pacific zone of volcanism known as the Ring of Fire
- Volcanoes of the Cascade Range erupted recently in geologic time; local inhabitants reported eruptions or signs of unrest at seven volcanoes since around A.D.1700
- Layers of lava and volcanic ash remain as evidence of a volcano's eruptive history
- People of the Pacific Northwest witnessed volcanic eruptions repeatedly after entering the region approximately 9,000 years ago; people recorded their observations in oral and written stories
- Each Cascade volcano possesses a unique history and eruption style
- Plate tectonics processes that produced the Cascade volcanoes remain unchanged. Future eruptions will occur

Diverse and Dynamic Processes Shaped Volcanoes of the Cascade Range

- The Cascadia Subduction Zone is the foundation for volcanoes of the Cascade Range
- Water plays a principal role in the development of eruptions; first, it lowers the melting point of mantle rock enough to transform solid rock to magma, and later it expands and propels magma up the conduit causing a volcanic eruption
- Water also plays a principal role in destruction of a volcano because it reduces rock stability; stream water and glacial ice erode the volcano; water mobilizes loose volcanic rock and forms debris flows and lahars (volcanic mudflows)
- When ice-age glaciers enveloped Mount Rainier, they influenced the movement of lava flows and thus, the location of today's ridges and valleys
- Lava flows and domes, volcanic ash, pyroclastic flows and lahars built the existing landscapes at volcanoes of the Cascade Range
- Mount Rainier consists of overlapping layers of lava flows and rock rubble
- Volcanic ash, tiny fragments of erupted magma, are blown by the wind and distributed thousands of miles distant
- Landslides and lahars have covered valley floors for tens of kilometers (miles) distant from some Cascade volcanoes
- Chemical composition and cooling conditions determine the appearance of volcanic rocks
- The geologic processes that built Cascade volcanoes pose hazards for the future

Studying a Volcano's Past and Present Behavior Provides Important Clues about Future Eruptions

- Geologists examine rock layers at each volcano to determine past eruptive behavior and thus the most likely type of volcanic activity to happen in the future
- Scientists consider Mount Rainier "active" (although it is not currently erupting) because of recurring earthquake activity, the presence of geothermal heat and gas release and the volcano's location in an active tectonic setting
- Volcanologists are on continual watch for changes that could indicate the onset of volcanic unrest; they watch for variations in earthquake activity, gas release and slope stability
- Magma, rising in the Earth, causes rock breakage and earthquakes that precede an eruption
- Earthquakes are a reliable tool for volcano forecasting because they occur weeks to months or more in advance of an eruption
- Lahars (volcanic mudflows) are the most significant hazard to people who live in the vicinity of Mount Rainier because they are known to have traveled more than 100 kilometers (60 miles) or more distant
- While most lahars form by snow and ice-melt during an eruption, landslides can also initiate lahars during non-eruptive times with little or no warning

We Can Prepare for the Next Eruption of Mount Rainier

- Mount Rainier has the potential to erupt during our lifetime
- Reviewing Mount Rainier's history can help us identify the lowland communities that could be adversely impacted by the mountain's power
- When people understand the risks presented by volcanic eruptions, they can take steps to prevent disasters
- Preparing and understanding hazard maps help us prepare for future volcanic activity
- Reducing volcano risk requires societal debate, tough choices, and the ability to view issues from a variety of perspectives
- Multiple career opportunities exist in the monitoring, planning, and preparation for the next eruption of Mount Rainier
- Observing and learning about Mount Rainier will help you be ready for renewed volcanic activity and associated hazards

Mount Rainier is Culturally Significant

- Mount Rainier is a principal cultural icon of the Pacific Northwest
- Volcanoes can be community assets, bringing aesthetic and economic benefit
- Interest in volcanoes is nearly universal and unites people globally as they address volcanic risk
- Mount Rainier inspires artistic and cultural traditions
- Mount Rainier offers a fascinating opportunity to learn about volcanoes and local ecology

ACTIVITY OVERVIEW

Chapter 1. What the Past Tells Us

This chapter provides a general overview of the volcanoes of the Cascade Range. The chapter begins with a preassessment activity entitled **"Eruption!"** *and then addresses the plate tectonics responsible for Cascades volcanism. It ends with activities regarding how volcanoes work.*

Overview

Blast from the Past

- **Eruption!** — In this preassessment activity, students describe their perceptions of a volcanic eruption in a personal journal entry. Then they read an actual eyewitness account of the A.D. 79 eruption of Mount Vesuvius in Italy and compare those events to the eruption events depicted in their journal entries.
- **Fire, Flood, and Fury** — Native American oral traditions chronicle geologic events in the history of Mount Rainier. These stories are read, interpreted, and illustrated by students with the use of storyboards.
- **Nineteenth-Century News** — Read nineteenth-century newspaper accounts of recent eruptions at Mount Rainier. The minor eruptive activity at Mount Rainier illustrates that not all eruptions are large or destructive.
- **Cascade Volcano Timeline** — Cascade volcanoes are young in relation to the geologic events that have shaped the Earth. A timeline illustrates the high incidence of Cascade volcano activity in comparison to geologic and human events since the signing of the Declaration of Independence. A hypothetical genealogy of one family's history illustrates the collective and individual activity of the Cascade volcanoes.
- **A String of Volcanoes** — Students research information about Cascade volcanoes and write the information on cards used to construct a mobile.
- **Volcano Hall of Fame** — This is a game where students use fun facts to try to identify a specific Cascade volcano.

Forces Responsible for Cascade Volcanism

- **Surrounded by Volcanoes** — Explore geographical information to learn about tectonic boundaries, origin of the "Ring of Fire," and volcanoes in the Pacific Northwest. Identify and label Cascade volcanoes on a satellite image.
- **Magma Mash** — Students take on the role of minerals cooling at different rates in an exploration of magma behavior, and then examine samples of rocks cooled at different rates.

- **Riding the Magma Elevator** — Examine the process of magma formation from mantle melting in the subduction zone, rising to the magma chamber, and erupting from the magma conduit. During this activity, the class will ride an imaginary elevator from the subduction zone and out the volcano crater.
- **Soda Bottle Volcano** — Examine how gases energize explosive volcanic eruptions by making comparisons to gases in a soda bottle and performing a carefully controlled "eruption" of baking soda and (or) vinegar or soda water.

Chapter 2. Today's Discoveries Unlock the Past

Volcanic processes are the principal focus of Chapter 2 and are the natural progression from the Chapter 1 overview about how volcanoes work. Activities invite inquiry about volcanic processes at Cascade volcanoes and about how researchers conduct their research.

Overview

Lava, Rock Rubble, and Mud, Oh My!

- **Understanding Volcanic Hazards Video/DVD** — Introduces students to the vocabulary and character of volcanic processes and how volcano hazards impact people living near and far from a volcano. This video/DVD is intended for older students only.
- **Volcanic Processes** — This activity is an alternative to the **Understanding Volcanic Hazards video**. Students view graphics of volcanic processes, then answer questions on a worksheet. As an optional activity, they can prepare a booklet or computer presentation about each process with an emphasis on the interaction of these processes during a volcanic eruption.
- **Tephra Popcorn** — Students study physical characteristics of tephra using samples and make mass and volume measurements of popcorn to understand the role gases play in tephra formation.
- **Lava Building Blocks of Mount Rainier** — Students explore the nature and motion of lava flows and learn their importance as the building blocks of Mount Rainier. Students learn how the composition and texture of lava differs between volcanoes and affects the ultimate shape of a volcano.
- **Rock Stars** — Using photos and rock samples, students identify the characteristics that tell a story about where and how each rock was formed.
- **Fire and Ice** — Students conduct or observe an experiment simulating glacier/lava flow interactions, then answer questions about how glacier and lava interactions shaped specific features on Mount Rainier.
- **Lahar in a Jar** — Using experimental and scientific methods, explore how loose rock is mobilized by small amounts of water to form lahars.

- **Rock Rubble Review** — This is a physically active game that tests the students' knowledge of volcano terminology, processes, and impacts on communities.

Interpreting Volcanic History

- **Earth Blocks** — Learn about the "Law of Superposition" and how to interpret rock and sediment layers by reading a short story and arranging "Earth Blocks."
- **Volcano Fan Club** — Students learn that tephra layers at Mount Rainier originated from several volcanoes by looking at tephra dispersal patterns and thickness contours on maps.
- **Tephra Explorer** — Students view distributions of tephra layers found around Mount Rainier and discover the source.
- **Shoebox Geologist** — Make a model of layers emplaced by processes of deposition and erosion in a volcanically active landscape. Students interpret geologic events from layers in a classmate's model using stratigraphic columns and the Law of Superposition.
- **Perilous Beauty video** — The "Perilous Beauty" video introduces students to the types of hazards common to Mount Rainier, specifically mudflows and the types of mechanisms that produce them.

Chapter 3. Don't be Scared—Be Prepared!

Chapter 3 contains information about volcanic hazards and suggestions for preparedness. Several activities suggest how students can appreciate the benefits of living near a Cascade volcano, and can enjoy them, most often from their own communities.

Overview

Mapping Your Way to Mount Rainier

- **Play-Dough Topo** — Students make a clay model volcano, complete with glacial and fluvial valleys and then create a topographic map of their volcano.
- **Topographic Maps and Mount Rainier** — Students explore how lines on a topographic map represent the real landscape by comparing features on photographs and topographic maps. Later, students analyze and answer questions about a Mount Rainier National Park map.
- **Planning Your Trip to Mount Rainier National Park** — Students will plan a trip to Mount Rainier National Park using topographic, highway, and official park maps.

Living with a Volcano in Your Backyard

- **The Next Eruption of Mount Rainier** — Through a series of activities, students will examine the hazards associated with Mount Rainier by making a timeline of Mount Rainier events, interpreting hazard maps, investigating the potential effects of volcanic events on their community, and becoming acquainted with how scientists watch for signs of volcanic unrest.
- **Reducing Volcanic Risk video/DVD** — Familiarizes students with the steps they can take to reduce volcanic risk.

Home and Community Preparedness Plans

- **Don't be Scared—Be Prepared!** — Students learn simple steps to preparedness by conducting basic preparedness tasks with their class and family.
- **A Volcano Tussle—How Much Do We Risk?** — Students play the roles of persons with interest in maintaining visitation facilities at Mount Rainier National Park while faced with the prospect of geologic hazards. They write position papers and later defend them within in group.
- **Living Well with a Volcano in Your Backyard!—Prepare, Then Enjoy It!** — This activity provides a variety of options for students to explore and appreciate the many ways that volcanoes are beneficial to their community. It includes the Mount Rainier paper model. Students color, cut, fold and paste a simple cone-shaped volcano, and in the process become familiar with many geographic features within Mount Rainier National Park.

Appendixes.

The appendices provide reference materials and enhance understanding of geologic concepts. Appendices 2 and 3 provide information specific to Mount Rainier and are useful for interpreting features located within Mount Rainier National Park.

- **Appendix 1. Volcanism in a Plate Tectonics Perspective** — To understand how volcanoes form, it is necessary to know something about the inner structure and dynamics of the Earth. This appendix describes plate tectonics, formation of magma, and creation of volcanoes, with an emphasis on volcano and mountain building in the Pacific Northwest.
- **Appendix 2. A Short History of Mount Rainier** — The edifice of modern Mount Rainier is assembled from many individual lava flows and layers of rock rubble that accumulated during eruptions that span half a million years. The volcano has been altered episodically by renewed eruptions, magma intrusions, and lahars, and more continuously by glacial erosion, rock fall, and debris flows. This appendix briefly describes the conditions of the landscape just prior to the onset of the volcano's construction, and presents a timeline of significant geologic events.

- ♦ **Appendix 3. Journey Back in Time—A Mount Rainier Geological Field Trip Guide for Teachers** — This appendix provides background information, suggested activities and itinerary for geology-oriented field trips to the southwest side of Mount Rainier National Park and the Paradise area. The guide can be used in conjunction with the classroom activities described above.
- ♦ **Appendix 4. Internet Resources** — This list provides guidance for additional resources that pertain to the subjects in this educator guide.
- ♦ **Appendix 5. Glossary** — Definitions are provided for the vocabulary words shown with ***bold italics*** in each activity.

NOTE: Teachers should consult "Recommended Activity Sequencing" to determine the most appropriate activities based on time and teaching goals.

EXPLANATION OF ACTIVITY FORMAT AND FONTS

- **Overview:** The overview provides a summary of concepts and general procedures addressed in the activity
- **Grade Level:** Authors based grade designation upon the level that best fit Skills and Benchmark activity
- **Learner Objectives:** Students should meet the listed objectives of each activity
- **Setting:** Authors chose the most practical location for completion of an activity
- **Timeframe:** Authors used classroom reviews to determine time frame required for completion of each activity
- **Materials:** A list of materials required for each section of the activity
- **Skills:** Skills are based on criteria established for Washington State teaching standards
- **Benchmarks:** See benchmarks for each activity in the Introduction.
- **Vocabulary:** First usage of a vocabulary word in an activity is designated in ***bold italics,*** and is included in the **Glossary**
- **Teacher Tips:** Teacher Tips highlight additional information and specific recommendations to increase added value to the activity
- **Teacher Background:** Provides the teacher with the content information required to complete the activity
- **Procedures:** Recommends course of action for conducting the activity
  - ♦ **Assessment**
  - ♦ **References**
  - ♦ **Credits**

- **Adaptations:** Alternate procedures for this activity
- **Extensions:** Ideas for expanding the study of concepts in this activity
- **Assessments:** Recommendations for student assessment
- **References:** Suggested references for additional information
- **Student and Teacher Pages:** Activity pages designed for student and teacher use

FONT KEY

- References to section titles within an activity are indicated by ***"bold italics."***
- References to other activities and units within the educator guide are indicated by "**Scrawlin.**"

RECOMMENDED ACTIVITY SEQUENCING

One week of classes (50 minutes each)

- **Eruption! or Fire, Flood and Fury,** or **Nineteenth Century News** (1 class)
- **Cascade Volcano Timeline** (2 classes)
- **Eruption!** (1 class)
- **Soda Bottle Volcano** (1 class)
- **Understanding Volcanic Hazards video/DVD** or **Volcanic Processes** (1 class)
- **Lahar in a Jar** (1 class)
- **The Next Eruption of Mount Rainier** (1 class)

Two weeks of classes (50 minutes each)

- Use all of the recommendations above, and add one additional activity from Chapter 2 or 3

Three weeks of classes (50 minutes each)

- Conduct the above two weeks and add the following three activities
  - **Earth Blocks** (1 class)
  - **Tephra Explorer** (2 classes)
  - **Shoebox Geologist** (2 classes)

Six weeks of classes (50 minutes each)

- Conduct all of Chapter 1 and Chapter 2 activities in order
- **Play-Dough Topo** (1 class)
- **Topo Scavenger Hunt** (1 class)
- **Planning Your Trip to Mount Rainier National Park**, or other Chapter 3 activities (2 classes)

Schools located in any volcano hazard zone

- **Eruption!** (1 class)
- **Perilous Beauty Video (**1 class)
- **The Next Eruption of Mount Rainier** (1 class)
- **Don't be Scared—Be Prepared** (1 class)
- **A Volcano Tussle** (1 class)
- **Living Well with a Volcano in Your Backyard** (1 class)

Schools in a lahar hazard zone

- **Lahar in a Jar** (1 class)
- **Understanding Volcanic Hazards Video/DVD** [older students only] (1 class)
- **Perilous Beauty video** (1 class)
- **Reducing Volcanic Risk Video/DVD** (1 class)
- **Don't Be Scared—Be Prepared!** (1 class)
- **The Next Eruption of Mount Rainier** (1 class)
- **A Volcano Tussle** (1 class)
- **Living Well with a Volcano in Your Backyard—Prepare, Then Enjoy It!** (1 class)

Schools in vicinity of volcanoes of the Cascade Range, but not in a hazard zone

- All of Chapter 1
- All of Chapter 2

Teachers with plans for class field trip to Mount Rainier National Park

- **Surrounded by Volcanoes** (2 classes)
- **Volcanic Processes** or **Understanding Volcanic Hazards Video/DVD** (1 class)
- **Play-Dough Topo** (1 class)
- **Topographic Maps and Mount Rainier** (2 classes)
- **Planning Your Trip to Mount Rainier National Park** (1 class)

Community and school safety

- **Perilous Beauty video** (1 class)
- **Reducing Volcanic Risk Video/DVD** (class 1)
- **Don't Be Scared—Be Prepared!** (1 class)
- **Living Well with a Volcano in Your Backyard—Prepare, Then Enjoy It!** (1 class)

Social studies and English

- **Eruption!** (1 class)
- **Fire, Flood and Fury** (1 class)
- **Nineteenth Century News** (1 class)

Note to teachers downloading files: In addition to downloading activity files, teachers are encouraged to download the chapter overviews, Glossary, and Internet Resources.

CONVERSION FACTORS

SI to Inch/Pound

For readers who wish to convert measurements from the metric system of units to the inch-pound system, the conversion factors are listed below.

Multiply	By	To obtain
Length		
kilometer (km)	0.6214	mile (mi)
meter (m)	3.281	foot (ft)
millimeter (mm)	0.039	inch (in)
Area		
hectacre (ha)	2.471	acre
square meter (m^2)	10.76	square foot (ft^2)
Volume		
cubic kilometers (km^3)	0.2399	cubic mile (mi^3)
milliliter (ml)	0.061	cubic inch (in^3)
Pressure		
kilopascal (kPa)	0.145	pounds/square inch (psi)
Flow rate		
liter per second (L/s)	15.85	gallon per minute (gal/min)
metric ton (t)	1.102	short ton (2,000 pounds)
metric ton (t)	0.9842	long ton (2,240 pounds)
kilogram per second (kg/s)	27.273	pound per minute (lb/s)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows: °F = (1.8 x °C) + 32

EDUCATOR STANDARDS MATRIX

Washington State and National Education Standards

In the matrix, this interdisciplinary curriculum is aligned with the middle school level Washington State 2009 K-12 Science Learning Standards.

Living with a Volcano in Your Backyard

Washington Essential Academic Learning Requirements & Grade Level Expectations

SCIENCE *Chapter One*

	Eruption!	Fire, Flood, and Fury	19th Century News	Cascade Volcano Timeline	A String of Volcanoes	Volcano Hall of Fame	Surrounded by Volcanoes	Magma Mash	Riding the Magma Elevator	Soda Bottle Volcano
EALR 1: Systems										
Big Idea: Systems (SYS); Core Content: Inputs, Outputs, Boundaries and Flows										
6-8 SYSA Systems and Subsystems										
6-8 SYSB Boundaries of a system										
6-8 SYSC Outputs and Inputs of Systems										
6-8 SYSD Open and Closed Systems										
6-8 SYSE Flow of matter into/out of systems										
6-8 SYSF Investigation of Systems in the natural and designed world										
EALR 2: Inquiry										
Big Idea: Inquiry (INQ); Core Content: Questioning and Investigating										
6-8 INQA Scientific questioning										
6-8 INQB Types of questions and investigations										
6-8 INQC Collecting, analyzing and displaying data are part of investigations										
6-8 INQD Types of variables										
6-8 INQE Modeling										
6-8 INQF Results vs. inference vs. general conclusions										
6-8 INQG Scientific reporting										
6-8 INQH Intellectual honesty in science										
6-8 INQI Ethical codes of experiments										

Revised: December 30, 2009

Educator Standards Matrix
Chapter One
SCIENCE

SCIENCE

	Eruption!	Fire, Flood, and Fury	19th Century News	Cascade Volcano Timeline	A String of Volcanoes	Volcano Hall of Fame	Surrounded by Volcanoes	Magma Mash	Riding the Magma Elevator	Soda Bottle Volcano
EALR 3: Application										
Big Idea: Application (APP); Core Content: Science, Technology and Problem Solving	■	■	■		■	■				
6-8 APPA People use technology to solve problems										
6-8 APPB Science and Technology Careers										
6-8 APPC Interdependence of science and technology										
6-8 APPD Technological design										
6-8 APPE Generating solutions to a problem			■							
6-8 APPF Designing and testing solutions			■				■			
6-8 APPG Benefits of science and technology		■								
6-8 APPH People contribute to society through science and technology	■	■	■		■	■				
EALR 4: Domains of Science: Physical Science										
Big Idea: Force and Motion (PS1); Core Content: Balanced and Unbalanced Forces									■	■
6-8 PS1A Average speed							■			
6-8 PS1B Friction is a force										
6-8 PS1C Unbalanced forces will cause change in speed or direction of motion							■		■	■
6-8 PS1D Unbalanced forces and motion changes of objects with more or less mass							■		■	
Big Idea: Matter Properties and Change (PS2); Core Content: Atoms and Molecules							■	■	■	■
6-8 PS2A Properties of substances							■	■	■	■
6-8 PS2B Properties of mixtures and compounds								■	■	■
6-8 PS2C Matter, elements, and atoms								■	■	
6-8 PS2D Compounds, molecules and atoms								■		
6-8 PS2E Solids, liquids and gases									■	■
6-8 PS2F Conservation of mass							■	■		■

SCIENCE

	Eruption!	Fire, Flood, and Fury	19th Century News	Cascade Volcano Timeline	A String of Volcanoes	Volcano Hall of Fame	Surrounded by Volcanoes	Magma Mash	Riding the Magma Elevator	Soda Bottle Volcano
Big Idea: Energy Transfer, Transformation and Conservation (PS3); Core Content: Interactions of Energy and Matter										
6-8 PS3A Forms of energy, transformations and transfers										
6-8 PS3B Transferring of heat energy										
6-8 PS3C Heat, vibration of atoms and thermal insulators										
6-8 PS3D Visible light										
6-8 PS3E Energy transformations into electricity										
6-8 PS3F Energy transferrance via waves; wave properties										
EALR 4: Domains of Science: Earth and Space Science										
Big Idea: Earth in Space (ES1); Core Content: The Solar System										
6-8 ES1A The Moon; its motion and properties										
6-8 ES1B Composition of the Solar System										
6-8 ES1C Motion of objects in Solar System										
6-8 ES1D Gravity										
6-8 ES1E Relationship of earth, sun, Milky Way galaxy, other galaxies										
Big Idea: Earth Systems, Structures and Processes (ES2); Core Content: Cycles in Earth Systems										
6-8 ES2A Atmosphere, stratosphere and troposphere										
6-8 ES2B Sun as the energy source for phenomena on Earth's surface										
6-8 ES2C Water cycle										
6-8 ES2D Water is a solvent										
6-8 ES2E Layers of earth: crust, mantle and core										
6-8 ES2F Crust structure and plate movement										
6-8 ES2G Landforms; processes that build them up and break them down										
6-8 ES2H Rock cycle; igneous, metamorphic and sedimentary rocks										

Educator Standards Matrix

Chapter One

SCIENCE

SCIENCE

	Eruption!	Fire, Flood, and Fury	19th Century News	Cascade Volcano Timeline	A String of Volcanoes	Volcano Hall of Fame	Surrounded by Volcanoes	Magma Mash	Riding the Magma Elevator	Soda Bottle Volcano
Big Idea: Earth History (ES3); Evidence of Change										
6-8 ES3A Earth history and processes										
6-8 ES3B Sedimentary rocks and fossils as evidence of earth's history and age										
6-8 ES3C Sedimentary rocks and formations as evidence of geologic events										
6-8 ES3D Processes that shaped the earth										
6-8 ES3E Living organisms play roles in shaping landforms										
EALR 4: Domains of Science: Life Science										
Big Idea: Structure and Function of Organisms (LS1); Core Content: From Cells to Organisms										
6-8 LS1A Cells as the fundamental unit of life										
6-8 LS1B One-celled organisms										
6-8 LS1C Multicellular organisms										
6-8 LS1D Plant and animals cells; their similarities and differences										
6-8 LS1E Classifying organisms										
6-8 LS1F Lifestyle choices and environments affect organisms										
Big Idea: Ecosystems (LS2); Core Content: Flow of Energy Through Ecosystems										
6-8 LS2A Populations and nonliving factors comprise all ecosystems										
6-8 LS2B Relationships between producers, consumers and decomposers										
6-8 LS2C Ecosystem processes: energy and photosynthesis										
6-8 LS2D Ecosystem processes: factors affecting populations										

Educator Standards Matrix

Chapter One

SCIENCE

SCIENCE

	Eruption!	Fire, Flood, and Fury	19th Century News	Cascade Volcano Timeline	A String of Volcanoes	Volcano Hall of Fame	Surrounded by Volcanoes	Magma Mash	Riding the Magma Elevator	Soda Bottle Volcano
Big Idea: Biological Evolution (LS3); Core Content: Inheritance, Variation, and Adaption										
6-8 LS3A Theory of Evolution										
6-8 LS3B Genes, chromosomes and genetic information										
6-8 LS3C Reproduction										
6-8 LS3D Sexual and asexual reproduction										
6-8 LS3E Adaptations										
6-8 LS3F Extinction										
6-8 LS3G Evidence for evolution										

SOCIAL STUDIES

	Eruption!	Fire, Flood, and Fury	19th Century News	Cascade Volcano Timeline	A String of Volcanoes	Volcano Hall of Fame	Surrounded by Volcanoes	Magma Mash	Riding the Magma Elevator	Soda Bottle Volcano
Social Studies										
EALR 3 Geography										
3.1 Physical & cultural characteristics	X	X	X	X	X	X	X	X	X	X
3.1.1 Maps and Geographic Tools	X				X		X			
3.1.2 Char & Spatial Org of Places/Regions	X	X	X	X	X	X	X	X	X	X
3.2 Human Interaction with Environment	X	X								
3.2.1 Human-Environmental Interaction	X	X								
3.2.2 Culture	X	X								
3.2.3 Human Migration										
3.3 Geographic Context of Global Issues										
3.3.1 Geographic Context of Global Issues										
EALR 4 History										
4.1 Understands Historical Chronology		X								
4.1.1 Chronology		X								
4.1.2 Chronological Eras										
4.2 Causal Factors that Shaped History										
4.2.1 Individuals and Movements										
4.2.2 Cultures and Cultural Groups										
4.2.3 Ideas and Technology										
4.3 Multiple Perspectives/Interp. Of History	X	X	X	X						
4.3.1 Historical Interpretation	X	X	X	X						
4.3.2 Multiple Causation										
4.4 Understand Present/Plan for Future	X	X	X	X						
4.4.1 Historical Antecedents	X	X	X	X						
EALR 5 Social Studies Skills										
5.2 Inquiry-based Research			X							
5.2.1 Forms Questions			X							

MATHEMATICS

	Eruption!	Fire, Flood, and Fury	19th Century News	Cascade Volcano Timeline	A String of Volcanoes	Volcano Hall of Fame	Surrounded by Volcanoes	Magma Mash	Riding the Magma Elevator	Soda Bottle Volcano
Mathematics										
EALR 1 Concepts/Procedures										
Number and Numeration										
1.1 Number Sense				✓			✓			
1.1.1 Concept & Symbolic Representation				✓			✓	✓		
1.1.2 Relative Values				✓			✓	✓		
1.1.3 Properties of Addition/Multiplication										
1.1.4 Ratio, Percent, Direct Proportion				✓						
Computation										
1.1.5 Meanings				✓						
1.1.6 Computational Procedures				✓						
1.1.7 Apply Strategies/Uses Tools				✓						
Estimation										
1.1.8 Estimation Strategies				✓			✓			
Probability and Statistics										
1.4 Probability and Statistics				✓			✓			
1.4.5 Data in Diagrams, Plots, and Graphs				✓			✓			

Educator Standards Matrix

Chapter One

MATHEMATICS

MATHEMATICS	Eruption!	Fire, Flood, and Fury	19th Century News	Cascade Volcano Timeline	A String of Volcanoes	Volcano Hall of Fame	Surrounded by Volcanoes	Magma Mash	Riding the Magma Elevator	Soda Baller Volcano
EALR 2 Define and Solve Problems										
2.2 Construct Solutions										
2.2.4 Determine Viable/Correct Answers										
EALR 3 Mathematical Reasoning										
Analyze Information										
3.1 Analyze Information										
3.1.1 Analyze Mathematical Info. or Results										
Conclude										
3.2 Conclude										
3.2.1 Draw and Support Conclusions										
Verify Results										
3.3 Verify Results										
3.3.1 Justify Results Using Evidence										
EALR 4 Communicates Knowledge										
Organize, Represent, and Share Info.										
4.2 Organize, Represent, and Share Info.										
4.2.2 Represent Info. in Graphs/Other Forms										

Educator Standards Matrix

Chapter One

READING

READING

	Eruption!	Fire, Flood, and Fury	19th Century News	Cascade Volcano Timeline	A String of Volcanoes	Volcano Hall of Fame	Surrounded by Volcanoes	Magma Mash	Riding the Magma Elevator	Soda Bottle Volcano
Reading										
EALR 1 Skills and Strategies to Read										
1.2 Vocabulary strategies	X	X	X	X	X	X	X	X	X	X
1.2.1 Use Resources/Reference Skills	X			X	X	X	X	X	X	X
1.2.2 Vocabulary Strategies	X	X	X			X	X		X	X
1.3 Build Vocabulary Through Wide Reading	X	X	X	X	X	X	X	X	X	X
1.3.1 Understand/Apply New Vocabulary		X	X	X	X	X	X	X	X	X
1.3.2 Content/Academic Vocabulary	X	X	X	X	X	X	X	X	X	X
1.4 Word Recognition/Read Fluently	X	X	X	X	X	X	X		X	X
1.4.2 Fluency to Enhance Comprehension	X	X	X	X			X		X	X
1.4.3 Different Reading Rates	X	X	X	X	X	X	X		X	X
EALR 2 Understand Meaning										
2.1 Evidence of Reading Comprehension	X	X	X	X	X	X	X		X	X
2.1.3 Comprehension During and After Reading	X	X	X	X	X	X	X		X	X
2.1.4 Use Prior Knowledge	X	X	X	X	X		X		X	X
2.1.5 Predict and Infer		X	X	X			X			
2.1.6 Generate and Answer Questions	X	X	X	X	X	X	X		X	X
2.1.7 Determine Importance/Summarize Text	X	X	X	X	X	X	X		X	X
2.2 Text Components to Comprehend Text	X	X	X	X	X	X	X		X	X
2.2.1 Time, Order, and/or Sequence	X	X	X	X		X	X		X	X
2.2.2 Printed/Electronic Text Features	X	X	X	X	X	X	X		X	X
2.2.3 Understand/Analyze Story Elements										
2.2.4 Text Organizational Structures	X	X	X		X	X	X		X	X
2.3 Analyzing, Interpreting, Synthesizing	X	X	X	X	X	X	X		X	X
2.3.1 Similarities/Differences and Cause/Effect	X	X	X	X	X	X	X		X	X

Educator Standards Matrix
Chapter One
READING

READING

	Eruption!	Fire, Flood, and Fury	19th Century News	Cascade Volcano Timeline	A String of Volcanoes	Volcano Hall of Fame	Surrounded by Volcanoes	Magma Mash	Riding the Magma Elevator	Soda Bottle Volcano
2.3.2 Information for Specific Topic or Purpose	X	X	X	X	X	X	X			
2.3.3 Literary Devices										
2.3.4 Information from Variety of Sources	X	X	X	X	X	X	X			
2.4 Use of language, style: Purpose&Persp	X	X	X	X	X		X		X	X
2.4.1 Draw Conclusions and Develop Insights	X	X	X	X			X		X	X
2.4.2 Style of Writing for Purpose/Influence	X		X							
2.4.3 Verify Validity and Accuracy										
2.4.4 Tone and Use of Persuasive Devices										
2.4.5 Generalize/Express Insight Beyond Text	X	X	X	X	X		X		X	X
2.4.6 Ideas/Concepts in Multiple Texts	X	X	X	X	X					
2.4.7 Author's Perspective/Beliefs/Assumptions										
EALR 3 Different Materials/Purposes										
3.1 Read to Learn New Information	X	X	X	X	X	X	X			
3.1.1 Appropriate resources	X	X	X	X	X	X	X			
3.2 Read to Perform a Task	X	X	X	X	X	X	X	X		
3.2.2 Functional Documents	X	X	X	X	X	X	X	X		
3.4 Literary/Narrative Experiance	X	X	X	X						
3.4.2 Variety of Literary Genres										
3.4.3 Recurring Themes	X	X	X	X						

Educator Standards Matrix

Chapter One

WRITING

WRITING

Writing	Eruption!	Fire, Flood, and Fury	19th Century News	Cascade Volcano Timeline	A String of Volcanoes	Volcano Hall of Fame	Surrounded by Volcanoes	Magma Mash	Riding the Magma Elevator	Soda Bottle Volcano
EALR 1 Understand/Use a Writing Process										
1.1 Prewrites to Generate Ideas										
1.1.1 Generates Ideas/Plans Writing										
1.5 Publishes Text to Share	X		X				X			
1.5.1 Appropriate for audience/purpose	X		X				X			
EALR 2 Variety of Forms/Audiences										
2.1 Adapts Writing for Variety of Audiences	X		X				X			
2.1.1 Multiple and Various Audiences	X		X				X			
2.2 Writes for Different Purposes	X		X	X	X			X		
2.2.1 Different Purposes for Writing	X		X	X	X			X		
2.3 Writes Variety of Forms/Genres	X		X		X		X			
2.3.1 Uses a Variety of Forms/Genres	X		X		X		X			

Educator Standards Matrix

Chapter One

WRITING

WRITING	Eruption!	Fire, Flood, and Fury	Age, Century, News	Cascade Volcano Timeline	A String of Volcanoes	Volcano Hall of Fame	Surrounded by Volcanoes	Magma Mash	Riding the Magma Elevator	Scale Bottle Volcano
EALR 3 Write Clearly and Effectively										
3.1 Develops Ideas and Organizes Writing	✓	✓	✓	✓	✓	✓	✓	✓	✓	
3.1.1 Selects topic/use relevant details	✓	✓	✓	✓	✓	✓	✓	✓		
3.1.2 Effective Organizational Structure	✓	✓	✓	✓		✓	✓			
3.2 Uses Appropriate Style	✓	✓	✓	✓	✓	✓	✓			
3.2.1 Different audience affect writer's voice	✓	✓	✓			✓	✓			
3.2.2 Language audience/purpose appropriate	✓	✓	✓			✓	✓			
3.2.3 Uses a Variety of Sentences										
3.3 Knows/Applies Writing Conventions	✓	✓	✓	✓	✓	✓	✓	✓		
3.3.1 Uses Legible Handwriting	✓	✓	✓	✓	✓	✓	✓	✓		
3.3.2 Spells Accurately in Final Draft	✓	✓	✓	✓	✓	✓	✓	✓		
3.3.3 Applies Capitalization Rules	✓	✓	✓	✓	✓	✓	✓	✓		
3.3.4 Applies Punctuation Rules	✓	✓	✓	✓		✓	✓	✓		
3.3.5 Applies Usage Rules	✓	✓	✓	✓	✓	✓	✓			
3.3.6 Uses Complete Sentences in Writing	✓	✓	✓	✓	✓	✓	✓			
3.3.7 Applies Paragraph Conventions	✓									
EALR 4 Effectiveness of Written Work										
4.1 Analyzes/Evaluates Others/Own writing	✓	✓								
4.1.1 Analyzes/Evaluates Using Est. Criteria	✓	✓								
4.1.2 Analyzes/Evaluates Own Writing										

Educator Standards Matrix

Chapter One

COMMUNICATION

COMMUNICATION	Eruption!	Fire, Flood, and Fury	19th Century News	Cascade Volcano Timeline	A String of Volcanoes	Volcano Hall of Fame	Surrounded by Volcanoes	Magma Mash	Riding the Magma Elevator	Soda Bottle Volcano
Communication										
EALR 1 Listening/Observation Skills										
1.1 Listening/Observation Skills										
1.1.1 Listening Strategies										
1.1.2 Skills/Strategies to interpret info.										
1.2 Synthesize info from variety of sources										
1.2.1 Relationships bt Visual/Auditory Info.										
1.2.2 Mass Media Bias/Persuasive Tech.										
EALR 2 Interact/Work Effectively w Others										
2.1 Interact Effectively in Multicultural Context										
2.1.1 Needs of Audience/Adjust Language										
2.2 Work Collaboratively, Solve problems										
2.2.1 Skills that Demonstrate Respect										
2.2.2 Contribute Responsibly in Group Setting										
2.3 Communicate Interculturally										
2.3.1 Cultural/Individual Perspectives										
2.3.2 Intercultural Communication Strategies										
EALR 3 Effectively Present Ideas										
3.1 Topic/Theme, Audience, Purpose to Plan										
3.1.1 Plan/Organize Presentation										
3.2 Uses Media to Support Presentations										
3.2.1 Uses resources to enhance presentation										
3.3 Uses Effective Delivery										
3.3.1 Effective Oral Comm./Presentations										

Educator Standards Matrix

Chapter One

COMMUNICATION

COMMUNICATION	Eruption!	Fire, Flood, and Fury	19th Century News	Cascade Volcano Timeline	A String of Volcanoes	Volcano Hall of Fame	Surrounded by Volcanoes	Magma Mash	Riding the Magma Elevator	Soda Bottle Volcano
EALR 4 Evaluates Effectiveness of Comm.										
4.1 Assesses Own/Others Communication	X									
4.1.1 Evaluates Own Strengths/Weaknesses										
4.1.2 Evaluates Others Strengths/Weaknesses	X									
Arts										
EALR 1 Arts Knowledge and Skills										
1.2 Develop Arts Skills and Techniques		X		X						
EALR 2 Using Artistic Processes										
2.1 Creative Process in the Arts		X								
EALR 3 Communicate Through the Arts										
3.1 Express and Present Ideas and Feelings		X								
EALR 4 Connections to Other Disiplines										
4.2 Connection Between Arts/Other Areas		X								

SCIENCE

	Understanding Volcanic Hazards	Volcanic Processes	Tephra Popcorn	Lava Building Blocks	Rock Stars	Fire and Ice	Lahar in a Jar!	Rock, Rubble, Review	Earth Blocks	Volcano Fan Club	Tephra Explorer	Shoebox Geologist	Perilous Beauty Video
EALR 3: Application													
Big Idea: Application (APP); Core Content: Science, Technology and Problem Solving	■												■
6-8 APPA People use technology to solve problems	■												■
6-8 APPB Science and Technology Careers													
6-8 APPC Interdependence of science and technology	■												■
6-8 APPD Technological design	■												■
6-8 APPE Generating solutions to a problem	■												
6-8 APPF Designing and testing solutions	■												
6-8 APPG Benefits of science and technology	■												■
6-8 APPH People contribute to society through science and technology	■												■
EALR 4: Domains of Science: Physical Science													
Big Idea: Force and Motion (PS1); Core Content: Balanced and Unbalanced Forces	■	■		■						■	■		■
6-8 PS1A Average speed				■							■		
6-8 PS1B Friction is a force													
6-8 PS1C Unbalanced forces will cause change in speed or direction of motion	■	■		■						■	■		■
6-8 PS1D Unbalanced forces and motion changes of objects with more or less mass										■	■		
Big Idea: Matter Properties and Change (PS2); Core Content: Atoms and Molecules			■			■							
6-8 PS2A Properties of substances													
6-8 PS2B Properties of mixtures and compounds													
6-8 PS2C Matter, elements, and atoms													
6-8 PS2D Compounds, molecules and atoms													
6-8 PS2E Solids, liquids and gases						■							
6-8 PS2F Conservation of mass			■										

SCIENCE

	Understanding Volcanic Hazards	Volcanic Processes	Tephra Popcorn	Lava Building Blocks	Rock Stars	Fire and Ice	Lahar in a Jar!	Rock, Rubble, Review	Earth Blocks	Volcano Fan Club	Tephra Explorer	Shoebox Geologist	Perilous Beauty Video
EALR 3: Application													
Big Idea: Application (APP); Core Content: Science, Technology and Problem Solving	■												■
6-8 APPA People use technology to solve problems	■												■
6-8 APPB Science and Technology Careers													
6-8 APPC Interdependence of science and technology	■												■
6-8 APPD Technological design	■												■
6-8 APPE Generating solutions to a problem	■												
6-8 APPF Designing and testing solutions	■												
6-8 APPG Benefits of science and technology	■												■
6-8 APPH People contribute to society through science and technology	■												■
EALR 4: Domains of Science: Physical Science													
Big Idea: Force and Motion (PS1); Core Content: Balanced and Unbalanced Forces	■	■		■						■	■		■
6-8 PS1A Average speed				■							■		
6-8 PS1B Friction is a force													
6-8 PS1C Unbalanced forces will cause change in speed or direction of motion	■	■		■						■	■		■
6-8 PS1D Unbalanced forces and motion changes of objects with more or less mass										■	■		
Big Idea: Matter Properties and Change (PS2); Core Content: Atoms and Molecules			■			■							
6-8 PS2A Properties of substances													
6-8 PS2B Properties of mixtures and compounds													
6-8 PS2C Matter, elements, and atoms													
6-8 PS2D Compounds, molecules and atoms													
6-8 PS2E Solids, liquids and gases						■							

Educator Standards Matrix
Chapter Two
SCIENCE

SCIENCE

	Understanding Volcanic Hazards	Volcanic Processes	Tephra Popcorn	Lava Building Blocks	Rock Stars	Fire and Ice	Lahar in a Jar!	Rock, Rubble, Review	Earth Blocks	Volcano Fan Club	Tephra Explorer	Shoebox Geologist	Perilous Beauty Video
Big Idea: Energy Transfer, Transformation and Conservation (PS3); Core Content: Interactions of Energy and Matter	✓	✓	✓			✓	✓			✓			✓
6-8 PS3A Forms of energy, transformations and transfers		✓	✓							✓			✓
6-8 PS3B Transferring of heat energy		✓	✓			✓	✓						
6-8 PS3C Heat, vibration of atoms and thermal insulators	✓						✓						
6-8 PS3D Visible light													
6-8 PS3E Energy transformations into electricity													
6-8 PS3F Energy transferrance via waves, wave properties													
EALR 4: Domains of Science: Earth and Space Science													
Big Idea: Earth in Space (ES1); Core Content: The Solar System													
6-8 ES1A The Moon, its motion and properties													
6-8 ES1B Composition of the Solar System													
6-8 ES1C Motion of objects in Solar System													
6-8 ES1D Gravity													
6-8 ES1E Relationship of earth, sun, Milky Way galaxy, other galaxies													
Big Idea: Earth Systems, Structures and Processes (ES2); Core Content: Cycles in Earth Systems	✓	✓		✓	✓	✓	✓	✓	✓		✓		✓
6-8 ES2A Atmosphere, stratosphere and troposphere													
6-8 ES2B Sun as the energy source for phenomena on Earth's surface											✓		
6-8 ES2C Water cycle													
6-8 ES2D Water is a solvent													
6-8 ES2E Layers of earth: crust, mantle and core													
6-8 ES2F Crust structure and plate movement	✓							✓					
6-8 ES2G Landforms; processes that build them up and break them down	✓	✓		✓		✓	✓	✓	✓		✓		✓
6-8 ES2H Rock cycle, igneous, metamorphic and sedimentary rocks	✓	✓		✓	✓	✓		✓	✓				

Educator Standards Matrix

Chapter Two

SCIENCE

SCIENCE

	Understanding Volcanic Hazards	Volcanic Processes	Tephra Popcorn	Lava Building Blocks	Rock Stars	Fire and Ice	Lahar in a Jar!	Rock, Rubble, Review	Earth Blocks	Volcano Fan Club	Tephra Explorer	Shoebox Geologist	Perilous Beauty Video
Big Idea: Earth Systems, Structures and Processes (ES2); Core Content: Cycles in Earth Systems	■	■		■	■	■	■	■	■		■		■
6-8 ES2A Atmosphere, stratosphere and troposphere													
6-8 ES2B Sun as the energy source for phenomena on Earth's surface											■		
6-8 ES2C Water cycle													
6-8 ES2D Water is a solvent													
6-8 ES2E Layers of earth: crust, mantle and core													
6-8 ES2F Crust structure and plate movement	■							■					
6-8 ES2G Landforms; processes that build them up and break them down	■	■		■		■	■	■	■		■		■
6-8 ES2H Rock cycle; igneous, metamorphic and sedimentary rocks	■	■		■	■	■		■	■				
Big Idea: Earth History (ES3); Evidence of Change	■	■		■	■	■	■	■	■	■	■	■	■
6-8 ES3A Earth history and processes					■	■	■	■	■	■	■	■	
6-8 ES3B Sedimentary rocks and fossils as evidence of earth's history and age									■			■	
6-8 ES3C Sedimentary rocks and formations as evidence of geologic events									■			■	
6-8 ES3D Processes that shaped the earth	■	■		■		■	■	■	■	■	■		■
6-8 ES3E Living organisms play roles in shaping landforms													
EALR 4: Domains of Science: Life Science													
Big Idea: Structure and Function of Organisms (LS1); Core Content: From Cells to Organisms													
6-8 LS1A Cells as the fundamental unit of life													
6-8 LS1B One-celled organisms													
6-8 LS1C Multicellular organisms													
6-8 LS1D Plant and animals cells; their similarities and differences													
6-8 LS1E Classifying organisms													
6-8 LS1F Lifestyle choices and environments affect organisms													

Educator Standards Matrix

Chapter Two

SCIENCE

SCIENCE	Understanding Volcanic Hazards	Volcanic Processes	Tephra Popcorn	Lava Building Blocks	Rock Stars	Fire and Ice	Lahar in a Jar!	Rock, Rubble, Review	Earth Blocks	Volcano Fan Club	Tephra Explorer	Shoebox Geologist	Perilous Beauty Video
Big Idea: Ecosystems (LS2); Core Content: Flow of Energy Through Ecosystems													
6-8 LS2A Populations and nonliving factors comprise all ecosystems													
6-8 LS2B Relationships between producers, consumers and decomposers													
6-8 LS2C Ecosystem processes: energy and photosynthesis													
6-8 LS2D Ecosystem processes: factors affecting populations													
6-8 LS2E Investigations of environmental issues													
Big Idea: Biological Evolution (LS3); Core Content: Inheritance, Variation, and Adaption													
6-8 LS3A Theory of Evolution													
6-8 LS3B Genes, chromosomes and genetic information													
6-8 LS3C Reproduction													
6-8 LS3D Sexual and asexual reproduction													
6-8 LS3E Adaptations													
6-8 LS3F Extinction													
6-8 LS3G Evidence for evolution													

SOCIAL STUDIES

	Understanding Volcanic Hazards	Volcanic Processes	Tephra Popcorn	Lava Building Blocks	Rock Stars	Fire and Ice	Lahar in a Jar!	Rock, Rubble, Review	Earth Blocks	Volcano Fan Club	Tephra Explorer	Shoebox Geologist	Perilous Beauty Video
Social Studies													
EALR 3 Geography													
3.1 Physical & cultural characteristics	X	X		X			X		X		X	X	X
3.1.1 Maps and Geographic Tools				X			X		X		X	X	
3.1.2 Char & Spatial Org of Places/Regions	X	X		X			X		X		X		X
3.2 Human Interaction with Environment	X	X					X						X
3.2.1 Human-Environmental Interaction	X	X					X						X
3.2.2 Culture													
3.2.3 Human Migration													
3.3 Geographic Context of Global Issues													
3.3.1 Geographic Context of Global Issues													
EALR 4 History													
4.1 Understands Historical Chronology													
4.1.1 Chronology													
4.1.2 Chronological Eras													
4.2 Causal Factors that Shaped History													
4.2.1 Individuals and Movements													
4.2.2 Cultures and Cultural Groups													
4.2.3 Ideas and Technology													
4.3 Multiple Perspectives/Interp. Of History													
4.3.1 Historical Interpretation													
4.3.2 Multiple Causation													
4.4 Understand Present/Plan for Future													
4.4.1 Historical Antecedents													
EALR 5 Social Studies Skills													
5.2 Inquiry-based Research													
5.2.1 Forms Questions													
5.2.2 Analyzes Sources													

Educator Standards Matrix
Chapter Two
MATHEMATICS

MATHEMATICS

	Understanding Volcanic Hazards	Volcanic Processes	Tephra Popcorn	Lava Building Blocks	Rock Stars	Fire and Ice	Lahar in a Jar!	Rock, Rubble, Review	Earth Blocks	Volcano Fan Club	Tephra Explorer	Shoebox Geologist	Perilous Beauty Video
Mathematics													
EALR 1 Concepts/Procedures													
Number and Numeration													
1.1 Number Sense			✓	✓			✓			✓		✓	
1.1.1 Concept & Symbolic Representation			✓	✓			✓			✓			
1.1.2 Relative Values			✓	✓			✓			✓			
1.1.3 Properties of Addition/Multiplication			✓	✓			✓			✓		✓	
1.1.4 Ratio, Percent, Direct Proportion			✓				✓						
Computation													
1.1.5 Meanings			✓	✓			✓			✓			
1.1.6 Computational Procedures			✓	✓			✓			✓			
1.1.7 Apply Strategies/Uses Tools			✓	✓			✓			✓			
Procedures and Estimation													
1.2 Concepts/Procedures from Measurement			✓				✓			✓			
1.2.3 Unit of Measurement Affects Precision			✓	✓			✓			✓			
1.2.6 Obtain Reasonable Estimates			✓	✓			✓			✓			
Probability and Statistics													
1.4 Probability and Statistics													
1.4.5 Data in Diagrams, Plots, and Graphs				✓			✓			✓			
Symbols and Notations													
1.5 Algebraic Sence			✓				✓						
1.5.3 Mathematical Equality and Inequality			✓				✓						
1.5.4 Variables to Write Expressions			✓				✓						
Evaluating and Solving													
1.5.6 Solve Equations with Variables			✓				✓						
EALR 2 Define and Solve Problems													
2.2 Construct Solutions			✓	✓			✓			✓			
2.2.4 Determine Viable/Correct Answers			✓	✓			✓			✓			

Educator Standards Matrix
Chapter Two
MATHEMATICS

MATHEMATICS

	Understanding Volcanic Hazards	Volcanic Processes	Tephra Popcorn	Lava Building Blocks	Rock Stars	Fire and Ice	Lahar in a Jar!	Rock, Rubble, Review	Earth Blocks	Volcano Fan Club	Tephra Explorer	Shoebox Geologist	Perilous Beauty Video
EALR 3 Mathematical Reasoning													
Analyze Information													
3.1 Analyze Information										X	X	X	
3.1.1 Analyze Mathematical info. or Results			X	X						X	X	X	
Conclude													
3.2 Conclude			X	X							X	X	
3.2.1 Draw and Support Conclusions			X	X							X	X	
Verify Results													
3.3 Verify Results			X				X			X			
3.3.1 Justify Results Using Evidence			X	X			X			X			
3.3.2 Reasonableness of Results			X	X			X			X			
3.3.3 Validate Thinking			X	X			X			X			
EALR 4 Communicates Knowledge													
Gather Information													
4.1 Gather Information			X	X			X			X			
4.1.1 Develop and Follow a Plan			X	X			X			X			
Organize, Represent, and Share Info.													
4.2 Organize, Represent, and Share Info.			X	X						X		X	
4.2.2 Represent Info. in Graphs/Other Forms				X			X			X		X	
4.2.3 Use Mathematical Language to Explain			X							X		X	

Educator Standards Matrix

Chapter Two

READING

Reading	Understanding Volcanic Hazards	Volcanic Processes	Tephra Popcorn	Lava Building Blocks	Rock Stars	Fire and Ice	Lahar in a Jar!	Rock, Rubble, Review	Earth Blocks	Volcano Fan Club	Tephra Explorer	Shoebox Geologist	Perilous Beauty Video
EALR 1 Skills and Strategies to Read													
1.2 Vocabulary strategies													
1.2.1 Use Resources/Reference Skills													
1.2.2 Vocabulary Strategies													
1.3 Build Vocabulary Through Wide Reading													
1.3.1 Understand/Apply New Vocabulary													
1.3.2 Content/Academic Vocabulary													
1.4 Word Recognition/Read Fluently													
1.4.2 Fluency to Enhance Comprehension													
1.4.3 Different Reading Rates													
EALR 2 Understand Meaning													
2.1 Evidence of Reading Comprehension													
2.1.3 Comprehension During and After Reading													
2.1.4 Use Prior Knowledge													
2.1.5 Predict and Infer													
2.1.6 Generate and Answer Questions													
2.1.7 Determine Importance/Summarize Text													
2.2 Text Components to Comprehend Text													
2.2.1 Time, Order, and/or Sequence													
2.2.2 Printed/Electronic Text Features													
2.2.3 Understand/Analyze Story Elements													
2.2.4 Text Organizational Structures													

Educator Standards Matrix

Chapter Two

WRITING

WRITING

	Understanding Volcanic Hazards	Volcanic Processes	Tephra Popcorn	Lava Building Blocks	Rock Stars	Fire and Ice	Lahar in a Jar!	Rock, Rubble, Review	Earth Blocks	Volcano Fan Club	Tephra Explorer	Shoebox Geologist	Perilous Beauty Video
3.3 Knows/Applies Writing Conventions	X	X	X	X	X		X	X	X	X	X	X	X
3.3.1 Uses Legible Handwriting	X	X	X	X	X		X	X	X	X	X	X	X
3.3.2 Spells Accurately in Final Draft	X	X	X	X	X		X	X	X	X	X	X	X
3.3.3 Applies Capitalization Rules	X	X	X	X	X		X		X	X	X	X	X
3.3.4 Applies Punctuation Rules	X	X	X	X	X		X		X	X	X	X	X
3.3.5 Applies Usage Rules	X	X	X	X	X		X		X	X	X	X	X
3.3.6 Uses Complete Sentences in Writing	X	X	X		X		X		X	X	X	X	X
3.3.7 Applies Paragraph Conventions	X		X						X	X	X	X	X
EALR 4													
4.1 Analyzes/Evaluates Others/Own writing													
4.1.1 Analyzes/Evaluates Using Est. Criteria													
4.1.2 Analyzes/Evaluates Own Writing													

Educator Standards Matrix

Chapter Two

WRITING

WRITING	Understanding Volcanic Hazards	Volcanic Processes	Tephra Popcorn	Lava Building Blocks	Rock Stars	Fire and Ice	Lahar in a Jar!	Rock, Rubble, Review	Earth Blocks	Volcano Fan Club	Tephra Explorer	Shoebox Geologist	Perilous Beauty Video
Writing													
EALR 1 Understand/Use a Writing Process													
1.1 Prewrites to Generate Ideas													
1.1.1 Generates Ideas/Plans Writing													
1.6 Publishes Text to Share													
1.5.1 Appropriate for audience/purpose													
EALR 2 Variety of Forms/Audiences													
2.1 Adapts Writing for Variety of Audiences													
2.1.1 Multiple and Various Audiences													
2.2 Writes for Different Purposes													
2.2.1 Different Purposes for Writing													
2.3 Writes Variety of Forms/Genres													
2.3.1 Uses a Variety of Forms/Genres													
2.4.1 Documents Used in Career Setting													
EALR 3 Write Clearly and Effectively													
3.1 Develops Ideas and Organizes Writing													
3.1.1 Selects topic/use relevant details													
3.1.2 Effective Organizational Structure													
3.2 Uses Appropriate Style													
3.2.1 Different audience affect writer's voice													
3.2.2 Language audience/purpose appropriate													
3.2.3 Uses a Variety of Sentences													

Educator Standards Matrix
Chapter Two
COMMUNICATION

COMMUNICATION

	Understanding Volcanic Hazards	Volcanic Processes	Tephra Popcorn	Lava Building Blocks	Rock Stars	Fire and Ice	Lahar in a Jar!	Rock, Rubble, Review	Earth Blocks	Volcano Fan Club	Tephra Explorer	Shoebox Geologist	Perilous Beauty Video
Communication													
EALR 1 Listening/Observation Skills													
1.1 Listening/Observation Skills	X	X	X	X	X		X	X	X	X	X	X	X
1.1.1 Listening Strategies	X	X	X	X	X		X	X	X	X	X	X	X
1.1.2 Skills/Strategies to interpret info.	X	X	X	X	X		X	X	X	X	X	X	X
1.2 Synthesize info from variety of sources	X	X	X		X		X		X		X	X	X
1.2.1 Relationships bt Visual/Auditory Info.	X	X	X	X	X		X		X		X	X	X
1.2.2 Mass Media Bias/Persuasive Tech.													
EALR 2 Interact/Work Effectively w Others													
2.1 Interact Effectively in Multicultural Context	X	X	X		X		X	X	X	X	X	X	X
2.1.1 Needs of Audience/Adjust Language	X	X	X	X	X		X	X	X	X	X	X	X
2.2 Work Collaboratively, Solve problems	X	X	X		X		X	X	X	X	X	X	X
2.2.1 Skills that Demonstrate Respect	X	X	X	X	X		X	X	X	X	X	X	X
2.2.2 Contribute Responsibly in Group Setting			X	X			X	X	X	X		X	
2.3 Communicate Interculturally													
2.3.1 Cultural/Individual Perspectives													
2.3.2 Intercultural Communication Strategies													
EALR 3 Effectively Present Ideas													
3.1 Topic/Theme, Audience, Purpose to Plan							X	X		X			
3.1.1 Plan/Organize Presentation							X	X		X			
3.2 Uses Media to Support Presentations													
3.2.1 Uses resources to enhance presentation													
3.3 Uses Effective Delivery								X					
3.3.1 Effective Oral Comm./Presentations								X					

Living with a Volcano in Your Backyard

Washington Essential Academic Learning Requirements & Grade Level Expectations

SCIENCE

Chapter Three

	Play-Dough Topo	Topographic Maps and Mount Rainier	Planning Your Trip to MRNP!	The Next Eruption of Mount Rainier	Reducing Volcanic Risk Video	Don't Be Scared - Be Prepared!	A Volcano Tussle	Living Well with a Volcano in your Backyard
EALR 1: Systems								
Big Idea: Systems (SYS); Core Content: Inputs, Outputs, Boundaries and Flows								
6-8 SYSA Systems and Subsystems								
6-8 SYSB Boundaries of a system								
6-8 SYSC Outputs and Inputs of Systems								
6-8 SYSD Open and Closed Systems								
6-8 SYSE Flow of matter into/out of systems								
6-8 SYSF Investigation of Systems in the natural and designed world								
EALR 2: Inquiry								
Big Idea: Inquiry (INQ); Core Content: Questioning and Investigating								
6-8 INQA Scientific questioning								
6-8 INQB Types of questions and investigations								
6-8 INQC Collecting, analyzing and displaying data are part of investigations								
6-8 INQD Types of variables								
6-8 INQE Modeling								
6-8 INQF Results vs. inference vs. general conclusions								
6-8 INQG Scientific reporting								
6-8 INQH Intellectual honesty in science								
6-8 INQI Ethical codes of experiments								

SCIENCE

	Play-Dough Topo	Topographic Maps and Mount Rainier	Planning Your Trip to MRNP!	The Next Eruption of Mount Rainier	Reducing Volcanic Risk Video	Don't Be Scared - Be Prepared!	A Volcano Tussle	Living Well with a Volcano in your Backyard
EALR 3: Application								
Big Idea: Application (APP); Core Content: Science, Technology and Problem Solving								
6-8 APPA People use technology to solve problems								
6-8 APPB Science and Technology Careers								
6-8 APPC Interdependence of science and technology								
6-8 APPD Technological design								
6-8 APPE Generating solutions to a problem								
6-8 APPF Designing and testing solutions								
6-8 APPG Benefits of science and technology								
6-8 APPH People contribute to society through science and technology								
EALR 4: Domains of Science: Physical Science								
Big Idea: Force and Motion (PS1); Core Content: Balanced and Unbalanced Forces								
6-8 PS1A Average speed								
6-8 PS1B Friction is a force								
6-8 PS1C Unbalanced forces will cause change in speed or direction of motion								
6-8 PS1D Unbalanced forces and motion changes of objects with more or less mass								

SCIENCE

	Play-Dough Topo	Topographic Maps and Mount Rainier	Planning Your Trip to MRNP!	The Next Eruption of Mount Rainier	Reducing Volcanic Risk Video	Don't Be Scared - Be Prepared!	A Volcano Tussle	Living Well with a Volcano in your Backyard
Big Idea: Matter Properties and Change (PS2); Core Content: Atoms and Molecules								
6-8 PS2A Properties of substances								
6-8 PS2B Properties of mixtures and compounds								
6-8 PS2C Matter, elements, and atoms								
6-8 PS2D Compounds, molecules and atoms								
6-8 PS2E Solids, liquids and gases								
6-8 PS2F Conservation of mass								
Big Idea: Energy Transfer, Transformation and Conservation (PS3); Core Content: Interactions of Energy and Matter								
6-8 PS3A Forms of energy, transformations and transfers								
6-8 PS3B Transferring of heat energy								
6-8 PS3C Heat, vibration of atoms and thermal insulators								
6-8 PS3D Visible light								
6-8 PS3E Energy transformations into electricity								
6-8 PS3F Energy transferrance via waves; wave properties								

SCIENCE

	Play-Dough Topo	Topographic Maps and Mount Rainier	Planning Your Trip to MRNP!	The Next Eruption of Mount Rainier	Reducing Volcanic Risk Video	Don't Be Scared - Be Prepared!	A Volcano Tussle	Living Well with a Volcano in your Backyard
Big Idea: Earth in Space (ES1); Core Content: The Solar System								
6-8 ES1A The Moon; its motion and properties								
6-8 ES1B Composition of the Solar System								
6-8 ES1C Motion of objects in Solar System								
6-8 ES1D Gravity								
6-8 ES1E Relationship of earth, sun, Milky Way galaxy, other galaxies								
Big Idea: Earth Systems, Structures and Processes (ES2); Core Content: Cycles in Earth Systems								
6-8 ES2A Atmosphere, stratosphere and troposphere								
6-8 ES2B Sun as the energy source for phenomena on Earth's surface								
6-8 ES2C Water cycle								
6-8 ES2D Water is a solvent								
6-8 ES2E Layers of earth: crust, mantle and core								
6-8 ES2F Crust structure and plate movement								
6-8 ES2G Landforms; processes that build them up and break them down								
6-8 ES2H Rock cycle; igneous, metamorphic and sedimentary rocks								

SCIENCE

	Play-Dough Topo	Topographic Maps and Mount Rainier	Planning Your Trip to MRNP!	The Next Eruption of Mount Rainier	Reducing Volcanic Risk Video	Don't Be Scared - Be Prepared!	A Volcano Tussle	Living Well with a Volcano in your Backyard
Big Idea: Earth History (ES3); Evidence of Change								
6-8 ES3A Earth history and processes								
6-8 ES3B Sedimentary rocks and fossils as evidence of earth's history and age								
6-8 ES3C Sedimentary rocks and formations as evidence of geologic events								
6-8 ES3D Processes that shaped the earth								
6-8 ES3E Living organisms play roles in shaping landforms								
EALR 4: Domains of Science: Life Science								
Big Idea: Structure and Function of Organisms (LS1); Core Content: From Cells to Organisms								
6-8 LS1A Cells as the fundamental unit of life								
6-8 LS1B One-celled organisms								
6-8 LS1C Multicellular organisms								
6-8 LS1D Plant and animals cells; their similarities and differences								
6-8 LS1E Classifying organisms								
6-8 LS1F Lifestyle choices and environments affect organisms								

Educator Standards Matrix

Chapter Three

SCIENCE

SCIENCE

	Play-Dough Topo	Topographic Maps and Mount Rainier	Planning Your Trip to MRNP!	The Next Eruption of Mount Rainier	Reducing Volcanic Risk Video	Don't Be Scared - Be Prepared!	A Volcano Tussle	Living Well with a Volcano in your Backyard
Big Idea: Ecosystems (LS2); Core Content: Flow of Energy Through Ecosystems								
6-8 LS2A Populations and nonliving factors comprise all ecosystems								
6-8 LS2B Relationships between producers, consumers and decomposers								
6-8 LS2C Ecosystem processes: energy and photosynthesis								
6-8 LS2D Ecosystem processes: factors affecting populations								
6-8 LS2E Investigations of environmental issues								
Big Idea: Biological Evolution (LS3); Core Content: Inheritance, Variation, and Adaption								
6-8 LS3A Theory of Evolution								
6-8 LS3B Genes, chromosomes and genetic information								
6-8 LS3C Reproduction								
6-8 LS3D Sexual and asexual reproduction								
6-8 LS3E Adaptations								
6-8 LS3F Extinction								
6-8 LS3G Evidence for evolution								

Educator Standards Matrix

Chapter Three

MATHEMATICS

MATHEMATICS

	Play-Dough Topo	Topographic Maps and Mount Rainier	Planning Your Trip to MRNP!	**The Next Eruption of Mount Rainier**	Reducing Volcanic Risk Video	Don't Be Scared - Be Prepared!	A Volcano Tussle	Living Well with a Volcano in your Backyard
1.5 Algebraic Sence								
1.5.3 Mathematical Equality and Inequality								
1.5.4 Variables to Write Expressions								
EALR 2 Define and Solve Problems								
2.2 Construct Solutions								
2.2.4 Determine Viable/Correct Answers								
EALR 3 Mathematical Reasoning								
Analyze Information								
3.1 Analyze Information								
3.1.1 Analyze Mathematical info. or Results								
Conclude								
3.2 Conclude								
3.2.1 Draw and Support Conclusions								
Verify Results								
3.3 Verify Results								
3.3.1 Justify Results Using Evidence								
EALR 4 Communicates Knowledge								
Organize, Represent, and Share Info.								
4.2 Organize, Represent, and Share Info.								
4.2.2 Represent Info. in Graphs/Other Forms								

READING

	Play-Dough Topo	Topographic Maps and Mount Rainier	Planning Your Trip to MRNP!	The Next Eruption of Mount Rainier	Reducing Volcanic Risk Video	Don't Be Scared - Be Prepared!	A Volcano Tussle	Living Well with a Volcano in your Backyard
Reading								
EALR 1 Skills and Strategies to Read								
1.2 Vocabulary strategies								
1.2.1 Use Resources/Reference Skills								
1.2.2 Vocabulary Strategies								
1.3 Build Vocabulary Through Wide Reading								
1.3.1 Understand/Apply New Vocabulary								
1.3.2 Content/Academic Vocabulary								
1.4 Word Recognition/Read Fluently								
1.4.2 Fluency to Enhance Comprehension								
1.4.3 Different Reading Rates								
EALR 2 Understand Meaning								
2.1 Evidence of Reading Comprehension								
2.1.3 Comprehension During and After Reading								
2.1.4 Use Prior Knowledge								

Educator Standards Matrix

Chapter Three

READING

READING

	Play-Dough Topo	Topographic Maps and Mount Rainier	Planning Your Trip to MRNP!	**The Next Eruption of Mount Rainier**	Reducing Volcanic Risk Video	Don't Be Scared - Be Prepared!	A Volcano Tussle	Living Well with a Volcano in your Backyard
2.1.5 Predict and Infer								
2.1.6 Generate and Answer Questions								
2.1.7 Determine Importance/Summarize Text								
2.2 Text Components to Comprehend Text								
2.2.1 Time, Order, and/or Sequence								
2.2.2 Printed/Electronic Text Features								
2.2.3 Understand/Analyze Story Elements								
2.2.4 Text Organizational Structures								
2.3 Analyzing, Interpreting, Synthesizing								
2.3.1 Similarities/Differences and Cause/Effect								
2.3.2 Information for Specific Topic or Purpose								
2.3.3 Literary Devices								
2.3.4 Information from Variety of Sources								
2.4 Use of language, style, Purpose&Persp.								
2.4.1 Draw Conclusions and Develop Insights								
2.4.2 Style of Writing for Purpose/Influence								
2.4.3 Verify Validity and Accuracy								
2.4.4 Tone and Use of Persuasive Devices								
2.4.5 Generalize/Express Insight Beyond Text								
2.4.6 Ideas/Concepts in Multiple Texts								
2.4.7 Author's Perspective/Beliefs/Assumptions								
EALR 3 Different Materials/Purposes								
3.1 Read to Learn New Information								
3.1.1 Appropriate resources								
3.2 Read to Perform a Task								
3.2.2 Functional Documents								
3.4 Literary/Narrative Experience								
3.4.2 Variety of Literary Genres								
3.4.3 Recurring Themes								

WRITING

	Play-Dough Topo	Topographic Maps and Mount Rainier	Planning Your Trip to MRNP!	**The Next Eruption of Mount Rainier**	Reducing Volcanic Risk Video	Don't Be Scared - Be Prepared!	A Volcano Tussle	Living Well with a Volcano in your Backyard
Writing								
EALR 1 Understand/Use a Writing Process								
1.1 Prewrites to Generate Ideas								
1.1.1 Generates Ideas/Plans Writing								
1.5 Publishes Text to Share								
1.5.1 Appropriate for audience/purpose								
EALR 2 Variety of Forms/Audiences								
2.1 Adapts Writing for Variety of Audiences								
2.1.1 Multiple and Various Audiences								
2.2 Writes for Different Purposes								
2.2.1 Different Purposes for Writing								
2.3 Writes Variety of Forms/Genres								
2.3.1 Uses a Variety of Forms/Genres								
2.4.1 Documents Used in Career Setting								

Educator Standards Matrix

Chapter Three

WRITING

WRITING

	Play-Dough Topo	Topographic Maps and Mount Rainier	Planning Your Trip to MRNP!	The Next Eruption of Mount Rainier	Reducing Volcanic Risk Video	Don't Be Scared - Be Prepared!	A Volcano Tussle	Living Well with a Volcano in your Backyard
EALR 3 Write Clearly and Effectively								
3.1 Develops Ideas and Organizes Writing								
3.1.1 Selects topic/use relevant details								
3.1.2 Effective Organizational Structure								
3.2 Uses Appropriate Style								
3.2.1 Different audience affect writer's voice								
3.2.2Language audience/purpose appropriate								
3.2.3 Uses a Variety of Sentences								
3.3 Knows/Applies Writing Conventions								
3.3.1 Uses Legible Handwriting								
3.3.2 Spells Accurately in Final Draft								
3.3.3 Applies Capitalization Rules								
3.3.4 Applies Punctuation Rules								
3.3.5 Applies Usage Rules								
3.3.6 Uses Complete Sentences in Writing								
3.3.7 Applies Paragraph Conventions								
EALR 4								
4.1 Analyzes/Evaluates Others/Own writing								
4.1.1 Analyzes/Evaluates Using Est. Criteria								
4.1.2 Analyzes/Evaluates Own Writing								

Educator Standards Matrix
Chapter Three
COMMUNICATIONS

COMMUNICATION

	Play-Dough Topo	Topographic Maps and Mount Rainier	Planning Your Trip to MRNP!	The Next Eruption of Mount Rainier	Reducing Volcanic Risk Video	Don't Be Scared - Be Prepared!	A Volcano Tussle	Living Well with a Volcano in your Backyard
Communication								
EALR 1 Listening/Observation Skills								
1.1 Listening/Observation Skills								
1.1.1 Listening Strategies								
1.1.2 Skills/Strategies to interpret info.								
1.2 Synthesize info from variety of sources								
1.2.1 Relationships bt Visual/Auditory Info.								
1.2.2 Mass Media Bias/Persuasive Tech.								
EALR 2 Interact/Work Effectively w Others								
2.1Interact Effectively in Multicultural Context								
2.1.1 Needs of Audience/Adjust Language								
2.2 Work Collaboratively, Solve problems								
2.2.1 Skills that Demonstrate Respect								
2.2.2 Contribute Responsibly in Group Setting								
2.3 Communicate Interculturally								
2.3.1 Cultural/Individual Perspectives								
2.3.2 Intercultural Communication Strategies								
EALR 3 Effectively Present Ideas								
3.1 Topic/Theme, Audience, Purpose to Plan								
3.1.1 Plan/Organize Presentation								
3.2 Uses Media to Support Presentations								
3.2.1 Uses resources to enhance presentation								
3.3 Uses Effective Delivery								
3.3.1 Effective Oral Comm./Presentations								
EALR 4 Evaluates Effectiveness of Comm.								
4.1 Assesses Own/Others Communication								
4.1.1 Evaluates Own Strengths/Weaknesses								
4.1.2 Evaluates Others Strengths/Weaknesses								

This page left intentionally blank

Living with a volcano in your backyard—An educator's guide with emphasis on Mount Rainier
Coordinated by Carolyn Driedger, Anne Doherty, Cheryl Dixon, and Lisa Faust
U.S. Geological Survey General Information Product 19
http://pubs.usgs.gov/gip/19/

Chapter 1. What the Past Tells Us

This chapter provides a general overview of the volcanoes of the Cascade Range. The chapter begins with the Overview and then presents a series of activities grouped under the theme "Blast from the Past." The theme "Forces Responsible for Cascade Volcanism" addresses the plate tectonics responsible for Cascades volcanism and ends with activities regarding how volcanoes work:

Overview

Blast from the Past

- **Eruption!**—In this pre-assessment activity, students describe their perceptions of a volcanic eruption in a personal journal entry. Then they read an actual eyewitness account of the A.D. 79 eruption of Mount Vesuvius in Italy and compare those events to the eruption events depicted in their journal entries.
- **Fire, Flood, and Fury**—Native American oral traditions chronicle geologic events in the history of Mount Rainier. These stories are read, interpreted, and illustrated by students with the use of storyboards.
- **Nineteenth-Century News**—Read nineteenth-century newspaper accounts of recent eruptions at Mount Rainier. The minor eruptive activity at Mount Rainier illustrates that not all eruptions are large or destructive.
- **Cascade Volcano Timeline**—Cascade volcanoes are young in relation to the geologic events that have shaped the Earth. A timeline illustrates the high incidence of Cascade volcano activity in comparison to geologic and human events since the signing of the Declaration of Independence. A hypothetical genealogy of one family's history illustrates the collective and individual activity of the Cascade volcanoes.
- **A String of Volcanoes**—Students research information about Cascade volcanoes and write the information on cards used to construct a mobile.
- **Volcano Hall of Fame**—This is a game where students use fun facts to try to identify a specific Cascade volcano.

Forces Responsible for Cascade Volcanism

- **Surrounded by Volcanoes**—Explore geographical information to learn about tectonic boundaries, origin of the "Ring of Fire," and volcanoes in the Pacific Northwest. Identify and label Cascade volcanoes on a satellite image.
- **Magma Mash**—Students take on the role of minerals cooling at different rates in an exploration of magma behavior, and then examine samples of rocks cooled at different rates.
- **Riding the Magma Elevator**—Examine the process of magma formation from mantle melting in the subduction zone, rising to the magma chamber, and erupting from the magma conduit. During this activity, the class will ride an imaginary elevator from the subduction zone and out the volcano crater.
- **Soda Bottle Volcano**—Examine how gases energize explosive volcanic eruptions by making comparisons to gases in a soda bottle and performing a carefully controlled "eruption" of baking soda/vinegar or soda water.

This page left intentionally blank

What The Past Tells Us
Overview—Chapter 1

Cascade Range volcanoes reward us with some of the most superb panoramas to be found between southern British Columbia and northern California. Although the grandeur of these 13 major volcanic centers inspires us, most people remain unfamiliar with volcano histories and hazards. Why should your students become interested? With virtual certainty, many of these volcanoes will erupt again. This we know because of the volcanoes' location on an active subduction zone, their active geothermal and earthquake systems, and the frequency and recentness of eruptions.

Chapter 1 activities set the stage for investigation of the Cascade volcanoes, with emphasis on Mount Rainier. The activities address the where, when and how questions that your students are certain to ask. Other Chapter 1 activities examine the human-volcano interface as viewed through historical and cultural lenses. **Eruption!** is a pre-unit assessment of knowledge and perception. Students read an eyewitness account of the A.D. 79 eruption of Mount Vesuvius, then write a journal entry as though they were watching a volcano erupt. Revisit **Eruption!** at the end of your unit as a postassessment activity. Native American oral traditions, kept alive by oral communication for centuries, provide amazingly detailed descriptions—and some metaphorical accounts—of geological events. Find some of these descriptions in **Fire, Flood, and Fury**. In **Nineteenth-Century Newspaper Accounts of an Eruption at Mount Rainier**, students read historical newspaper accounts of the 1894–95 steam and ash eruptions of Mount Rainier. **Cascade Volcano Timeline** places the eruptive histories of Cascade volcanoes in the larger context of American and geological history, then sets it in the more personal context of one hypothetical family's history. Students research information and construct a mobile in **Volcano Hall of Fame** and **A String of Volcanoes**.

Surrounded by Volcanoes addresses plate tectonics and the Ring of Fire. Students role-play minerals within cooling magma in **Magma Mash** and then take an imaginary trip inside a volcano in **Riding the Magma Elevator**. In **Soda Bottle Volcano**, they learn how gases energize volcanic eruptions.

Make your message clear:

Cascade volcanoes are part of the fabric of the Pacific Northwest. Expect future eruptions at many of these volcanoes. Chapter 1 activities provide a solid background for activities in Chapters 2 and 3, which address volcanic processes, hazards, and preparations for community safety.

Last modified: September 5, 2014

Eruption!

Grade Level: 6+

Learner Objectives:

Students will:

- Identify existing knowledge of volcanoes and volcano–related myths
- Visualize and describe a volcanic eruption through creative story writing
- Gain insight on volcanic processes, hazards, and community risk

Setting: Classroom

Timeframe: 30 minutes; 20 minutes

Writing A Journal Entry

Reading A Real Volcano Eruption Story

Materials:

Writing A Journal Entry

- Copies of *"Eruption!"* student page
- Pen or pencil

Reading A Real Volcano Eruption Story

- Copies of *"Letters from Pliny, A.D. 79"* student page
- Graphic for *"Map of Vesuvius Area"*

USGS
science for a changing world

Living with a Volcano in Your Backyard–An Educator's Guide with Emphasis on Mount Rainier

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

In this preassessment activity, students describe their perceptions of a volcanic eruption in a personal journal entry. They then read an incredible eyewitness account from the A.D. 79 eruption of Mount Vesuvius in Italy and compare this account to the eruption events depicted in journal entries.

Teacher Background

Testing student perceptions about volcanoes

Movie portrayals of volcanic eruptions such as "Volcano" or "Dante's Peak" and television footage of Hawaiian ***lava flows*** often shape student perceptions of volcanoes. Although these types of media can sometimes be educational, they can also be deceptive and advance commonly held misperceptions and myths. This activity is best used as a preassessment tool to evaluate students' understanding and perceptions of a volcanic ***eruption***.

Pliny the Elder as model volcano observer

Pliny the Younger wrote letters to a friend, the Roman historian Tacitus, describing his observations and those of his uncle, Pliny the Elder, during the Mount Vesuvius eruption of A.D. 79. This eruption devastated nearby cities and killed 3,360 people. Numerous researchers have studied Pliny's account and have found archeological and geological evidence to support his version of events. His account depicts what can happen in other volcanic eruptions.

Some volcanic processes described from Mount Vesuvius are similar to processes that might occur during eruptions at Cascade Range volcanoes. Pliny the Younger portrays

Vocabulary: Ash cloud, eruption, hot ash flow, lava flows, pyroclastic flow, tsunami, volcanic ash

Skills: Communicating, creative writing

Benchmarks:

See benchmarks in Introduction.

the ***ash cloud*** from the eruption, "likening it to a pine tree." Italian pine trees are shaped differently from those in the Pacific Northwest. They have a trunk with branches concentrated at the top to form a broad canopy. Hence, the volcanic cloud described by Pliny is similar in shape to the mushroom-shaped cloud commonly observed in a volcanic ash eruption. Later on, Pliny talked about the darkness being "darker and thicker than any night." Similar darkness also occurred during the May 18, 1980, eruption of Mount St. Helens, when ***volcanic ash*** darkened skies over eastern Washington.

Pliny observes volcanic processes that are common at many volcanoes

At one point, Pliny wrote that a cloud "stretched down to the ground and covered the sea" and "looms behind us following us like a flood poured across the land." Pliny probably observed a ***pyroclastic flow*** or ***hot ash flow***. These deadly clouds of hot gas and ash and larger particles are so dense they flow close to the ground and move rapidly down the sides of volcanoes. Most of the victims in the Vesuvius eruption were killed from asphyxiation in these pyroclastic flows. Casts of victims who were buried by ash and debris in Pompeii and Herculaneum can be seen in museums today. The sulfur smell noted by Pliny was from volcanic gases.

Pliny also described the earthquakes that occurred before, during, and after the eruption. Similar seismic activity would be expected prior to an eruption of Cascade Range volcanoes, a good warning of an impending eruption. When Pliny mentioned that the "sea was being sucked backwards," he described what happens just before a ***tsunami***. Water typically recedes from shore before rushing quickly back and washing inland. Strong earthquakes associated with the eruption of Mount Vesuvius caused tsunamis to flood coastal areas near the volcano.

Pliny wrote about lightning in the Vesuvius eruption cloud; many people have observed this phenomenon in other volcanic eruptions. The bright sheets of flame observed by Pliny could have been incandescent pyroclastic flows or fires started by volcanic ash.

With Pliny the Elder's interest in the natural world and his ability to make careful observations, he would have made an excellent geologist. Pliny's natural curiosity and careful note-taking are important traits for all scientists to develop.

Teacher Tips

In order to help students develop good observation and note-taking skills, ask students to place all materials from this guide into a portfolio or field journal. This activity can be used as an introduction to their portfolio or field journal.

Procedure

Writing a Journal Entry

Write a journal entry about a volcanic eruption to assess knowledge of volcanic processes and terms.

1. Instruct students to read the account of a hypothetical eruption on the **Eruption!** student page. Students should then finish the story by writing their own hypothetical account of the remainder of the eruption based on their existing knowledge of volcanoes. This exercise is useful as a preassessment tool.

2. Discuss some of the volcanic events portrayed in the students' stories. Write a list of volcano-related terms on a whiteboard or overhead.

Reading a Real Volcano Eruption Story

Read accounts about the A.D. 79 eruption of Mount Vesuvius and compare with the students' journal entries.

1. Briefly describe Pliny the Younger, the A.D. 79 Mount Vesuvius eruption, and the location of the eruption. Use the graphic "***Map of Vesuvius Area***" to show the major cities mentioned by Pliny in his letters. Continue to display the graphic when reading the letters so that students may refer to it.

2. As a class or smaller group, read the eruption accounts on the ***"Letters from Pliny, A.D. 79***" student page as a group. Add to your whiteboard or overhead list of volcano-related terms.

3. Use this list of volcano-related terms and processes to discuss the similarities and differences between Pliny's account of a real volcanic eruption and the students' journal entries.

Adaptations

- Instead of reading Pliny's letters, read survivor accounts from the Mount St. Helens eruptions.
- Direct younger students to draw a picture of a volcanic eruption and label the drawing.

Extensions

- Instruct students to highlight any words they do not understand in Pliny's letters and students should research the definitions.
- At the end of your volcano teaching unit, tell students to reread Pliny's letters and identify the volcanic processes that Pliny describes. How are they similar to processes at Mount St. Helens? At Mount Rainier?
- Use Internet and library research to find drawings or photographs of Pompeii, during the A.D. 79 eruptions and Pompeii today.
- Use Internet or library research to find similarities between the volcanic processes described by Pliny and those predicted by geologists during an eruption of a Cascade volcano.
- Invite an eyewitness of a Mount St. Helens eruption to talk to the class about what they observed when the volcano erupted.
- Watch any video that provides eyewitness accounts of volcanic eruptions and compare the observations made by survivors of any volcanic eruption to Pliny's observations.

Assessment

Use **Eruption!** as a preassessment activity, and to engage students in the study of volcanoes. Repeat writing of "Journal Entry" after completion of activities in Chapters 2 and 3 about volcanic processes and hazards. Compare and assess how the student's ideas have grown to an understanding of eruptions at Mount Rainier and other Cascade volcanoes. Responses should indicate recognition of eruption processes at Cascade volcanoes, including ashfall, lava flows, pyroclastic flows and lahars. Refer to a scoring rubric to assess journal entry writing skills.

References

Gilman, B., 2007, Ashen sky, the letters of Pliny the Younger on the eruption of Vesuvius, illustrated by Barry Moser: Los Angeles, Getty Publications, 39 p.

Harris, S.L., 2005, Fire mountains of the west–the Cascade and Mono Lake volcanoes: Missoula, Mont, Mountain Press Publishing Company, 3rd ed., 454 p.

Lipman, P.W., and Mullineaux, D.R., eds., 1981, The 1980 eruptions of Mount St. Helens, Washington: U.S. Geological Survey Professional Paper 1250, 3rd ed., 844 p.

Radice, B., 1968: Pliny and the Panegyricus: Greece and Rome, v. 15, issue 2, p. 166–172.

Tilling, R.I., Topinka, L., and Swanson, D.A., 1990, Eruptions of Mount St. Helens—past, present, and future: U.S. Geological Survey General Interest Publication (revised edition), 57 p.

Resources

A variety of videos about Mount St. Helens and other Cascade volcanoes are available through:
Discover Your Northwest
164 S. Jackson St.
Seattle, WA 98104
Customer Service: (877) 874-6775
http://www.discovernw.org/

Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

Letters from Pliny the Younger

Instructions: *Read the eyewitness accounts of a real volcanic eruption. Pliny, the Younger wrote these letters about his own and his uncle's experiences during the A.D 79 eruption of Mount Vesuvius in Italy.*

Letter One

My Dear Tacitus,

You ask me to write you something about the death of my uncle so that the account you transmit to posterity is as reliable as possible. I am grateful to you, for I see that his death will be remembered forever if you treat it [sc. in your Histories]. He perished in a devastation of the loveliest of lands, in a memorable disaster shared by peoples and cities, but this will be a kind of eternal life for him. Although he wrote a great number of enduring works himself, the imperishable nature of your writings will add a great deal to his survival. Happy are they, in my opinion, to whom it is given either to do something worth writing about, or to write something worth reading; most happy, of course, those who do both. With his own books and yours, my uncle will be counted among the latter. It is therefore with great pleasure that I take up, or rather take upon myself the task you have set me.

He was at Misenum in his capacity as commander of the fleet on the 24th of August [sc. in 79 AD], when between 2 and 3 in the afternoon my mother drew his attention to a cloud of unusual size and appearance. He had had a sunbath, then a cold bath, and was reclining after dinner with his books. He called for his shoes and climbed up to where he could get the best view of the phenomenon. The cloud was rising from a mountain-at such a distance we couldn't tell which, but afterwards learned that it was Vesuvius. I can best describe its shape by likening it to a pine tree. It rose into the sky on a very long "trunk" from which spread some "branches." I imagine it had been raised by a sudden blast, which then weakened, leaving the cloud unsupported so that its own weight caused it to spread sideways. Some of the cloud was white, in other parts there were dark patches of dirt and ash. The sight of it made the scientist in my uncle determined to see it from closer at hand.

He ordered a boat made ready. He offered me the opportunity of going along, but I preferred to study-he himself happened to have set me a writing exercise. As he was leaving the house he was brought a letter from Tacitus' wife Rectina, who was terrified by the looming danger. Her villa lay at the foot of Vesuvius, and there was no way out except by boat. She begged him to get her away. He changed his plans. The expedition that started out as a quest for knowledge now called for courage. He launched the quadriremes and embarked himself, a source of aid for more people than just Rectina, for that delightful shore was a populous one. He hurried to a place from which others were fleeing, and held his course directly into danger. Was he afraid? It seems not, as he kept up a continuous observation of the various movements and shapes of that evil cloud, dictating what he saw.

Ash was falling onto the ships now, darker and denser the closer they went. Now it was bits of pumice, and rocks that were blackened and burned and shattered by the fire. Now the sea is shoal; debris from the mountain blocks the shore. He paused for a moment wondering whether to turn back as the helmsman urged him. "Fortune helps the brave," he said, "Head for Pomponianus."

LETTER ONE CONTINUED

At Stabiae, on the other side of the bay formed by the gradually curving shore, Pomponianus had loaded up his ships even before the danger arrived, though it was visible and indeed extremely close, once it intensified. He planned to put out as soon as the contrary wind let up. That very wind carried my uncle right in, and he embraced the frightened man and gave him comfort and courage. In order to lessen the other's fear by showing his own unconcern he asked to be taken to the baths. He bathed and dined, carefree or at least appearing so (which is equally impressive). Meanwhile, broad sheets of flame were lighting up many parts of Vesuvius; their light and brightness were the more vivid for the darkness of the night. To alleviate people's fears my uncle claimed that the flames came from the deserted homes of farmers who had left in a panic with the hearth fires still alight. Then he rested, and gave every indication of actually sleeping; people who passed by his door heard his snores, which were rather resonant since he was a heavy man. The ground outside his room rose so high with the mixture of ash and stones that if he had spent any more time there escape would have been impossible. He got up and came out, restoring himself to Pomponianus and the others who had been unable to sleep. They discussed what to do, whether to remain under cover or to try the open air. The buildings were being rocked by a series of strong tremors, and appeared to have come loose from their foundations and to be sliding this way and that. Outside, however, there was danger from the rocks that were coming down, light and fire-consumed as these bits of pumice were. Weighing the relative dangers they chose the outdoors; in my uncle's case it was a rational decision, others just chose the alternative that frightened them the least.

They tied pillows on top of their heads as protection against the shower of rock. It was daylight now elsewhere in the world, but there the darkness was darker and thicker than any night. But they had torches and other lights. They decided to go down to the shore, to see from close up if anything was possible by sea. But it remained as rough and uncooperative as before. Resting in the shade of a sail he drank once or twice from the cold water he had asked for. Then came a smell of sulfur, announcing the flames, and the flames themselves, sending others into flight but reviving him. Supported by two small slaves he stood up, and immediately collapsed. As I understand it, his breathing was obstructed by the dust-laden air, and his innards, which were never strong and often blocked or upset, simply shut down. When daylight came again 2 days after he died, his body was found untouched, unharmed, in the clothing that he had had on. He looked more asleep than dead.

Meanwhile at Misenum, my mother and I–but this has nothing to do with history, and you only asked for information about his death. I'll stop here then. But I will say one more thing, namely, that I have written out everything that I did at the time and heard while memories were still fresh. You will use the important bits, for it is one thing to write a letter, another to write history, one thing to write to a friend, another to write for the public.

FAREWELL,

PLINY THE YOUNGER

LETTER TWO

MY DEAR TACITUS,

You say that the letter I wrote for you about my uncle's death made you want to know about my fearful ordeal at Misenum (this was where I broke off). "The mind shudders to remember ... but here is the tale."

After my uncle's departure I finished up my studies, as I had planned. Then I had a bath, then dinner and a short and unsatisfactory night. There had been tremors for many days previously, a common occurrence in Campania and no cause for panic. But that night the shaking grew much stronger; people thought it was an upheaval, not just a tremor. My mother burst into my room and I got up. I said she should rest, and I would rouse her (sc. if need be). We sat out on a small terrace between the house and the sea. I sent for a volume of Livy; I read and even took notes from where I had left off, as if it were a moment of free time; I hardly know whether to call it bravery, or foolhardiness (I was seventeen at the time). Up comes a friend of my uncle's, recently arrived from Spain. When he sees my mother and me sitting there, and me even reading a book, he scolds her for her calm and me for my lack of concern. But I kept on with my book.

Now the day begins, with a still hesitant and almost lazy dawn. All around us buildings are shaken. We are in the open, but it is only a small area and we are afraid, nay certain, that there will be a collapse. We decided to leave the town finally; a dazed crowd follows us, preferring our plan to their own (this is what passes for wisdom in a panic). Their numbers are so large that they slow our departure, and then sweep us along. We stopped once we had left the buildings behind us. Many strange things happened to us there, and we had much to fear.

The carts that we had ordered brought were moving in opposite directions, though the ground was perfectly flat, and they wouldn't stay in place even with their wheels blocked by stones. In addition, it seemed as though the sea was being sucked backwards, as if it were being pushed back by the shaking of the land. Certainly the shoreline moved outwards, and many sea creatures were left on dry sand. Behind us were frightening dark clouds, rent by lightning twisted and hurled, opening to reveal huge figures of flame. These were like lightning, but bigger. At that point the Spanish friend urged us strongly: "If your brother and uncle is alive, he wants you to be safe. If he has perished, he wanted you to survive him. So why are you reluctant to escape?" We responded that we would not look to our own safety as long as we were uncertain about his. Waiting no longer, he took himself off from the danger at a mad pace. It wasn't long thereafter that the cloud stretched down to the ground and covered the sea. It girdled Capri and made it vanish, it hid Misenum's promontory.

LETTER TWO CONTINUED

Then my mother began to beg and order me to flee however I might, saying that a young man could make it, that she weighed down in years and body, would die happy if she escaped being the cause of my death. I replied that I wouldn't save myself without her and then I took her hand and made her walk a little faster. She obeyed with difficulty, and blamed herself for delaying me.

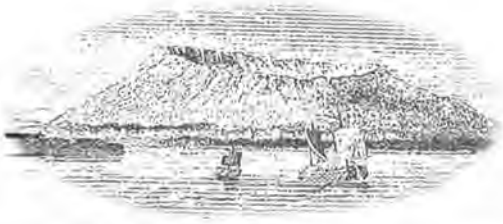
Now came the dust, though still thinly. I look back: a dense cloud looms behind us, following us like a flood poured across the land. "Let us turn aside while we can still see, lest we be knocked over in the street and crushed by the crowd of our companions." We had scarcely sat down when a darkness came that was not like a moonless or cloudy night, but more like the black of closed and unlighted rooms. You could hear women lamenting, children crying, men shouting. Some were calling for parents, others for children or spouses; they could only recognize them by their voices. Some bemoaned their own lot, other than that of their near and dear. There were some so afraid of death that they prayed for death. Many raised their hands to the gods, and even more believed that there were no gods any longer and that this was one last unending night for the world. Nor were we without people who magnified real dangers with fictitious horrors. Some announced that one or another part of Misenum had collapsed or burned; lies, but they found believers. It grew lighter, though that seemed not a return of day, but a sign that the fire was approaching. The fire itself actually stopped some distance away, but darkness and ashes came again, a great weight of them. We stood up and shook the ash off again and again, otherwise we would have been covered with it and crushed by the weight. I might boast that no groan escaped me in such perils, no cowardly word, but that I believed that I was perishing with the world, and the world with me, which was a great consolation for death.

At last the cloud thinned out and dwindled to no more than smoke or fog. Soon there was real daylight. The sun was even shining, though with the lurid glow it has after an eclipse. The sight that met our still terrified eyes was a changed world, buried in ash like snow. We returned to Misenum and took care of our bodily needs, but spent the night dangling between hope and fear. Fear was the stronger, for the earth was still quaking and a number of people who had gone mad were mocking the evils that had happened to them and others with terrifying prognostications. We still refused to go until we heard news of my uncle, although we had felt danger and expected more.

You will read what I have written, but will not take up your pen, as the material is not the stuff of history. You have only yourself to blame if it seems not even proper stuff for a letter.

FAREWELL,

PLINY THE YOUNGER



Student Page

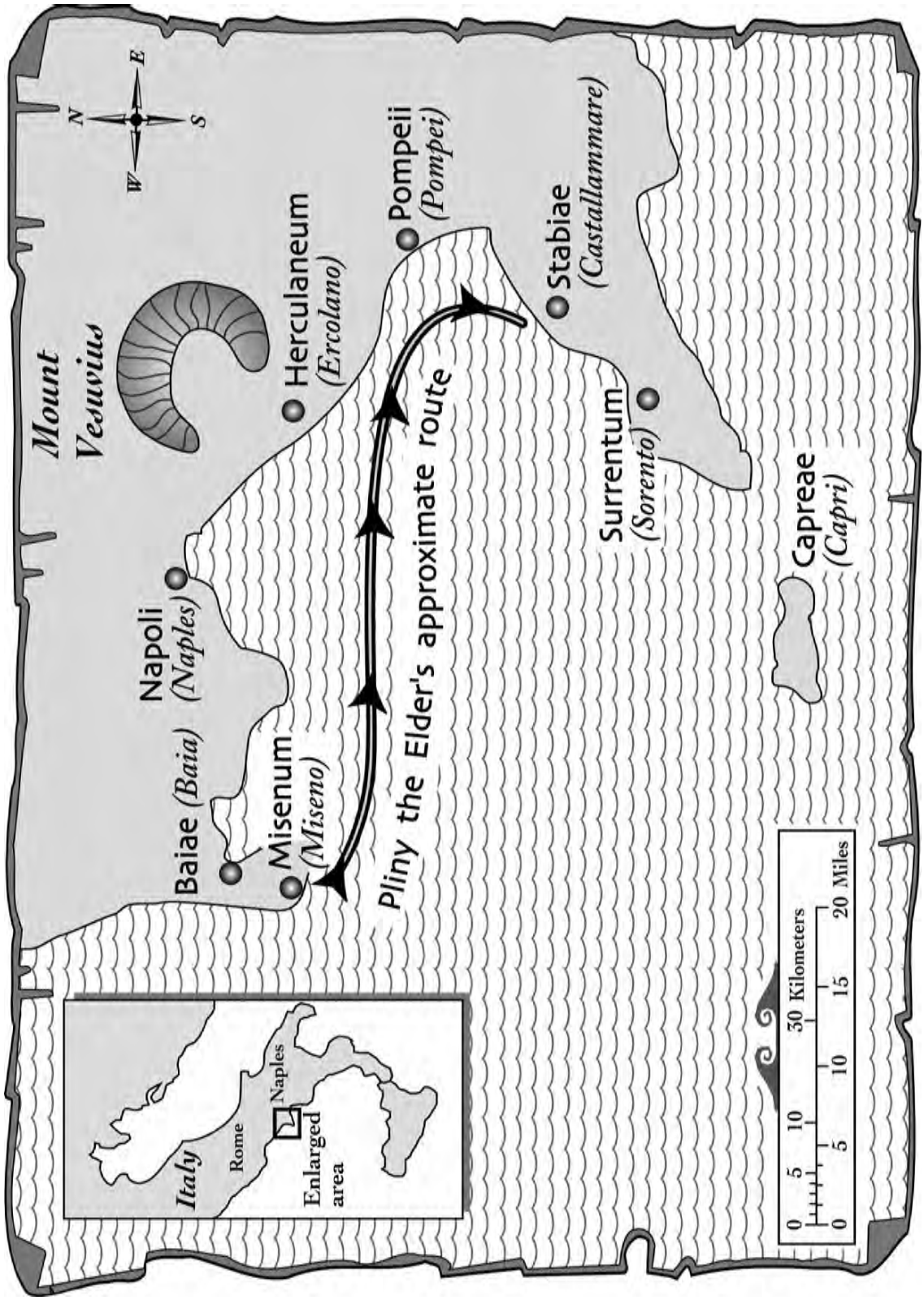
Name _____

Eruption!

Geologists told us that the volcano in our community's backyard was becoming restless. They were right. The volcano erupted! You won't believe all the things that happened?

(Finish the journal entry, explaining the events before, during, and after the eruption.)

Map of the Mount Vesuvius Area



Fire, Flood and Fury!

Geologic Events at Mount Rainier in Native American Oral Traditions

Living with a VOLCANO in Your Backyard
MOUNT RAINIER

Grade Level: 5–9

Learner Objectives:

Students will:

- Recognize that humans and volcanic activity at Mount Rainier coexisted during the past 10,000 years
- Recognize how people have used metaphors to interpret volcanic activity
- Identify and interpret the main points of a story

Setting: Classroom

Timeframe: 50 minutes

Introducing the Native American Tribes near Mount Rainier

Exploring Native American Interpretations of Geologic Events

Materials:

Introducing the Native American Tribes near Mount Rainier

- Graphic of *"Map of Native American Tribes Near Mount Rainier"*

USGS
science for a changing world

Living with a Volcano in Your Backyard- An Educator's Guide with Emphasis on Mount Rainier

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

Native American oral traditions chronicle geologic events in the recent history of Mount Rainier. These stories are read, interpreted, and illustrated by students with the use of storyboards.

Teacher Background

This activity provides information about how some of the earliest human inhabitants in the Pacific Northwest witnessed geologic activity at Mount Rainier. Native Americans used oral, rather than written, communication to pass down historical information, heritage, and traditions (see sidebar on "***Story Telling as a Talent***.")

Native Americans settle near the Cascade Volcanoes

The first humans to live in the vicinity of the Cascade volcanoes arrived during a period of climatic warming at the end of the last great Ice Age approximately 10,000 years ago. Early inhabitants west of the Cascades encountered a landscape undergoing a vast transformation from glacial to vegetative cover. Gigantic glacial floods abated east of the Cascades, which permitted revegetation of freshly scoured land surfaces and river channels.

These first inhabitants consisted of foragers who ranged widely across the landscape and had the skills to utilize a variety of plants and animals from their local environments. Approximately 3,000 to 4,000 years ago, most people settled into villages along the waterways where they had easy access to their canoes and nearby food sources, especially salmon. Villagers became expert at seasonal harvesting and preserving.

Activity last modified: September 5, 2014

- Graphic *"Early Observer Views Mount Rainier and a Lahar Spreading over the Valley Floor"*

Exploring Native American Interpretations of Geologic Events

- Copies of *"Fire, Flood, and Fury—Native American Stories of Mount Rainier"* student page
- Copies of *"Fire, Flood, and Fury—Native American Stories of Mount Rainier"* teacher discussion questions

Vocabulary: Lahar, metaphor

Skills: Communicating, presenting

Benchmarks:

See benchmarks in Introduction.

Native Americans witness volcanic eruptions

Volcanic activity at Cascade Range volcanoes has been frequent and dramatic throughout the last 10,000 years. Most volcanoes in the Cascades have lit the skies with eruptions during the period between the beginning of settlements and the present. Mount Rainier experienced remarkable changes during this period. Hundreds of eruptions produced volcanic rock and ash that enlarged the volcano. At one point, a large piece of the volcano disappeared during a massive landslide, but the mountain rebuilt itself. Rock debris from ***lahars*** (volcanic mudflows) buried valley floors repeatedly, sometimes as far away as 100 kilometers (60 miles) from their source on Mount Rainier.

The ancestors of people now affiliated with tribes such as the Cowlitz, Nisqually, Squaxin Island, Puyallup, Muckleshoot and Yakama observed many volcanic events and depicted them through stories in an attempt to understand the world. People on the west side of the Cascades told their stories in various dialects of the Salishan language, while those on the east side spoke in dialects of the Sahaptin language. The name of the mountain varied with the dialect—Tacobed, Taqo'men, Takhoma, and Tahoma. These words are interpreted most often as "the mountain," but have also been expressed as "snow peak" or "water/young person." The stories provided in this activity are selected from broader collections available in local bookstores and libraries. From the descriptions, we can understand the kinds of geologic events that happened in the past, though the timing is less well known. These stories provide early human narratives about volcanic impacts in the Pacific Northwest—the same hazards facing people today.

Sidebar 1 Who were the Native Americans That Lived near Mount Rainier?

Survival in the Pacific Northwest required continuous hunting, gathering and storing food. The land on and around Mount Rainier provided much for their daily needs.

West of the Cascades

Inhabitants on the west side of Mount Rainier (now members of the Nisqually, Squaxin Island, Puyallup, Cowlitz and Muckleshoot Tribes) lived with relative ease most of the time. Everything required for their livelihood was found in abundance in the world around them. Cedar trees supplied wood for construction of their multi-family longhouses, canoes, articles of clothing, and household goods. They obtained food easily because nearby rivers, wetlands, and shorelines teemed with life. Salmon was their staple food, but meats, shellfish, berries, bulbs, roots, and other wild plants were also eaten.

SQUAXIN

ISLAND

East of the Cascades

Inhabitants on the east side (now primarily affiliated with the Yakama Nation) hunted on the high ground where deer and elk were plentiful. They harvested berries, bulbs, roots, and other wild plants from the land around them.

People from both sides of the Cascades ventured to the slopes of Mount Rainier for foraging and hunting. Because the rock at Mount Rainier was not suitable for making sharp-edged implements, the people carried most tool-making materials with them. Goat wool, highly sought for clothing, was obtainable at Mount Rainier. All of the tribes recognized the mountain as a source of water, life, and inspiration.

YAKAMA

Sidebar 2 Commentaries on the Native American Stories in this Activity

The Lake on Mount Rainier

A young man carried shell offerings to the mountain's icy summit and camped by a lake within the crater rim. The presence of lake water at the summit impressed him, and he became convinced that the lake would one day drain. When the lake did drain, water swept away trees from where the city of Orting now exists, and left the area covered with stones. Some believe that this story refers to a lahar (volcanic mudflow) that swept across the Puyallup River Valley.

PUYALLUP

The Mountains

This classic story of jealousy between two wives (two mountains) is used to explain how Taqo'men (Mount Rainier) lost its original summit. The reference to an event where the volcano's "head broke off" could refer to one or more large landslides that removed summit rocks.

COWLITZ

The Husband and Wife Arguement

According to this story, feuding Mount Rainier and Mount St. Helens erupted simultaneously. The suggestion that Mount St. Helens knocked the top off Mount Rainier is intriguing.

COWLITZ

Tacobed and Changer

The story speaks of Tacobed (the Puyallup name for Mount Rainier) growing taller and broader, like a monster devouring people who harvested berries on its slopes. The people asked their divine being the Changer) to rescue them. After a contest with Changer, Tacobed's blood vessels burst causing streams of blood that rushed down her sides, followed by rivers of water, then quiescence. Some people interpret the blood as lava and the rivers that followed as lahars (volcanic mudflows) and (or) present-day rivers.

PUYALLUP

The Miser of Mount Rainier

(For more advanced readers who can do research). Volcanic activity serves as the impetus for life transformation in this classic story of personal conversion from greediness to benevolence.

NISQUALLY

Sidebar 3

Storytelling is a Talent

Stories can be told by anyone. A storyteller changes the focus or emphasis of a story in an elastic manner, depending on the audience's needs. Native Americans developed skills and talents such as, hunting, tool making, healing or storytelling that were beneficial to the entire tribe. Individuals born into families with specific gifts were groomed to use and bequeath that knowledge. Storytelling still plays a major role in passing down the traditions, heritage, and history of Native American tribes.

Storytelling and legends taught native people lessons they needed to know—the way to live safely and harmoniously within their society and nature. Often, the vehicles Native Americans used were metaphors to relate these stories to everyday life. In using metaphor to teach aspects of culture, Native Americans did not always distinguish the sacred from the secular. Characters in stories who personify human traits are as sacred as characters who personify non-human deities or elements. In one personification, native people saw Mount Rainier as a mother providing bounties of food and medicinal plants, cedar and yew materials, meat and fur-bearing animals. In an alternate incarnation, Mount Rainier was the hallowed residence of spirits, a place where intruders who climbed above an invisible line were punished with death.

Native people who lived in the Mount Rainier area told many stories that recorded geologic events and warned of the hazards of living in a volcanic area. For example, the Puyallup Tribe tells a story of conflict between Tacobed (Mount Rainier) and Changer (the creator of all things). Tacobed and Changer hold a contest to see who can be the highest. The story shows people's awareness of the growth of a volcanic cone. In the story, Changer builds a fire inside Tacobed until the grease inside begins to drip and her insides get smoky. After a time, she ceases to move and Changer pronounces her dead. The dying fire may describe native people's observation that Rainier, compared to more eruptive volcanoes in the Cascades, had grown quiet. Other stories describe the 500-year-old Electron Mudflow that inundated the land near Orting (see The Lake on Mount Rainier).

Through the use of metaphor, native people explained natural history and geologic events at Mount Rainier, and understood these events as shapers and transformers of human affairs. Their oral traditions survive today and provide an important record of ancient historical events.

Europeans who first settled in the Pacific Northwest roughly two hundred years ago also observed volcanic activity at Rainier. They communicated their stories through written documents, journals, and mass media publications. Today, geologists use scientific methods to study and decipher Mount Rainier's geologic record, expanding the scope of knowledge beyond anecdote. We can benefit from interpreting the rock formations and oral traditions of the Native Americans by discovering and understanding the evidence of past geologic and volcanic activity at Mount Rainier in anthropological and scientific terms. In this way, we can more effectively anticipate the kinds of eruptive events common to Mount Rainier and prepare for the future.

The New World Dictionary describes "metaphor" as "a figure of speech containing an implied comparison...where a word or phrase usually and primarily applied to one thing is applied to another." Native Americans used metaphor commonly to describe and catalog events in the world around them. Take the time to introduce your students to the concept before conducting the activity. The sidebar "Story Telling as a Talent" provides background information about their use of metaphor.

Procedure

Introducing the Native American Tribes Near Mount Rainier

Introduce the Native American tribes that lived near Mount Rainier by using the map and teacher-led discussion.

Display the graphics "***Map of American Indian Tribes near Mount Rainier***" and "***Early Observer Views Mount Rainier and a Lahar Spreading over the Valley Floor***."

1. Use information in the background section and sidebars to guide students in a discusion about why they think Native Americans may have lived near Mount Rainier.

2. Point out the Native American groups and their tribal symbols on the map. Tribal names represent the modern remnant of previously larger populations.

3. Ask students to explain what the symbols tell us about features of importance to each Native American group.

4. Query students about why Native Americans ventured onto the slopes of Mount Rainier. What animals, plants, and rocks from Mount Rainier's slopes might these people have used?

5. Did Mount Rainier hold spiritual value? How does Mount Rainier hold value for inhabitants of the region today?

6. Discuss the definition and examples of metaphors. How might Native Americans have used metaphors in their stories about events?

Consider inviting a local Native American storyteller, members of your local storytelling guild, or your school's drama and (or) theater group to read aloud or act out the stories in this activity.

Exploring Native American Interpretations of Geologic Events

Examine and interpret five Native American stories about geologic events at Mount Rainier by making a storyboard.

It is highly recommended that the teacher read the story or stories used before class. Some stories may not be appropriate for younger students.

1. Divide the class into groups of 5 to 6 persons.

2. Provide each group with one of the stories in "***Fire, Flood, and Fury—Native American Stories of Mount Rainier***" student page.

3. Instruct each group to read their story aloud within their group.

4. Choose the level of discussion and activity below that is most appropriate for your students.

5. Use the ***"Fire, Flood, and Fury—Native American Stories of Mount Rainier"*** teacher discussion questions to foster additional thought.

Option 1: Instruct students to make a storyboard depicting their story.

- Explain that a storyboard is a cartoon rendering of the story. The storyboard is divided into frames, and each frame contains a student illustration depicting a scene.
- The storyboard should include 2 to 5 illustrations of scenes from the story.
- Students decide which scenes to include that will depict their interpretation.

Option 2: Direct students to make a storyboard, explain the storyboard to the class, then narrate or perform the story as a skit from their storyboard renderings.

Adaptations

- Instead of using a storyboard, discuss and read the stories aloud as a class.
- In place of the storyboard, instruct each student group to write their interpretations of the story. Ask each group to share their interpretations with the class.
- In classes for younger students, draw a storyboard on large poster paper. Display the storyboard while reading the story, and then discuss the scenes with students.
- Use stories about volcanic activity at other Cascade volcanoes. Students can find these stories using the Internet and library resources.

Extensions

- Learn all you can about the Native Americans living near Mount Rainier using computer research or library resources.
- Interview a Native American who lives near one of the volcanoes in the Cascades about the significance of the volcano in their culture.
- Make a poster-size version of the "***Map of Native American Tribes near Mount Rainier***." Attach to the poster stories, photos, and drawings of people interacting with Mount Rainier to the poster.
- Write your own explanation to describe a volcanic eruption in the Cascades.
- Interview people in your family about geologic events (e.g., volcanic eruptions, earthquakes, tsunamis, and large floods) that they remember happening in their lifetimes.
- Use video, audiotapes, photos and written records to assemble a record of uncommon and extraordinary natural events that have occurred in your community.

Assessment

For assessment, review the storyboards and look for evidence of student recognition that humans and volcanic activity have coexisted at Mount Rainier for many millennia; that people have used metaphor to interpret volcanic activity; and that students can identify and interpret the main points of a story. Assess application to real-world situations by assigning an additional storyboard that depicts current natural events.

References

Blukis O., Astrida R., 1999, Tahoma legends—history in two voices: BOAS Research Report 9300.2b for National Park Service Pacific Northwest Region, 126 p.

Carpenter, C.S., 1989, They walked before us—The Indians of Washington state: Tacoma, Wash., A Tahoma Research Publication, 69 p.

Carpenter, C.S., 1994, Where the waters begin: Seattle, Wash., Northwest Interpretive Association, 108 p.

Clark, E., 1953, Indian legends of the Pacific Northwest: Berkeley, Calif., University of California Press, 225 p.

Guralnik, D.B., 1980, Webster's new world dictionary: Cleveland, Ohio, Williams Collins Publishers, p. 893.

Wilson, R.I., 2001, Legends of the Cowlitz Indian Tribe: Bremerton, Wash., Cowlitz Indian Tribe, 401 p.

Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

Credits

Drawing "***Native American Views Mount Rainier and a Lahar Spreading over the Valley Floor***" by Linda Feltner, Seattle, Washington, used with permission.

Teacher Discussion Questions

General Questions

Q: What might scientists hope to learn from these stories?
A: ***Native stories provide very general information about the occurrence of volcanic events and how the events affected local populations. In some cases, Native stories tell us about events that either left no geologic deposits or deposits that are hard to find.***

The Lake on Mount Rainier

Q: Tacobed tells the grandfather that Tacobed's head will burst open. What is the fate of water within the lake at the mountain summit? What does this mean for the land below.
A: ***The lake on Tacobed will drain and pour down the flanks of the volcano, carrying away rock debris and vegetation that will bury the valley floor.***

Q: Geologists know that a lahar (volcanic mudflow) gushed from Mount Rainier, poured over the land, and flooded the present site of Orting around 500 years ago. Does this story describe first-hand knowledge of the flood?
A: ***The story describes the mudflow that settled in the present site of Orting, but it is not first hand knowledge. Each generation of inhabitants delivered the story orally to the next, the story perhaps changing in detail.***

The Mountains

Q: What characters are the mountains? What are their relationships?
A: ***White Mountain or Patu is Mount Adams. He is the Husband of two wives—Taqo'men (Mount Rainier) and Lawelatla (Mount St. Helens).***

Q: What do you think the fighting between these characters describes?
A: ***The fighting describes two mountains (Mount Rainier and Mount St. Helens) erupting in the same general period of time.***

Q: What happens to Taqo'men? What do you think that symbolizes?
A: ***Taqo'men is hit on the head and her head falls off. This could symbolize the change in shape of Mount Rainier's volcanic cone caused by a volcanic eruption or landslide.***

The Husband and Wife Argument

Q: What is the rumbling heard by Xwa'ni? What is its source?
A: ***Xwa'ni heard rumbling from Lawelatla (Mount St. Helens) and Takhoma (Mount Rainier). The two volcanoes erupted (fought, as told in this story).***

Q: Lawelatla blows her top. What could this symbolize? Takhoma's head is knocked off. What does that communicate?

A: ***Lawelatla's blowing her top symbolizes Mount St. Helens erupting. Takhoma's head being knocked off describes how Mount Rainier's volcanic cone changed shape after the eruption. The description may indicate that part of the volcano was removed by eruption of rock fragments or by collapse in a landslide.***

Q: This very old story describes simultaneous eruptions of Mount Rainier and Mount St. Helens. The story of eruptions at multiple volcanoes was told long before scientists discovered physical evidence of their occurrence. How might the reports of these simultaneous eruptions be of value to scientists and planners who wish to prepare for future events?

A: ***Scientific evidence enables scientists and planners to theorize that the eruptions were "simultaneous" within a human generation. These "simultaneous" eruptions of Mount St. Helens and Rainier could have occurred around 2,500 to 2,600 years ago, between 1480 and 1583, or between 1843 and 1850. Multiple volcanoes have erupted during the same general time period in the past; they could do so again.***

Tacobed and Changer

Q: Native people respected and feared natural forces. Why do you think they created this story? How did this story help them understand nature?

A: ***All cultures seek explanations for the origin of features and events familiar to them. They created this story to comprehend the origin of the two mountain ranges (Cascades and Olympics) and to explain why Mount Rainier erupted in the past but not at the time when the story was told.***

Q: Why is Tacobed getting bigger?

A: ***Tacobed is getting bigger because it is erupting and depositing volcanic materials on its flanks.***

Q: What might have made native people change their opinion of Tacobed and see her as a monster?

A: ***An eruption that destroyed the land might have caused native people to change their opinion of Tacobed.***

Q: Before Tacobed turned into a monster, she provided life-sustaining substances to the people. What did she give them?

A: ***She provided food (salmon) and water.***

Q: When Tacobed draws in a very deep breath, she bursts her blood vessels, and the blood gushes and pours down her sides. What does blood do for a body? Why does this native story see the gushing fluid as blood?

A: ***Blood and hot lava can both be red. Blood gives the body life. The gushing fluid coming from Tacobed is described as blood because the life and activity of the mountain is taken away and the mountain becomes harmless.***

Q: The blood is changed into rivers of water. Why is water important? What promise does Changer make about the water?

A: ***Water is necessary for humans. Changer promises that Tacobed will remain harmless; fish will return to the rivers. The story tells how a volcano, after an active period, regains its calm. Wildlife and plants will return to the volcano's slopes and provide sustenance.***

Q: Do you think Tacobed is dead or napping?

A: ***Tacobed is napping.***

The Miser of Mount Rainier

Q: The old man takes all the hiaqua he can find. Why does this make Sahale angry? What is the punishment?

A: ***This made Sahale angry because he did not leave any hiaqua as an offering to the tamanowas powers that helped him discover the treasure. Sahale punished the old man by causing a great storm, burying the man in snow, sending demons, erupting fire and ash, and causing water to pour down the slopes of the volcano from the lake at the summit of the volcano.***

Q: What evidence in the story tells us Mount Rainier is a volcano?

A: ***Sahale erupted fire (perhaps lava and pyroclastic flows) and the air became thick and hot (ash). Water flowed from the summit, which may have been the summit lake draining or lahars (mud flows).***

Q: What changes does he see in the mountain?

A: ***The mountain lost its top and generally changed shape.***

Fire, Flood and Fury—Native American Stories of Mount Rainier

Native Oral Traditions from the Puyallup Tribe

The Lake on Mount Rainier

When the grandfather of my grandmother was a young man, he climbed Tacobed. He climbed to the top in search of spirit power.

Before he started, he made five wedges of elk horn. After he reached the snow line, he used the elk-horn wedges to cut steps in the snow and ice. When one wedge wore out, he threw it away and used another one. At the end of a day of climbing, when he reached the top of the mountain, the fifth wedge was worn out.

On the mountaintop he saw a small lake. He made camp beside it and stayed there all night. Next morning he swam and washed himself in the lake. There he gained spirit power. He felt strong and brave and wise.

Then the mountain spoke to him. 'Because you have stayed one night with me, I can talk to you. You will become an old, old man, because of your spirit power. When you are very old, moss will grow on your knees and on your elbows. Moss will grow on your head after your hair has fallen out. At last you will die of old age.

At the time of your death, my head will burst open. The water from the lake here will flow down my sides into the valleys below. I, Tacobed, have spoken. All things will come to pass even as I have prophesied.'

When the mountain stopped talking, the young man picked up five shells and started home. Before he had gone far, snow began to fall.

'Oh, I have displeased Tacobed. He does not wish me to carry shells away,' the young man said.

He threw one shell down, then the other four, one at a time. The snowing stopped. With empty hands but with strong spirit power within him, he returned home.

Years passed. The man became old. When he was very old, everything happened just as Tacobed had prophesied. His hair fell out. Moss grew on his knees, his elbows, his head. To his people he said, 'When I die, look up at the mountain. Tacobed's head will burst open. The water from the lake on top will spill down the mountainsides.'

The old man died, and it was as he had said. Tacobed's head burst open, the lake on top spilled out, and the water rushed down. It swept the trees from where Orting now is, and left the prairie covered with stones.

White people have never seen the lake on Tacobed. My grandmother, who told me the story, remembered when the lake burst and spilled out.

from Indian Legends of the Pacific Northwest
by Ella E. Clark

Fire, Flood and Fury—Native American Stories of Mount Rainier-continued

Native Oral Traditions from the Cowlitz Tribe

The Mountains

White Mountain was a man (Patu-Mount Adams). He had two wives and stood midway between them. The two women became angry with one another and started to fight. The one at the south threw fire at Mount Rainier (taqo'men). The fire hit taqo'men but she threw it back at her rival. They kept this up. Finally, taqo'men got struck very badly and her head broke off. The other woman got the best of her.

from Legends of The Cowlitz Indian Tribe
edited by Roy I. Wilson

The Husband and Wife Argument

Once in the long ago time Xwa'ni was going up the Seqiku (Toutle River), and he heard a great rumbling. He perked up his ear and soon realized that it was Lawelatla (Mount St. Helens). He could tell that she was very angry. Soon he heard another great rumbling coming from another direction. He perked up his other ear and soon realized that this was Takhoma (Mount Rainier). He was also very angry. They were having a husband and wife argument and fight, and he was in between them. Then he saw Lawelatla blow her top and knock the head off of her husband Takhoma.

from Legends of The Cowlitz Indian Tribe
edited by Roy I. Wilson, Roy I. Wilson, used with permission:
Roy L. Wilson, Bremerton WA © 2001

Fire, Flood and Fury—Native American Stories of Mount Rainier-continued

Native Oral Traditions from the Puyallup Tribe

Tacobed and Changer

Long ago, the peaks of Ho-had-hun were people. White people call Ho-had-hun the Olympic Mountains. One of the warrior peaks there was named Swy-loobs. He married a maiden peak, Tacobed.

Even after they were married, they and the other peaks kept on growing. They became so large that after a while they were crowded in their small space. Tacobed especially was growing both taller and broader. At last she said to the others, "I will move to a place not so crowded. Then there will be more room for the rest of you."

She spoke to the rising sun. "The people over there have no mountains. I will move across the water and give myself plenty of room. I will take salmon and berries with me, so that the people over there will have plenty to eat."

The peaks of Ho-had-hun had grown so close together that Tacobed found it hard to get loose from them. But she freed herself and moved across the Sound. There she had plenty of room. She grew taller and taller, broader and broader, until she became a giant mountain.

After she had been on the east side of the water for a while, she turned into a monster. She devoured the people who came up on her slopes for berries. She devoured those who came to her forests for deer and elk. She sucked into her cavelike stomach all the people who came near her. Then she devoured them. Their friends and their tribesmen lived in great fear.

At last they asked the Changer to come and rescue them from the mountain monster. When the Changer came, in the form of Fox, he decided to challenge Tacobed to a duel. But first he made a strong rope by twisting twigs of hazel bushes and tying them together. He tied himself to a mountain near Tacobed and then called out to her, "O mountain monster, I challenge you to a sucking contest. I defy you to swallow me as you have swallowed your neighbors."

Tacobed drew in one deep breath after another. She sucked in rocks and boulders and trees, but she could not make Fox move. Again and again she tried, but Fox did not even stir. The rocks which rolled by scratched and bruised him, but he could not be moved. At last Tacobed drew in such a deep breath that she burst her blood vessels. All over her body, rivers of blood gushed forth and flowed down her sides.

Then the mountain monster died, and the Changer made a law. "Hereafter, Tacobed shall be harmless. The streams of blood shall turn to rivers of water. The waters shall have plenty of fish, for the good of all the people who come to the lakes and rivers on the mountain."

from Indian Legends of the Pacific Northwest
by Ella E. Clark, Roy I. Wilson, used with persmission: Roy I. Wilson, Bremerton, WA,© 2001

Fire, Flood and Fury—Native American Stories of Mount Rainier-continued

Native Oral Traditions from the Nisqually Tribe

The Miser of Mount Rainier

There was an old man living near the Mountain who was very avaricious and desirous of obtaining much 'hiaqua'—which is shell money still common among Indians of the Sound. This old Indian was on very intimate terms with Sahale and kept begging him to supply him with more money by magic, for the long and laborious processes of saving and hoarding were too slow for the old Indian. Sahale, however, was aware that his greed for hiaqua was liable to make the old man a victim of Kahahete, the chief of the demons, and therefore he always refused to grant him any magic power.

But Moosmoos, the Elk divinity, obtained a tamanowas [spirit] power over the old Indian and whispered magic in his ear, telling him that on the summit of the Mountain he might find much hiaqua and become the richest man in the world. Going back to his camp, he informed his wife that he was going on a long hunt—but in reality he was setting forth for the summit of the Mountain. The first day he climbed almost to the top, and next morning at the rising of the sun he stood upon the crest. He discovered that there was a great valley on the summit, filled except in one place with snow. Here was a lake of black water, and at one end of the lake there were three black rocks. The old man was confident that those were the tamanowas rocks; for one was shaped like a salmon's head, another like a camas root, and the third like the head of his own totem or divinity, Moosmoos, the elk.

The old Indian, observing these symbolic rocks, concluded that this must be the place where the hiaqua was secreted. He began to dig at once with the elk horn pick which he had brought for the purpose, at the feet at the elk shaped rock. At this gesture, a number of otter came out of the lake and gathered around in a circle. When the man had struck the ground a number of times equal to the number of otter, they began to pound the ground with their tails. Still he continued to dig, and about sundown he overturned a large rock under which he discovered a large cavity completely filled with hiaqua—great strings of it, and enough to make him the richest of all men.

But now the greedy adventurer made a great mistake. He loaded himself with the strings of hiaqua and left not a single shell as an offering to the tamanowas powers by whose magic he had made the discovery. Sahale was greatly displeased at such ungrateful conduct, and all the tamanowas powers combined to show their wrath. Skamson [Wha-quoddie], the thunder bird,

Fire, Flood and Fury—Native American Stories of Mount Rainier-continued

Native Oral Traditions from the Nisqually Tribe

The Miser of Mount Rainier continued

Tootah, the thunder, and Colasnass, the snow god, all swooped down from the clouds, turned the sky black and blew the old man with the strings of hiaqua about him across the rocks causing him to lose his way and finally burying him in the snow. out of the darkness came the terrible voice of Sahale, denouncing his wickedness. Also the terrified Indian began to hear the mocking voices of Kahatete and his attending demons. The whole framework of nature seemed about to disrupt; for after the snowstorm there came a burst of volcanic fire from the summit, the air became thick and hot and streams of water poured down the mountainside.

In spite of all of this confusion of nature, the Indian retained his consciousness, and he began to think of how he might propitiate the offended deities. He dropped one of the strings of hiaqua as an offering—but this seems to have been a mere mockery, and the demons kept howling at him in derisive tones, 'Hiaqua! Hiaqua!' then the Indian flung away one string after another until they were all gone, and fell upon the ground exhausted and entered into a deep sleep. When he awoke, he found that he was at the same place where he had fallen asleep on the night before he set out for the summit.

Being very hungry, he set about gathering camas roots with which to refresh himself, and while eating he began to have many thoughts in regard to his life and doings. His 'tum-tum' (heart) was much softened as he contemplated his greed for hiaqua. He found that he no longer cared for it, and that his mind was calm, tranquil and benevolent. Moreover, when he looked at himself in a pool, he discovered that he had changed marvelously. His hair had become long and white as snow. The Mountain itself had changed its form. The sun shone brightly, the trees glistened with new leaves and the mountain meadows were sweet with the perfume of many flowers. Birds sang in the trees, and the great mountain towered calm, tranquil and majestic into the deep blue sky, glistening with the fallen snow. All nature seemed to rejoice and the old Indian found that he was almost in a new world.

Then he seemed to remember where he was, and he made his way without difficulty to his camp. There he found an old woman with white hair whom he did not recognize at first, but soon he discovered her to be his own 'klootchman' (woman). She told him that he had been gone many suns and

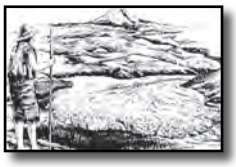
Fire, Flood and Fury—Native American Stories of Mount Rainier-continued

Native Oral Traditions from the Nisqually Tribe

The Miser of Mount Rainier continued

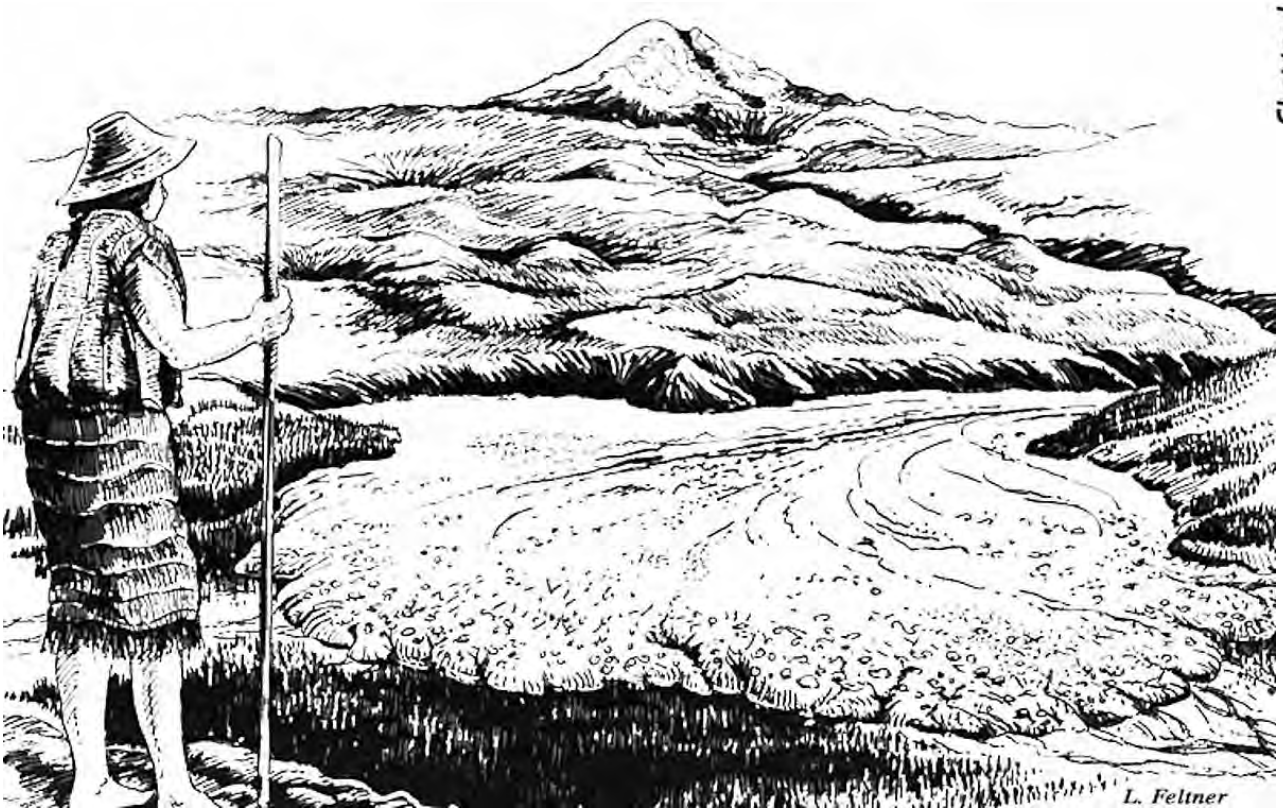
moons, and that in the meantime she had been digging camas and trading for hiqua, of which she had accumulated much. The old Indian now perceived all the mistakes of his former avaricious life and settled down on the banks of the Nisqually in peace and contentment. He became a great tamanowas man and a counselor and advisor to the Indians in all kinds of trouble. He was worshipped by them for his wisdom and experience and benevolence, as well as for his strange experience upon the summit of the Mountain."

from Where the Waters Begin, Cecelia Svinth Carpenter,
Used with permission: Northwest Interpretive Association, Seattle, © 1994



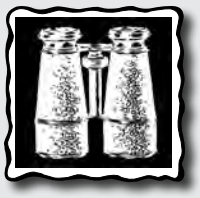
Native American Tribes near Mount Rainier

Early Observer Views Mount Rainier and a Lahar Spreading over the Valley Floor



Drawing by Linda Feltner, Seattle, Washington, used with permission.

Nineteenth-Century Newspaper Accounts of an Eruption at Mount Rainier



Grade Level: 5+

Learner Objectives:

Students will:

- Recognize that eruptive activity at Mount Rainier occurred as recently as the end of the nineteenth century
- Understand that not all volcanic activity at Mount Rainier is large or destructive
- Recognize that the number of eruptions at Mount Rainier exceeds the number of eruptions we know about because not all eruptions leave long-lasting physical evidence

Setting: Classroom

Timeframe: 30 minutes; plus interviewing and writing time

Reading about Nineteenth-Century Volcanic Activity at Mount Rainier

Getting the Scoop

continued.....

USGS science for a changing world
NATIONAL PARK SERVICE

Living with a Volcano in Your Backyard-An Educator's Guide with Emphasis on Mount Rainier

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

Nineteenth-century newspaper accounts report recent eruptions at Mount Rainier. The minor eruptive activity at Mount Rainier illustrates not all eruptions are large or destructive.

Teacher Background

Reports imply activity at Mount Rainier during the nineteenth-century

Oral reports passed down by Native Americans and early pioneers imply that Mount Rainier's summit experienced unusual steam activity during the middle and near the end of the nineteenth century. While some reports bear accurate resemblance to accounts at other awakened volcanoes, today's geologists find no physical evidence of an actual ***eruption***. Some people theorize that the mountain experienced a period of reheating and explosive steaming that did not culminate in an eruption of fresh lava. Certainly, many small events leave little long-lasting physical evidence. Other people dismiss the observations as unusual weather phenomena, or to sensational journalism. These news reports, first published in pioneering newspapers, make for interesting reading. A few reports are reproduced by permission. A variety of accounts also refer to additional volcanic activity around 1873, though little detail is known of those events.

Activity last modified: November 21, 2014

Materials:

- Graphic of *"Steam Activity at Mount Rainier as Viewed from Seattle, Washington, during late Nineteenth Century"*
- Copies of *"Nineteenth-Century Newspaper Accounts"* student page
- Copy of *"Nineteenth-Century Newspaper Accounts"* teacher discussion questions
- Copies of *"Getting the Scoop"* student page

Vocabulary: Ash cloud, earthquake, eruption, lava, magma, tephra, volcanic ash

Skills: Data collection, interviewing, reading, reporting synthesis

Benchmarks:

See benchmarks in Introduction.

Newspaper reports during 1894 and 1895 list eyewitness accounts

According to contemporary newspaper accounts, hundreds of people in Seattle, and staff on an exploratory winter expedition to Mount Rainier watched "black smoke" (recognized today as steam and fragments of rock), rise from the summit in pulses of a fraction of a minute apart. Many observers noted slight changes to the mountain's profile, now presumed to be changes in the snow pack. They also sensed an increase in ***earthquakes***, and observed avalanches, and rockfalls on the slopes of the mountain. The majority of eyewitnesses were Seattle residents who had a more direct view the Columbia Crest part of the summit than their Tacoma counterparts.

Procedure

Reading About Nineteeth-Century Volcanic Activity at Mount Rainier

Write a journal entry about a volcanic eruption to assess knowledge of volcanic processes and terms.

1. Introduce this activity by initiating discussion using information from the "***Chapter 1 Background***" in this guide about different types of volcanoes and styles of eruptions. Small events can lead to larger scale volcanic activity, intermittent activity, or a sudden return to slumber. Display the graphic "***Steam Activity at Mount Rainier as Viewed from Seattle, Washington, during late Nineteenth-Century***" during your discussion.

2. Provide each student with a "***Nineteenth-Century Newspaper Accounts***" student page.

3. Instruct students to read the passages as though they were observers one hundred years ago. Then, ask them how their descriptions of these events might be similar or different today.

4. Describe the history behind the newspaper articles as explained in the teacher background.

5. Use the "***Nineteenth-Century Newspaper Accounts***" teacher discussion questions to discuss the articles as a class.

Getting the Scoop

Practice writing a newspaper article on a geologic event in the Pacific Northwest by interviewing an adult who remembers or witnessed it.

1. Discuss some recent geologic events (volcanic eruptions, earthquakes, lahars, ash falls, floods, etc.) that have taken place in the Pacific Northwest during the students', parents' and grandparents' lifetimes. If needed, refer to the **Cascade Volcano Timeline** activity.

2. For homework, ask students to prepare a list of five to ten questions on the "***Getting the Scoop***" student page to use to interview an adult about a geologic event. Questions should include who, what, where, when, why, and how.

3. Instruct students to interview an adult about a geologic event in the Pacific Northwest that the person remembers or witnessed. Students should use the questions they prepared and

4. Ask students to write a newspaper article (two to three paragraphs long) to "report"the geologic event.

5. Compile all the student articles and share them with the class.

Adaptations

- Using "***Getting the Scoop***," ask students to check their witnesses' stories with published articles about the geologic events. Did the witness remember the event correctly? Did they remember all the important details?

Extensions

- Instruct students to conduct an Internet or library search on different types of volcanoes (shield, cinder cone, stratovolcano or composite) and volcanic eruptions (Plinian, Strombolian, Hawaiian, etc.). How are they different?
- Instruct students to perform an Internet or library search on current natural hazards or volcanic activity in the world. Advise students to follow the course of volcanic activity at one of Earth's more frequently active volcanoes, such as Arenal, Colima, Etna, Kilauea, Mayon, Merapi, Oshima, Poas, Pacaya, Pavlov, Popocatepetl, Ruapehu, Sakura-Jima, San Cristobal, Santa Maria (Santiaguito), Spurr, St. Helens and Unzen. Students assemble a chronology of events that took place over a period of weeks, months or years. They write a report about the activity that took place and predict what volcanic activity people living near the volcano can expect in the future. Was volcanic activity spectacular and destructive at all volcanoes?

Assessment

Use results of the teacher discussion questions to assess students' recognition of the recentness of eruptive activity at Mount Rainier; about how eruptions can be so small as to be disputable; that not all eruptions leave long-lasting physical evidence. Assess students' ability to think on a global scale by review of their results on student page "***Getting the Scoop***." Do their interview questions glean information based on observations? Do students recognize that observations can be disputable? How well have they applied information learned in this activity to a real-world situation?

References

Harris, S.L., 2004, Fire mountains of the west: The Cascade and Mono Lake volcanoes: Missoula, Mont., Mountain Press Publishing Company, 3rd ed., 454 p.

Majors, H., 1981, Mount Rainier—The tephra eruption of 1894: Seattle, Wash., Northwest Discovery, v. 2, no. 6, p. 334–381.

Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

Credits

Drawing ***"Native American Views Mount Rainier and a Lahar Spreading over the Valley Floor"*** by Linda Feltner, Seattle, Washington, used with permission.

News accounts were assembled by Harry Majors and used here with permission from their source, Seattle Post-Intelligencer.

Steam Activity at Mount Rainier as Viewed from Seattle, Washington, during Late-Nineteenth Century

Drawing by Linda Feltner, Seattle, Washington, used with permission.

Student Page

Nineteenth-Century Newspaper Accounts

Background: *Experts largely disbelieved reports of an 1894 eruption at Mount Rainier until the 1981 discovery and reprinting of these early newspaper accounts.*

Instructions: *Read the 1894 newspaper accounts on steam eruptions at Mount Rainier. Discuss the newspaper accounts with your class. Are the eyewitness accounts of an eruption consistent? Do you find the eyewitness accounts believable?*

Eye-Witness News

1894 — *Page 1*

ERUPTION OF MOUNT RAINIER

[few minutes past 6 a.m., from Seattle] Mrs. S.B. Selmes…is another witness of the eruption of Mount Rainier….. on the morning of Nov. 21 at a few minutes past 6 o'clock Mrs. Selmes happened to look out of the south window and was immediately attracted by the strange sight on the mountain. For over a half hour she watched it, and called her daughter's attention to it. She had never seen the mountain clearer, and there were no clouds near, save a low cloud to the left (to the east). At intervals of every few seconds a huge volume of smoke, quite dark in the center, shot up from the west rim of the crater, and then would die down again. The smoke looked like that from a stack of a large steamer. Mrs. Selmes is quite positive about the phenomenon, and related the particulars to her son-in-law, Rev. Garrett…soon after the event.
(Post – Intelligencer, Dec. 2, 1894, p. 8)

STEAM AND SMOKE PUFFS SEEN

Frank Johnson [sic], driver of the patrol wagon, viewed the sight through a small glass and said: "I saw steam and smoke puffing out of the mountain and rolling down on the eastern side of the mountain. The smoke rose like big balloons at regular intervals. All the snow appeared to have melted off, and the jagged ends of the rock stuck up. I saw a peak this side and in the center of the mountain, that I never saw before. It was 6:45 a.m. when I first saw it. Many others also saw it at the same time. It got hazy after 8 o' clock and I could see nothing more."
(Press Times, Nov. 21, p. 1)

BLACK SMOKE A RISING

[few minutes past 6 a.m., from Seattle.] "When I looked I saw a vast amount of black smoke arising from the southwestern part of the peak, where the crater is located [sic]. Great puffs of this smoke would come up at regular intervals of about fifteen seconds, and rise to a height of what appeared to be about 100 feet and then drift away to the eastward in jagged, irregular form. It would then seem to curve downward and encircle the mountain and, catching another current of air, would pass to the eastward and back of the mountain. These puffs of smoke reminded me of a slowly beating pulse. They would rise in conical form and at their greatest height would remain stationary a moment before drifting away."
(Press-Times, Nov. 21, p. 1)

NO GROUND FOR DENIAL

[probably morning, from Seattle] A great many people discredit the story of the phenomenon, but all who saw it declare that there is no ground for denying that they saw smoke in great quantities coming out of the mountain. It was not vapor, but dense, black smoke, which caused an old Pennsylvania man to say that it reminded him of a conflagration in an oil works he had on three different occasions seen. The smoke would come up from the top of the mountain in great puffs and then remain stationary a moment until a current of air would carry it away.
(Post-Intelligencer, Nov. 23, p. 8)

Student Page

Nineteenth-Century Newspaper Accounts-continued

Eye-Witness News

1894 *Page 2*

HIS CROWN IS BROKEN

His crown is broken. Weird disturbances at the summit of Mt. Rainier. He belches smoke and steam. A new or transformed peak appears in place of the old one. Strange phenomena on the old mountain greets early risers. Sceptical [sic] Tacoma is convinced by earthquakes.... A dispatch sent from this city [Seattle] yesterday to Tacoma announcing the phenomenon was at once treated with ridicule, as the Tacomans, being on the west side of the mountain, had that portion of the crater which had caved in hidden from their view, and consequently would not credit what could be seen from the north only. A series of earthquake shocks last evening [November 21], however, shook their incredulity as well as their houses, and aroused them to the truth.. o the front several persons who also saw the smoke rising over the mountain...(The Seattle Post-Intelligencer, November 22, 1894, p. 8, cols. 1-3).

NO EARTHQUAKE FELT

...Mr Sarvin, who is employed in Colonel Plummer's engineering department, and who has been...all over the mountain, viewed the mountain yesterday [November 21] through his [field] glasses... and declared positively that there had been no change in the appearance of the mountain. When seen today [Nov.22] he was positive that there had been no eruption of any kind. He laughed at the report and expressed doubt that there could have been any disturbance in the mountain which could be seen only from Seattle... Mount Tacoma was obscured today [November 22] by clouds except for a very brief period, shortly before noon. At that time Col. Plummer, who is constantly keeping an eye on the mountain, succeeded in catching a glimpse of it through his glasses.... "I am not a good witness this time, because I did not feel the earthquake last night nor have I seen any evidences of any volcanic disturbances on the mountain. However, I am not ready to declare that those people who say they saw some evidences of an eruption or believe that they saw such, are mistaken. Because 100 persons say they did not see a certain thing, it does not follow that because one lone man says he did see it that he is lying."(Tacoma Daily News, November 22, 1894, p. 1, col. 2)

ERUPTION DISCREDITED

(few minutes past 6 a.m., from Van Trum[p] ....one of the first to make the ascent of the mountain, is among those who discredit the statement that any eruption, however slight, or any change in the form of the summit has occurred.... He has made a special study of the phenomena connected with the great mountain. Prof. Van Trump writes thus: ... "It is worthy of note that the veteran mountain climber, Major Ingraham, when interviewed by the Post-Intelligencer, gave no credence to the alleged eruption. I confidently venture the prediction that when the clouds pass away and the fanciful mist clears away from the minds of the mountain observers at Seattle, and their imitators at Tacoma, they will see the mountain exactly as of yore and as they will continue to see it in their brief future. Every mountaineer who has become familiar with the mountain and its kaleidoscope phases, who have frequently climbed and studied its crater, can not fail to have become impressed by the idea of its immutability. To him it is ever a sublime type of unchangeableness, as far as anything purely mundane can be a type of the unchangeable." (The Seattle Telegraph, November 24, 1894, p. 3, cols. 1-3.)

ERUPTION QUESTIONED

[...The fact seems to be that those who saw the mountain on the morning of November 21 saw the changes in it, and those who did not see it then did not see the changes and have not since been able to find them. The situation on this subject is well summed up in the San Francisco Examiner by Ambrose [Gwinett] Bierce [1842-1914, a western author, satirist, and columnist for the San Francisco Examiner] in the following manner: Question: Resolved, That during the lives of men still living Mount Rainier has been in visible eruption.

Affirmative—Prof. George Davidson, United States Geodetic Survey.

Negative—Dr. William C. Bartlett of the [San Francisco] Bulletin.

Evidence for the affirmative—Prof. Davidson has seen it in eruption.

Evidence for the negative—Dr. Bartlett has not seen it in eruption.

Decision (by the Bulletin): "The preponderance of testimony is in favor of non-eruption." (The Seattle-Post Intelligencer, December 1, 1894, p. 4, col. 4.)

Used with permission, Seattle Post-Intelligencer, Seattle, Washington

Nineteenth-Century Newspaper Accounts-Teacher Discussion Questions

1. What evidence in the newspaper articles suggests a volcanic eruption was in progress?
   Pulsing jets of steam and ash, dark column of ash rising into the air, snowmelt, possible deposition of volcanic ash, snowmelt revealed rocks not seen before.

2. Are the reports consistent? Do you find them believable?
   Some aspects of the reports are consistent. Observers close to one another made reports with greater consistency than observers geographically separated.

3. What could be done (or may have been done) to verify that an eruption had occurred?
   An expedition was sent to Mount Rainier to verify that an eruption had occurred. The group did not reach the summit, but viewed eruptions of steam and hot water. Ash deposited on the surface would provide additional verification of an eruption. Modern day instruments could quantify the amount of change to the surface.

4. If a small eruption did occur, why might evidence for it no longer exist?
   A fresh layer of volcanic ash may be thin and indistinguishable from dust, buried by snowfall, slowly carried away by moving glaciers, blown away by wind, washed away by rain, and obscured by soil and vegetation.

5. What does the occurrence of these small events suggest about the actual number of eruptions we know about?
   Evidence for small eruptive events is not always preserved over geologic time, and so the actual number of eruptions almost always exceeds the number for which we have evidence.

6. What do these newspaper reports tell us about the sizes of eruptions possible at Mount Rainier?
   Eruptions at Mount Rainier can be small, difficult to identify and uneventful as well as large, highly visible and destructive.

Student Page

Name _____

Getting the Scoop

Instructions: *Develop a list of 5 to 10 questions for an interview with an adult about a geologic event in the Pacific Northwest that he or she has witnessed or remembers. Interview your subject and record their responses on this page. Use this information to write a newspaper article about the event.*

Cascade Volcano Timeline

Grade Level: 5–8

Learner Objectives:

Students will:

- Recognize that the formation of the Cascade Range is a relatively recent event compared to other events in Earth's history
- Understand that frequent eruptions over the past 200 years are evidence of a continuously active volcanic environment
- Understand volcanic events within an historical context

Setting: Classroom, hallway, or large open field

Timeframe: Two class sessions (80 minutes)

Touchdown to Geologic Time—15 minutes

Introducing a Timeline of Eruptions in the Cascades—15 minutes

Assembling the Timeline of Historical And Volcanic Events—40 minutes

USGS
science for a changing world

Living with a Volcano in Your Backyard-An Educator's Guide with Emphasis on Mount Rainier

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

Cascade volcanoes are young in relation to other geologic events that have shaped the Earth. In this activity, timelines and a hypothetical genealogy illustrate the high incidence of eruptive activity when compared to other geologic and human events.

Teacher Background

Geologic processes transform the Pacific Northwest

The Pacific Northwest began taking shape one hundred million years ago, when dinosaurs roamed the earth and oceans covered all but the eastern margins of present-day Washington and Oregon. Then, as today, the continent of North America was gradually sliding westward. In doing so, it met face to face with several small continents. These small landmasses collided with North America in a series of slow-motion crashes, each event piling rocks against the continent's western edge. These repeated bump-and-dump episodes enlarged North America.

Today's Cascade Volcanoes are the current manifestation of volcanism in the Pacific Northwest

The first episode of Cascades volcanism began about forty million years ago, when ancient volcanoes punched through shallow ocean waters. Volcanoes erupted continuously during this period, assembling layers of volcanic rock several kilometers thick. Twenty million years of tectonic plate motion and volcanism eventually raised these ancient rocks to form the backbone of the Cascade Range. By 10 million

Adding Human Genealogy to the Timeline—10 minutes

Materials:

Touchdown to Geologic Time

- Graphic *"Touchdown to Geologic Time"*
- Copies of *"List of Geologic Events"* student page
- Calculators (optional)
- Pencil

Introducing a Timeline of Eruptions in the Cascades

- Copies of student page *"Eruptions in the Cascades"*
- Graphic *"Cascade Eruptions During the Past 4,000 Years"*

Assembling the "Declaration of Independence to Today" Timeline

Each student or group will need:

- Copies of *"Historical And Volcanic Events"* student page
- String
- Tape measure, meter stick, or ruler
- Masking tape, clothes pins, or binder clips
- Colored tape or colored clips (optional)
- Markers
- Copies of *"Historical And Volcanic Events"* cards

Adding Human Genealogy to the Timeline

- Copies of *"Eruptions through the Generations"* student page

Vocabulary: Eruption, eruptive period, volcanic ash

years ago, these ancestral mountains had eroded significantly, forming the foundation of current Cascade volcanoes. About two million years ago ***eruptions*** began construction of the ancestral cones in the vicinity of the present Cascade volcanoes. Mount Rainier's current volcanic cone began building around 500,000 years ago. Other volcanic edifices are much younger: Mount Baker began forming less than 30,000 years ago and most of the present cone of Mount St. Helens began forming only 4,000 years ago.

Today's Cascade volcanoes are young

Cascade volcanoes may seem ancient, but their 40-million-year history is a small percentage of Earth's history. Thus, geologists consider the Cascade Mountains rather young. Consider the weathered and eroded Appalachian Mountains that are 250 million years old; the 80-million-year-old Sierra Nevada; and the 70-million-year-old Rocky Mountains.

Cascade volcanoes—Active during the past 200 Years

More than a dozen active or potentially active volcanoes crown the Cascade Range. Since the signing of the Declaration of Independence in 1776, at least seven Cascade volcanoes have erupted. The frequency of eruptions varies with each volcano. Volcanoes can sleep for several human generations before reawakening and erupting, or they may erupt several times within a few years as part of an ***eruptive period*** (a period of time, often lasting decades or more, when multiple eruptions occur). On average, a volcano will erupt in the Cascade Range once or twice per century.Lassen Peak in California (1914–1917) and Mount St. Helens in Washington (1980–1986), and at this writing in 2004–2008) erupted most recently. During

Skills: Calculating, measuring, recording, graphing

Benchmarks:

See benchmarks in Introduction.

recent millennia, Mount St. Helens has erupted more often than any other Cascade volcano. Mount Rainier last erupted as a series of ash and steam blasts in 1894–1895. The frequency and recentness of eruptions illustrates that the Cascades are an active volcanic range. They are capable of erupting again, even within our lifetimes.

Stories about volcanic eruptions improve and skew our record of eruptions

Erosion or burial destroyed physical evidence of many eruptions, but accounts remembered or recorded by Native Americans and American settlers improve the eruption record. These accounts are fascinating, but can skew the chronological record by suggesting more eruptive activity during human occupation than throughout earlier millennia.

For more information on human history and volcanoes, see activities Fire, Flood, and Fury ***and*** Nineteenth-Century News.

Procedure

What to do Before Class Begins:

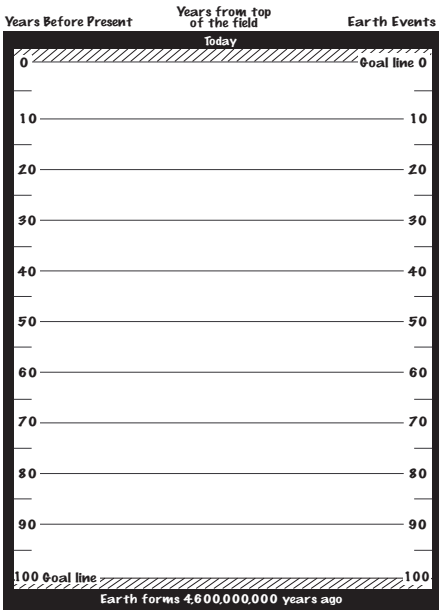
1. Make preparations for display of graphic "***Touchdown to Geologic Time***" and "***Cascade Eruptions during the Past 4,000 Years***."

2. Make multiple copies of the blank cards for "***Eruptions in the Cascades***." For each group, you will need 32 copies of the volcano event cards, and 25 historical event cards, that is, one for each volcanic and historical event listed on the "***Historical And Volcanic Events***" student page (note that there are two cards per page). Instruct students to add volcanic and historical events on the blank cards or fill in the dates and events yourself, prior to class. Use the list on student page "***Historical And Volcanic Events***." You may wish to add some more recent cultural events as well.

3. Determine the space for the "***Historical And Volcanic Events***" timeline (see Procedure). Construct your timeline indoors or outdoors by taping string to a wall, or other object, such as wooden stakes in a field.

4. Measure the length of string intended to represent the timeline. Display the string in the location chosen for the lesson. If you have time before class, label the decades using tape or colored markers.

Touchdown to Geologic Time



Use the visual representation of a football field to demonstrate the recentness of eruptions in the Cascade Range in relation to other geologic events on Earth.

1. Explain that geologic time covers billions of years versus the measurement of human time. Geologically, the reign of dinosaurs and certainly the development of Cascade volcanoes are relatively recent events.

2. Distribute "***Touchdown to Geologic Time***" and "***Some Significant Earth Events***" student pages. Display the "***Touchdown to Geologic Time***" graphic overhead. Introduce the concept that the bottom goal line of the football field of geologic time represents the formation of Earth (4.6 billion years ago); the top goal line represents today. As a class, calculate the scale for the football field entitled "***Touchdown to Geologic Time"***

Calculate Time Scale for "Touchdown to Geologic Time"

Years per yard = 4,600,000,000 years / 100 yards (i.e. length of football field)

Each yard represents 460,000,000 years; that is, the 10-yard line below the "present-day" end zone represents 460,000,000 years ago; the 20-yard line represents 2*0.46=0.92 billion years ago, and so on. On the left side of the football field, write the geologic time represented by each of the 10-yard lines from the present day back to the formation of the Earth.

3. Students work individually or as a class to find the position of each geologic event on the football field entitled "***Touchdown to Geologic Time***." They can estimate location by ages calculated in instruction 2 above, or calculate positions precisely with the equation below.

Calculate Distance for Geologic events from Top of the "***Touchdown to Geologic Time***"
Distance from top of football field = (100 yards)* (age in years ago)/(4,600,000,000 years)

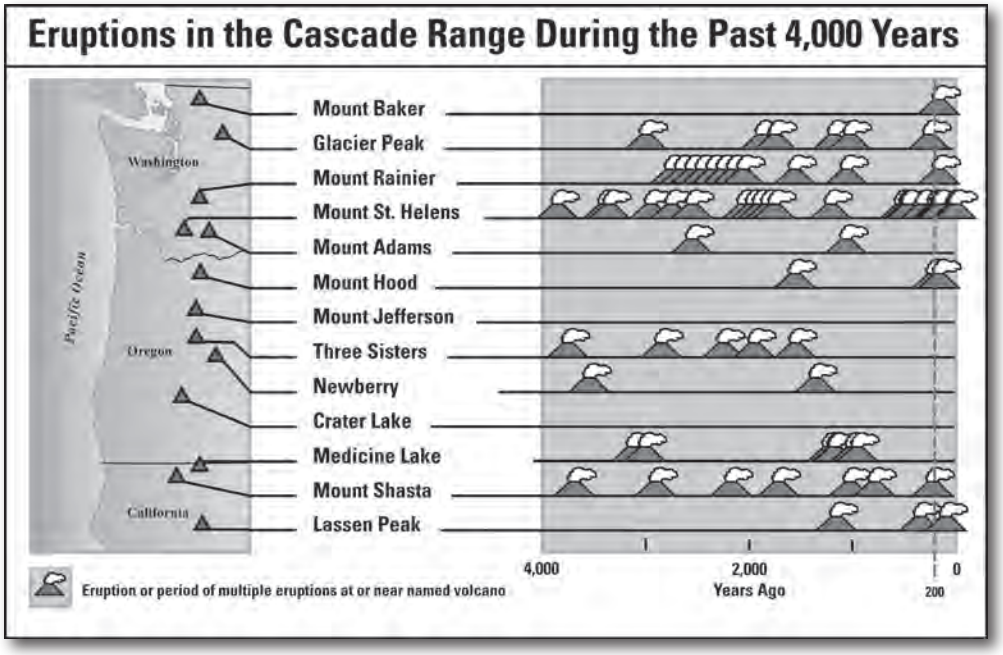
4. Plot each event on the graphic "***Touchdown to Geologic Time***." After all the events are marked, look at the timeline holistically. Ask students to consider the following questions. Did the geology of the earth change quickly or slowly? Is it easy or difficult to relate geologic events on the scale of human time? When did the majority of activity in the Cascade Range take place? What geologic events happened since the earliest humans inhabited the Earth? Emphasize that the 10,000 years of human history is but a small slice of the "***Touchdown to Geologic Time***" football field.

Introducing a Timeline of Eruptions in the Cascades

Use the worksheet to introduce students to the frequency of eruptions in the Cascades during the past 4,000 years.

1. Display the graphic "***Cascade Eruptions during the Past 4,000 Years***." Explain that each puffing volcano represents an eruptive period. The vertical dashed line represents 200 years ago, close to the time the Declaration of Independence was signed (1776).

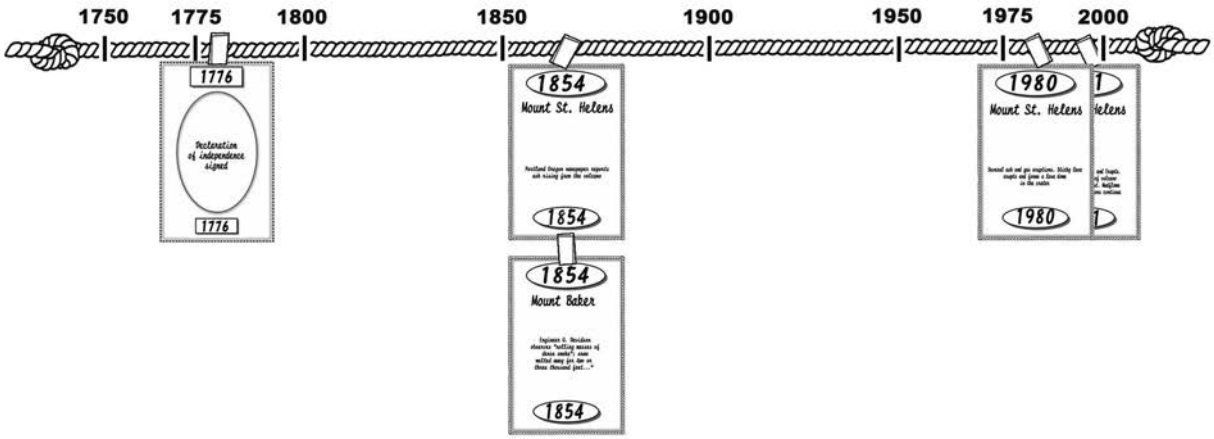
2. Answer the questions on the student page "***Eruptions in the Cascades***" individually or as a class.



Assembling the Timeline "Historical and Volcanic Events"

Illustrate the youthful and highly active nature of the volcanoes in the Cascade Range by constructing a timeline showing both human and volcanic events since the signing of the Declaration of Independence.

Explain to students that you are going to focus on some of the most recent events since the formation of the Earth. Students will develop a class timeline of historical events and Cascade eruptions that have occurred since the signing of the Declaration of Independence.



1. Measure and display a length of string (25, 50 or 100 feet) on the classroom wall or hallway. Label one end of the string with the date 1776 and label the other end with today's date.

2. ***<u>With the students calculate the scale to be used on the timeline.</u>***

$$\text{Unit of Measure (i.e., 1 cm or 1 inch)} = \frac{\text{\# of years represented}}{\text{Length of Timeline (String)}}$$

   To make it easier to find each year, use colored tape or colored clips to divide the timeline into decades and label them appropriately.

3. Provide each student with a copy of the student page "***Historical and Volcanic Events***," and several blank volcanic and blank historic event cards. Divide the events on the list among activity on the cards. Students then place their cards on the timeline using tape, clothespins or binder clips.

4. After you have attached all cards to the timeline, discuss any observations about volcanic activity in the Pacific Northwest over the last 200 years. Which volcanoes were most active? Are all eruptions the same type? What types of volcanic eruptions have occurred over the last 200 years? Does each volcano have a set time or frequency of eruptions? Which volcano may show evidence today of an eruption in the past? Which years had both a significant historical event and a volcanic eruption? Point out to students that some cards represent single events with which we are acquainted, while others show eruptive periods when the volcano erupted on an unknown number of occasions.

Adding Human Genealogy to the Timeline

Compare human life spans to the frequency of eruptions in the Cascades by making a timeline representing five generations of Christina's family (a person the same age as the student).

1. Hand out an "***Eruptions through the Generations***" student page to each student.

2. Referring to the timeline "***Historical and Volcanic Events***," instruct students to answer the questions on the "***Eruptions through the Generations***" student page.

3. Discuss the questions as a class emphasizing the frequency of eruptions in the Cascade Range.

Your School's Volcano Museum

Choose any or all of the above procedures for your students. After completion, display students' projects in a "school volcano museum" for viewing by other students and their families. Your museum can include emergency preparedness information and student projects from other activities, such as **A String of Volcanoes**, **Play-Dough Topo**, **Planning your Trip to Mount Rainier National Park!**, and **The Next Eruption of Mount Rainier**, and **Living Well with a Volcano in your Backyard**.

Adaptations

- For younger students, use fewer points on the timeline.
- People sometimes liken the Cascade volcanoes to humans, each with a distinctive personality. Some volcanoes erupt explosively; others erupt with less fanfare. Research other volcanoes using materials cited in the References. Instruct students to write a report comparing volcano "personalities."
- Students use library and Internet research to research and write a report about one historic natural event—volcano, earthquake, flood, hurricane, wildfire, etc.
- For older students, assign a fact–finding mission using the Internet or library resources to find additional information on volcanic events in the Pacific Northwest.
- Construct a geologic timeline on rolled paper, such as that used on adding machines or cash registers.
- Instruct students to find new and creative ways to graph timeline data.
- Use sidewalk chalk to draw timelines on the playground or school sidewalk.

Extensions

- ***Make a Timeline of Your Family.*** Interview people in your family about their memories of geologic events (i.e., volcanic eruptions, earthquakes, large floods).
- ***Add Events from Other Disciplines.*** Add important historical events from other disciplines to your timeline—Social Studies, English, and Music.
- ***Add the History of Mount Rainier National Park to Your Timeline.*** Students research historical events in the history of Mount Rainier National Park. Use the Mount Rainier National Park Web site for historical dates and information.
- ***Make Timeline cards "permanent."*** Laminate the timeline cards for repeated use.
- ***Make a Tree Ring Timeline.*** Draw a picture of tree rings in a stump. Every tree ring equals one year. Mark important geologic and historic events during the growth of the tree by counting the tree rings.
- ***Age of the Earth Timeline Calculation.*** Instruct students to use the lengths of the "Historical Cascade Volcano Events" timeline to calculate the length of string needed to make a timeline that extends back to the formation of the earth (4.6 billion years ago).

Assessment

Cascade Volcano Timeline addresses the temporal aspect of eruptions in the Cascades, while **Surrounded by Volcanoes** addresses the spatial aspect. Use student pages to assess how students' knowledge of geologic time has grown over the course of this activity. Compare results to verbal predictions made at beginning of "***Touchdown to Geologic Time.***" Identify their misperceptions. Do students express an improved understanding of the recentness of volcanic activity at Cascade volcanoes? Use student page "***Touchdown to Geologic Time***" to assess students' grasp of the recentness of the formation of Cascade volcanoes in geologic time, and student page "***Timeline of Eruptions in the Cascades***" to assess recognition that Cascade volcanoes have erupted frequently and recently during the past 4,000 years. Use "***Eruptions Through the Generations***" to assess students' skills at adapting this to a hypothetical family. Assess their knowledge of historical context of eruption events by observing students' ability to add historical events to the "***Historical and Volcanic Events***." Is this process difficult for them? If the timeline remains on display in the classroom throughout the school year, how readily can students add historical events as they learn about them? Do students speak of volcanic activity in the Cascades as a process of the past only, or as a process for the present and future as well?

References

Clynne, M.A., Christiansen, R.L., Felger, T.J., Stauffer, P.H., and Hendley, J.W., II, 1999, Eruptions of Lassen Peak, California, 1914 to 1017: U.S. Geological Survey Fact Sheet 173–98, 2 p.

Clynne, M.A., Ramsey, D.W., and Wolfe, E.W., 2005, Pre-1980 eruptive history of Mount St. Helens, Washington: U.S. Geological Survey Fact Sheet 2005–784–544, 4 p.

Driedger, C., and Scott, W., 2008, Mount Rainier—Living safely with a volcano in your backyard: U.S. Geological Survey Fact Sheet 2008–3062, 4 p.

Dzurisin, D., Stauffer, P., and Hendley, J.W., II, 2003, Living with volcanic risk in the Cascades (revised March, 2008): U.S. Geological Survey Fact Sheet 165–97, 2 p.

Gardner, C.A., Scott, W.E., Major, J.J., and Pierson T.C., 2000, Mount Hood—History and hazards of Oregon's most recently active volcano: U.S. Geological Survey Fact Sheet 060–00, 4 p.

Harris, S.L., 2005, Fire mountains of the West: the Cascade and Mono Lake Volcanoes: Missoula, Mont., Mountain Press Publishing Company, 3rd ed., 454 p.

Major, J.J., Scott, W.E., Driedger, C.L., and Dzurisin, D., 2005, Mount St. Helens erupts again—Activity from September 2004 through March 2005: U.S. Geological Survey Fact Sheet 2005–3036, 4 p.

Myers, B., Brantley, S.R., Stauffer, P.H., and Hendley, J.W., II, 1997, What are volcano hazards? (revised March 2008): U.S. Geological Survey Fact Sheet 002–97, 2 p.

Myers, B., and Driedger, C., 2008, Eruptions in the Cascade Range during the past 4,000 years: U.S. Geological Survey General Information Product 63, poster.

Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

Student Page

Some Significant Earth Events

Geologic Event	Years Ago Event Occurred
A. Earth is formed	4,560,000,000
B. Oldest known fossil of bacteria	3,250,000,000
C. Oldest known hard-shelled fossil	543,000,000
D. Oldest known plant fossil	470,000,000
E. Ancestral Appalachian Mountains are formed	250,000,000
F. Oldest known dinosaur fossil	228,000,000
G. Rocky Mountains formed	70,000,000
H. Dinosaurs become extinct	65,000,000
I. Ancestral Cascade volcanoes are formed	40,000,000
J. Uplift begins—Cascades, Coast Range, Olympics	10,000,000
K. Oldest fossil finds of Homo sapiens	100,000
L. First evidence of hunter-gatherers at Mount Rainier	8,500

Math Work Here:

Student Page

Name _____

Touchdown to Geologic Time

Years Before Present	Years from top of the field	Earth Events
	Today	
0	Goal line 0	
10		10
20		20
30		30
40		40
50		50
60		60
70		70
80		80
90		90
100 Goal line		100
	Earth forms 4,600,000,000 years ago	

Teacher Page

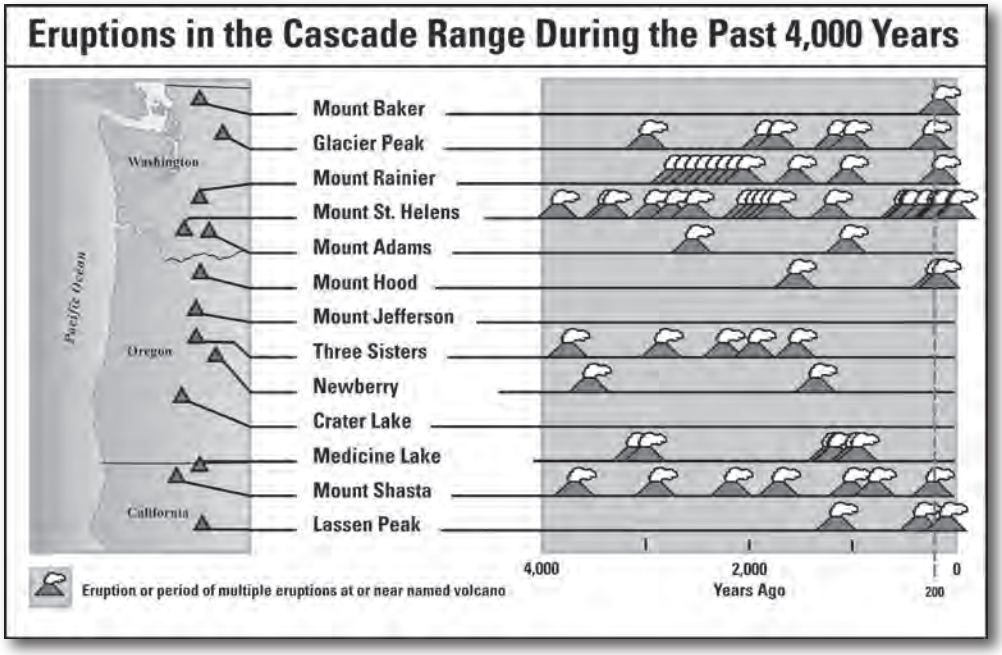
Touchdown to Geologic Time

Years Before Present	Years from top of the field	Earth Events
Today		
0		Goal line 0
	I J K L H 65,000,000	Dinosaurs extinct
	G 70,000,000	Rocky Mountains formed
	F 228,000,000	Oldest known dinosaur fossil
	E 250,000,000	Ancestral Appalachians formed
10		10
	D 470,000,000	Oldest known plant fossil
	C 543,000,000	Oldest known hard-shelled fossil
20		20
	L 8,500	Evidence of hunter-gatherers.
	K 100,000	Oldest Fossil finds-Homo Sapiens
	J 10,000,000	Uplift begins-Cascades, Coast Range, Olympics
	I 40,000,000	Ancestral Cascade Volcanoes formed
30		30
40		40
50		50
60		60
70		70
	B 3,250,000,000	Oldest known bacteria fossil
80		80
90		90
100 Goal line	A 4,600,000,000	Earth is formed 100
Earth forms 4,600,000,000 years ago		

Name _____

Eruptions in The Cascades

The diagram below shows how often each volcano in the Cascade Range has erupted over the last four thousand years. Each puffing volcano illustrates an ***eruptive period****—a time when the volcano had several lava or ash eruptions over a short period (days, months, or years). Use the diagram to answer the questions.*



1. Which volcanoes erupted during the past 200 years?

2. What does the diagram suggest about the likelihood of future volcanic activity in the Cascades?

3. Based on the eruptive history represented by the timeline, which volcano do you think is most likely to erupt next? Explain your answer.

Teacher Page

Eruptions in The Cascades—Answers

1. Which volcanoes have had eruptions in the last 200 years?
   Mount Baker, Glacier Peak, Mount Rainier, Mount St. Helens, Mount Hood, Mount Shasta, Lassen Peak

2. What does the diagram suggest about the likelihood of future volcanic activity in the Cascades?
   The Cascade volcanoes erupted recently in geologic time and can erupt again.

3. Based on the eruptive history represented by the timeline, which volcano do you think is most likely to erupt next? Explain your answer. Many students might answer with ***Mount St. Helens, because it has erupted more frequently and more recently than other volcanoes in the Cascades. Many scientists contend that there are equally compelling reasons for other volcanoes to erupt next.***

Student Page

Historical and Volcanic Events

Instructions: *Use information on the list to construct cards for your timeline.*

Volcanic Events

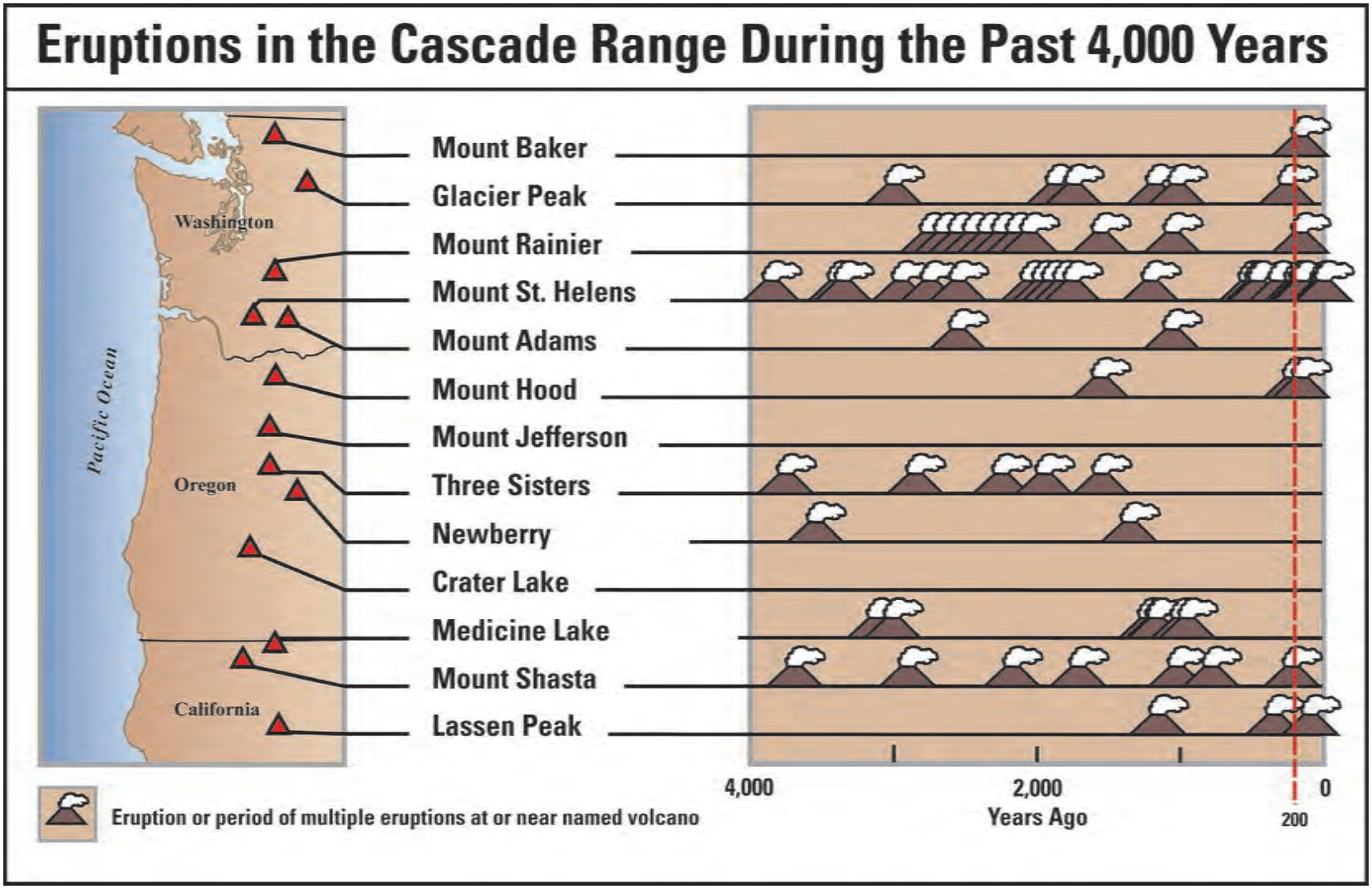
2004 – 2008 – Mount St. Helens lava-dome and steam and ash eruptions
1997 – present – Three Sisters volcanoes uplift
1989 – 1991 – Mount St. Helens steam and ash eruptions
1981 – 1986 – Mount St. Helens ash eruptions; lava dome continues to grow
1980 – Mount St. Helens A powerful landslide and blast, lahars, many steam and ash eruptions
1975 – Mount Baker thermal activity, steaming
1921 – Mount St. Helens steam eruptions reported
1914 – 1917 – Lassen Peak a powerful pyroclastic flow, lahars, multiple eruptions of ash and steam
1907 – Mount Hood reports of steam, ash, and glowing rocks
1903 – Mount St. Helens minor steam explosion
1898 – Mount St. Helens possible steam explosion
1894 - 1895 – Mount Rainier possible steam and ash explosions
1880 – Mount Baker reports of ash eruption
1865 – Mount Hood steam and ash eruption
1859 – Mount Hood steam and ash eruption
1858 – 1860 Mount Baker reports of ash eruptions and lahars
1857 – Mount St. Helens ash and lava-dome eruption, lahars
1854 – Mount St. Helens ash eruption
1854 – Mount Baker report of an eruption
1847 – Mount St. Helens eruption on NW side of volcano noted by fur traders at Fort Vancouver
1843 – Mount Baker Native Americans note that ash eruption caused forest fires; landslides, lahars killed fish
1840 – 1845 – Mount St. Helens numerous ash eruptions and lahars; growth of lava dome
1835 – Mount St. Helens ash eruptions
1831 – Mount St. Helens ash eruptions
1800 – 1801 – Mount St. Helens A series of lava flow and ash eruptions begins
1786 – Mount Shasta reports of ash eruption
1781 – Mount Hood eruptions of ash, lahars
1700's – Glacier Peak Native Americans report minor eruptions

Historical Events

Make some additional cards noting events that are significant to your students and your community.

2005 – Cassini-Huygens spacecraft reaches Saturn's moon Titan
1997 – Cassini-Huygens spacecraft launched
1990 – Internet language HTML invented
1987 – First 3D video games invented
1979 – Cell phones and roller blades invented
1972 – Video games and email invented
1969 – Man first walks on the moon
1945 – World War II ends
1936 – Bonneville Dam completed
1929 – Great Depression begins
1920 – First radio broadcast in Washington State
1910 – Washington women win right to vote
1903 – Wright Brothers' first powered flight
1899 – Mount Rainier National Park established
1889 – Washington enters statehood
1861 – American Civil War begins
1859 – Oregon enters statehood
1854 – Medicine Lake Treaty signed with Nisqually and Puyallup Indian tribes
1850 – California enters statehood
1843 – Migration begins on Oregon Trail
1832 – First school in Washington
1824 – Fort Vancouver founded by the Hudson's Bay Company
1805 – 1806 – Lewis and Clark view several Cascade volcanoes; name Mount Jefferson
1792 – Captain George Vancouver explores the Pacific Northwest; names Mounts Baker, Rainier, St. Helens and Hood
1776 – Declaration of Independence signed

Cascade Eruptions During the Past 4,000 years



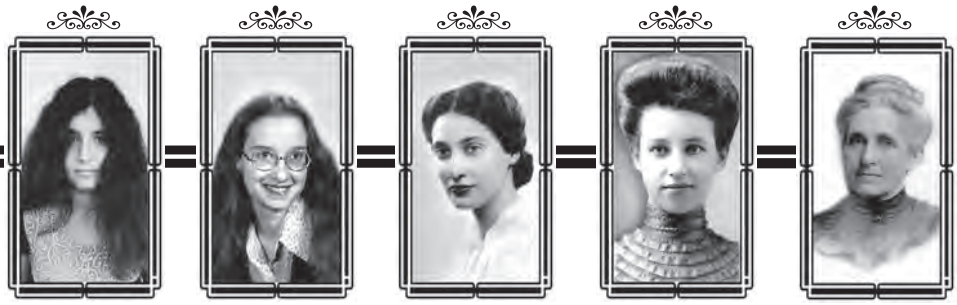
Graphic Page

Volcanic Event Cards

Historical Event Cards

Name _____

Eruptions through the Generations



	Christina	Christina's Mother	Christina's Grandmother	Christina's Great-Grandmother	Christina's Great-Great-Grandmother
BORN	Your Birth Year	1970	1940	1910	1890
DIED				1985	1950

Instructions: *Use your timeline to answer the following questions.*

1. Which Cascade volcano erupted during the lifetime of Christina's mother?

2. Which Cascade volcanoes displayed some activity while Christina's grandmother was alive?

3. Who in Christina's family might have seen Lassen Peak erupt?

4. Which Cascade volcanoes erupted during the lifetime of Christina's great-great-grandmother?

5. Based on the experiences of Christina's family, how many generations could have experienced some volcano-related activity in the Cascades?

Eruptions through the Generations—Answers

1. Which Cascade volcano erupted during the lifetime of Christina's mother?
   Mount St. Helens in 1980

2. Which Cascade volcanoes displayed some activity while Christina's grandmother was alive?
   Mount St. Helens, Three Sisters, and Mount Baker

3. Who in Christina's family might have seen Lassen Peak erupt?
   Christina's great-grandmother

4. Which Cascade volcanoes erupted during the lifetime of Christina's great-great-grandmother?
   Lassen Peak (1914–17), Mount Rainier (1894), and according to oral reports, Mount Hood (1907) and Mount Baker (1880, 1850–1860)

5. Based on the experiences of Christina's family, how many generations could have experienced some volcano-related activity in the Cascades?
   All five generations

A String of Volcanoes

Grade Level: 3–9

Learner Objectives:

Students will:

- Become familiar with important aspects about each of the Cascade volcanoes
- Identify sources of information about Cascade volcanoes, in Washington, Oregon, and California

Setting: Classroom

Timeframe: 50 minutes—research; 50 minutes—mobile construction

Materials:

- Crayons or colored pencils
- USGS Fact Sheet 165–97 (optional)
- Scissors
- Glue
- Internet access or library resources
- Copies of *"A String of Volcanoes"* student page
- Copies of *"A String of Volcanoes Mobile Pieces"*

Materials continued....

USGS
science for a changing world

Living with a Volcano in Your Backyard-An Educator's Guide with Emphasis on Mount Rainier

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

Students research information about Cascade volcanoes in Washington, Oregon, and California, and then transfer information onto appropriate mobile piece before constructing the mobile **A String of Cascade Volcanoes**.

Teacher Background

Refer to U.S. Geological Survey Fact Sheet 165–97 for general information about Cascade volcanoes and their locations in the Cascade Range. Find additional information in related activities, including **Cascade Volcano Timeline**, **Volcano Hall of Fame**, and **Surrounded by Volcanoes**.

Procedure

What to do Before Class Begins

Assemble grade-appropriate resources for student research. Cut string to required lengths.

1. Provide each student or student group with ***"A String of Volcanoes"*** student page and ***"A String of Volcanoes—Mobile Pieces."***

2. Students research information from Internet, library resources, or USGS Fact Sheets and write it on volcano mobile pieces before coloring and assembling mobile. Most answers can be found at the U.S. Geological Survey Web sites.

3. Construct the mobile for one, two or three states using instructions using one of two methods proposed on the student page.

Activity last modified: September 5, 2014

- *Kite string or yarn for mobile: 4.3 meters (approximately 14 feet) for single string; 5 meters (approximately 17 feet) for either mobile arrangement*
- *1 paper clip for hanging mobile*

Vocabulary: Caldera, cinder cone, eruption, debris avalanche, debris flow, lahar, landslide, lava dome, lava flows, pyroclastic flow, shield volcano, steam explosion, stratovolcano, tephra, volcanic ash

Skills: Data collection, ordering, researching

Benchmarks:

See benchmarks in Introduction.

Assessment

Use **A String of Volcanoes** as a learning tool, and **Volcano Hall of Fame** as an assessment of students' knowledge about important aspects of Cascade volcanoes. After completing these two activities, students should be able to identify important aspects of Cascade volcanoes and identify sources of information. Assess each student's ability to identify important aspects and to record them.

References

Dzurisin, D., Stauffer, P., and Hendley, J.W., II, 2003, Living with volcanic risk in the Cascades (revised March, 2008): U.S. Geological Survey Fact Sheet 165–97, 2 p.

Harris, S.L., 2005, Fire mountains of the West: the Cascade and Mono Lake volcanoes: Missoula, Mont., Mountain Press Publishing Company, 3rd ed., 454 p.

Tilling, R.I., Topinka, L., and Swanson, D.A., 1990, Eruptions of Mount St. Helens: past, present, and future: U.S. Geological Survey General Interest Publication (revised edition), 57 p.

Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

A String of Volcanoes

The Cascade volcanoes extend from southern British Columbia, Canada, to northern California. To learn more about these volcanoes, make a string of volcanoes using the ***"String of Volcanoes"*** *mobile templates. Use the Internet or library resources to research information about each volcano. Hang the* ***"String of Volcanoes"*** *mobile in your home or classroom.*

Instructions:

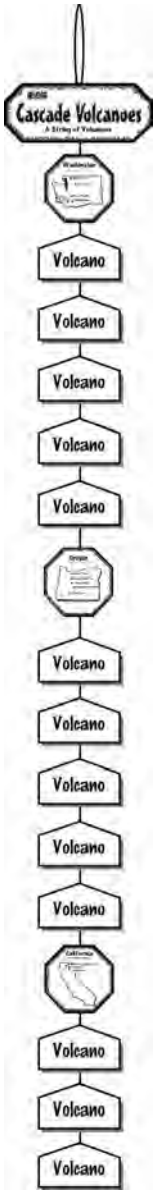
1. Fill in the blanks on mobile pieces with information that you have researched on the Internet, in library books, or other materials provided by your teacher.

2. Color the volcanoes (most are snow capped and have trees, but some also have lakes or meadows).

3. Cut out each mobile piece along the outline and fold each piece in half along the dotted line.

4. Cut out the small black triangle along the bottom (folded) edge.

5. Assemble mobile starting at top with title piece, followed by state map and then the volcanoes for each state. You can hang volcanoes in one long string *(assembly method A)* or hang a triangular piece of cardboard horizontally below the title and hang a state from each corner *(assembly method B)*. Your teacher will tell you which method to use. Follow the appropriate instructions below.



Assembly: Method A.

Instructions for hanging volcanoes of Washington, Oregon and California singly, or together on one long string.

1. Cut a piece of string 4.3 meters (14 feet) long. To make a loop for hanging, bend the string into an 18 centimeter (7 inch) long loop at one end of the string that will extend upward from the center top of the title piece. Run the remainder of the string through hole at the center bottom of title piece and tie a knot just below it. Glue string in place and glue title piece closed.

2. Add the state map, then the volcano mobile pieces. Run a glue line around edges and down center of the backside of the next volcano piece.

3. Place the glue side of the volcano piece face up. Slide the volcano piece onto the string, through the hole you cut in bottom (folded) edge. Place top edge of next volcano piece 5 centimeters (2 inches) below the bottom of the previous piece.

4. Press the volcano piece closed and adjust on the string for balance and location. Tie a knot in string at bottom of the volcano piece. Make sure the string is glued in place.

5. Repeat steps 2 through 4 for each volcano piece of the mobile.

6. Tie a large knot below bottom piece and trim off excess string.

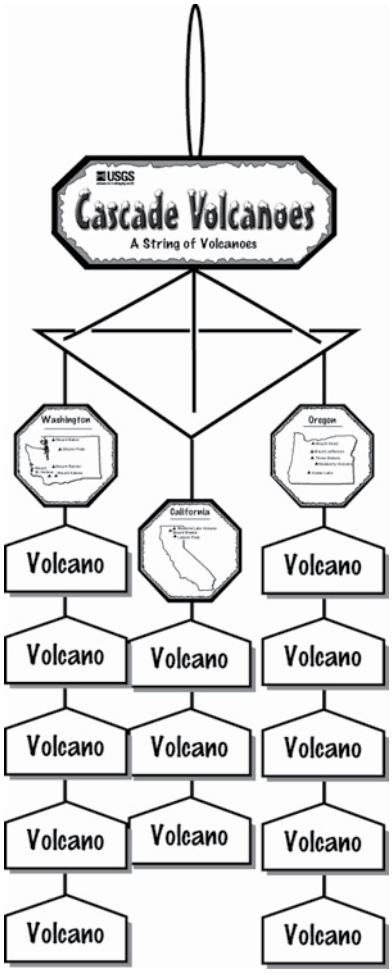
7. Balance mobile by adding weights inside individual volcano piece.

A String of Volcanoes-continued

Assembly: Method B.

Instructions for hanging volcanoes for the states of Washington, Oregon, and California side-by-side.

1. Cut a triangular piece of cardboard that will be suspended horizontally below the title piece, for the purpose of separating the three strings of volcano pieces. Make each side of the triangle about 25 centimeters (approximately 10 inches) long.
2. Make a loop above the title piece for hanging the mobile. Do so by cutting three pieces of string 1.7 meters (5 feet long). Make an 18 centimeter-long (7 inch-long) loop that extends above the center of the title piece. Tie a knot to secure all three strings at the bottom of the loop.
3. Run the three pieces of string through the hole at the bottom of the title piece and glue the string in place. Now glue title piece closed and tie a knot below the bottom of the title piece.
4. Add the cardboard triangular spacer. Punch a small hole in each corner of the cardboard triangle. Suspend the triangle 7 to 10 centimeters (3 to 4 inches) below title by running each string through a different hole. Knot each string below triangle (try to keep triangle hanging evenly).
5. Add the state map and volcano pieces using instructions 2 through 7 in Method A.



Is Mount St. Helens north or south of Mount Adams? Since they are at almost the same latitude you may want to hang them side-by-side. If so, cut two small triangles in the bottom of Mount Rainier (one on each side about 1.3 centimeters or 0.5 inch), from the edge. Cut two pieces of string 30 centimeters (1 foot) long and tie knots in the tops. Pull string through new holes and secure knot inside with glue. Hang Mount St. Helens and Mount Adams on strings as instructed in steps 2 through 7.

Hint

The knots you tie help support pieces in the event that the glue does not hold. You will need to tie big knots if you make big holes. Or, tie the knots around matchsticks.

Student Page

A String of Volcanoes

Note to teacher: *Most answers can be found on web pages of the U.S. Geological Survey's Volcano Hazards Program. For filling in the blanks on the individual volcano cutouts, there is a broad range of good answers from detailed scientific, to historic (like "volcano named after…"), to personal (like "went there on vacation last year"). The elevation of several volcanoes has multiple correct answers depending on which publication or topographic map is used for research. Older students could determine latitude and longitude.*

Mount Baker

Location: Northwestern Washington

Elevation: 3,285 meters (10,781 feet or 10,778, depending on source)

Closest cities: Bellingham, Washington; Vancouver, British Columbia

Most recent volcanic activity: Landslide and lahar in 1891; increased steam and heat in 1975

Most likely volcano hazards: Lahars and landslides, lava flows, pyroclastic flows, minor tephra

Another fact about this volcano: Stratovolcano; known by Native Americans as Kulshan; named after Joseph Baker, a third lieutenant with British explorer George Vancouver; second most glacier ice of volcanoes in Cascades, public often reports steaming of Sherman Crater

Glacier Peak

Location: Northern Washington

Elevation: 3,213 meters (10,541 feet)

Closest cities: Everett and Seattle, Washington

Most recent volcanic activity: Small steam explosion approximately 300 years ago

Most likely volcano hazards: Tephra, lava flows and domes, pyroclastic flows, lahars

Another fact about this volcano: Stratovolcano; most remote of the Cascade volcanoes; not prominently visible from metropolitan centers; did not appear on maps under current name until 1898

A String of Volcanoes-continued

Mount Rainier

Location: West central Washington

Elevation: 4,392 meters (14, 410 feet)

Closest cities: Tacoma, Seattle, Olympia, and Yakima, Washington

Most recent volcanic activity: Small steam explosions during nineteenth-century

Most likely volcano hazards: Lahars (greatest hazard in terms of effect), lava flows, pyroclastic flows, landslides

Another fact about this volcano: Stratovolcano; named Tahoma by Native Americans; named after Rear Admiral Peter Rainier in 1792; highest peak in the Cascades; volume of ice and perennial snow is equivalent to the volume on all other Cascade volcanoes combined—a major hazard during an eruption

Mount St. Helens

Location: Southwest Washington

Elevation: 2,549 meters (crater rim 8,364 feet)

Closest cities: Vancouver, Kelso, and Longview Washington; Portland, Oregon

Most recent volcanic activity: Landslides, eruptions and lahars on May 18, 1980, followed by eruptions of tephra and lava-dome building eruptions between 1980 and 1986; small eruptions in 1989–1991; steam and ash eruptions in 2004; dome-building eruptions in 2004 through 2008

Most likely volcano hazards: Tephra, pyroclastic flows, lahars, lava flows

Another fact about this volcano: Stratovolcano; known by Native Americans as Loowit; most frequently active volcano in the Cascades during the last 4,000 years; 1980 eruptions and lahars caused one billion dollars in damage—most expensive volcanic event in United States history; summit elevation was 9,677 feet before landslide and eruptions of May 18, 1980; dome-building eruptions of 2004–08 helped to rebuild the mountain

Mount Adams

Location: South central Washington

Elevation: 3,742 meters (12,276 feet)

Closest cities: White Salmon, Yakima, Washington; Hood River, Oregon

Most recent volcanic activity: Approximately one thousand years ago there were eruptions of lava and tephra

Most likely volcano hazards: Lava flows, landslide, lahars

Another fact about this volcano: Stratovolcano; known by Native Americans as Pahto or Klickitat; second highest of the volcanoes in Washington; about 6,000 years ago, a lahar inundated about fifteen square kilometers (6 square miles) of the lowland and dammed a stream to form Trout Lake; sulfur was mined near summit during the 1930s

A String of Volcanoes-continued

Mount Hood

Location: Northern Oregon

Elevation: 3,426 meters (11,239 feet)

Closest cities: The Dalles, Hood River, Troutdale and Portland, Oregon; White Salmon and Vancouver, Washington

Most recent volcanic activity: Numerous nineteenth-century steam eruptions; most recent major eruption occurred in 1780's; formed lava domes, pyroclastic flows and lahars

Most likely volcano hazards: Lava flows and domes, pyroclastic flows, lahars

Another fact about this volcano: Stratovolcano; named Wy'east by Native Americans Oregon's most recently erupting volcano; highest peak in Oregon; only Oregon volcano to produce yearly earthquake swarms; eruption in 1780's triggered lahar in Sandy River Valley that reached the Columbia River and formed a delta of quicksand; Lewis and Clark noted this in their journals and named river the "Quicksand River"

Mount Jefferson

Location: North central Oregon

Elevation: 3,199 meters (10,495 feet)

Closest cities: Bend, Madras and Salem, Oregon

Most recent volcanic activity: lava flows and domes, pyroclastic flows and lahars during the last ice age

Most likely volcano hazards: Tephra, landslides, lahars, future eruptions likely to be from smaller adjacent volcanoes

Another fact about this volcano: Stratovolcano; least active volcano in the Cascade Range—no known eruptions during the last 20,000 years; erupted repeatedly for hundreds of thousands of years, with its last eruptive episode during the ice ages; Lewis and Clark named this volcano in honor of President Thomas Jefferson

Three Sisters

Location: Central Oregon

Elevation: North Sister is 3,074 meters (10,085 feet); Middle Sister is 3,062 meters (10,047 feet); South Sister is 3,157 meters (10,358 feet)

Closest cities: Bend, Oregon

Most recent volcanic activity: Approximately two thousand years ago on flanks of South Sister

Most likely volcano hazards: Tephra, lava flows, pyroclastic flows, lahars

Another fact about this volcano: Stratovolcanoes, named by a group of Methodist missionaries; a broad area of volcanic uplift (about 2.5 centimeters per year (1 inch per year) is ongoing just west of South Sister; these three volcanoes have the closest spacing of any major stratovolcanoes in the Cascade Range

A String of Volcanoes-continued

Newberry Crater

Location: Central Oregon
Elevation: 2,434 meters (7,985 feet)
Closest cities: Bend, Oregon
Most recent volcanic activity: Big Obsidian Flow (lava flow) formed 1,300 years ago
Most likely volcano hazards: Lava flows, tephra and lahars
Another fact about this volcano: Shield volcano and caldera; covers 1,300 square kilometers (500 square miles); lava flows extend to city of Bend, Oregon, and beyond; more than 400 cinder cones dot the flanks of this volcano

Crater Lake

Location: Southern Oregon
Elevation: 2,487 meters (8,156 feet) (the lake is 594 meters deep (1,949 feet)
Closest cities: Medford and Klamath Falls, Oregon
Most recent volcanic activity: Ancient Mount Mazama erupted and formed Crater Lake caldera 7,700 years ago; Wizard Island and underwater cones erupted between 7,700 and 4,800 years ago
Most likely volcano hazards: Tephra, pyroclastic flows
Another fact about this volcano: Mount Mazama was a cluster of volcanoes—not a single cone; caldera-building eruption 7,700 years ago was the largest eruption to take place at a Cascade volcano during the past 100,000 years; caldera-forming eruption scattered gritty volcanic ash that can be found today, across Washington, Oregon and southern Canada; Native Americans witnessed the collapse of this volcano and kept the event alive in their legends; Crater Lake is the deepest lake in the United States

Medicine Lake Volcano

Location: Northern California
Elevation: 2,376 meters (7,762 feet)
Closest cities: Klamath Falls, Oregon
Most recent volcanic activity: Approximately 900 years ago
Most likely volcano hazards: Lava flows, pyroclastic flows, tephra
Another fact about this volcano: Shield volcano, by volume the largest volcano in the Cascade Range; well known for its extensive system of lava tube caves—at least 435; rugged volcanic landscape sheltered Native Americans of the Modoc War of 1872–1873

A String of Volcanoes-continued

Mount Shasta

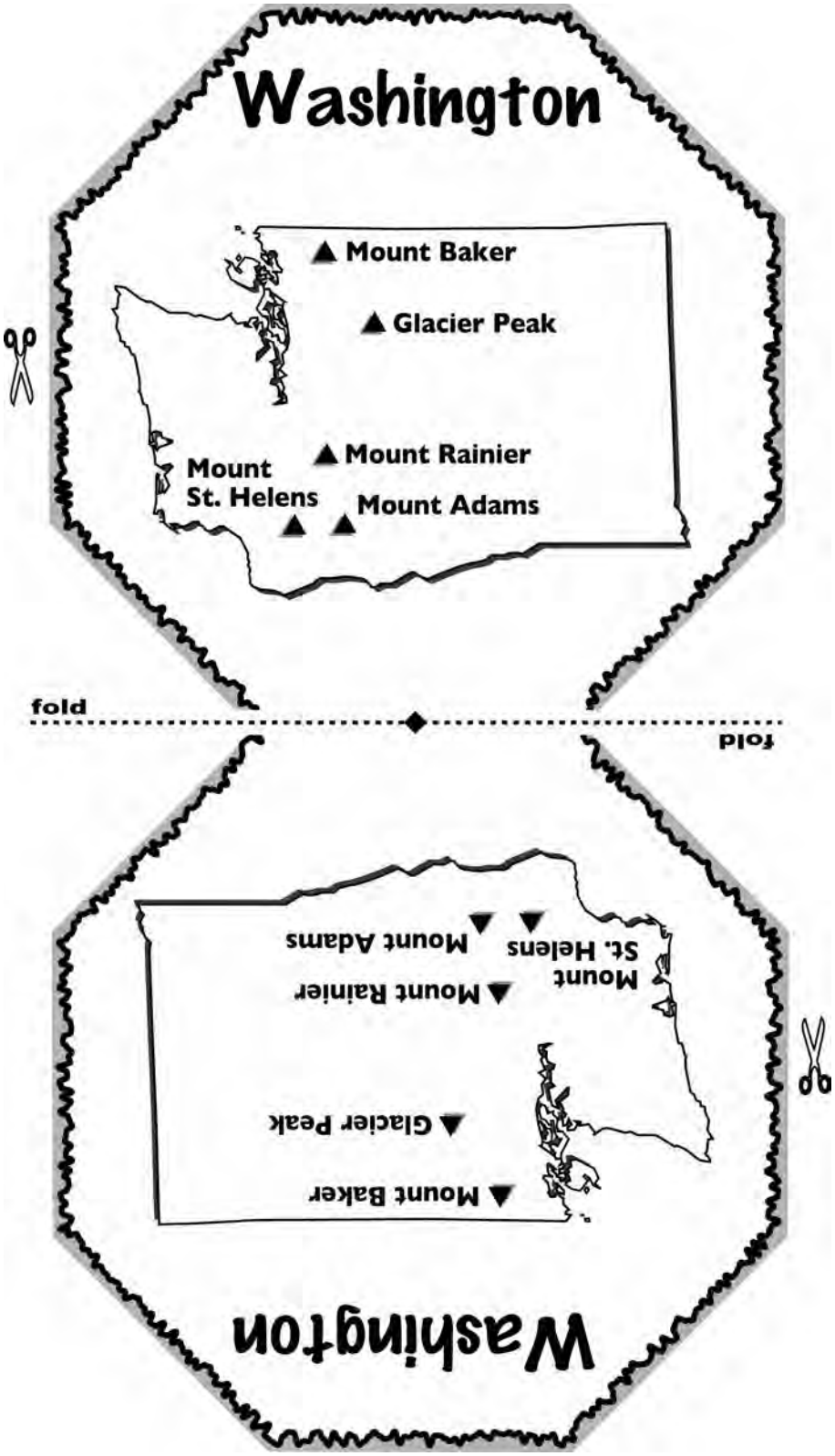
Location: Northern California
Elevation: 4,317 meters, (14,161 feet)
Closest cities: Mount Shasta City and McCloud, California
Most recent volcanic activity: 1786 eruptions of steam and ash
Most likely volcano hazards: Lava flows and domes, pyroclastic flows, tephra, lahars
Another fact about this volcano: Mount Shasta is a large stratovolcano that has erupted every 600 to 800 years for past 10,000 years; debris avalanche (landslide) 300,000 years ago spread at least 45 cubic kilometers (6.2 cubic miles) of rock debris over surface ten times larger than debris avalanche at Mount St. Helens in 1980; smaller cone Shastina was formed between 9,700 and 9,400 years before present

Lassen Peak

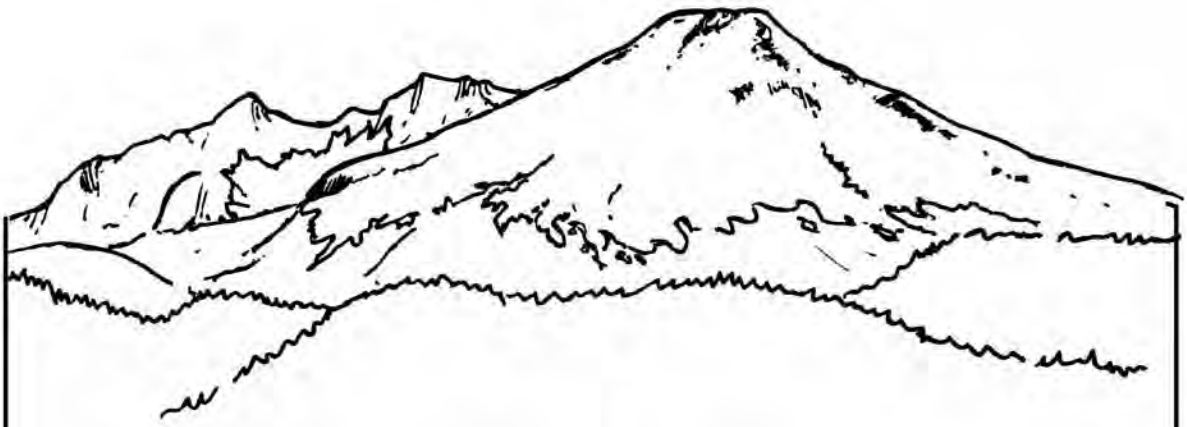
Location: Northern California
Elevation: 3,187 meters (10,457 feet)
Closest cities: Redding, Red Bluff, California
Most recent volcanic activity: 1914–1917 eruptions of steam, tephra and lava flows caused pyroclastic flows, lahars, and new dome growth
Most likely volcano hazards: Lava flows and domes, pyroclastic flows, lahars
Another fact about this volcano: Lassen Peak in large part consists of overlapping lava domes; named Tehama by Native Americans; Bumpass Hell is the largest geothermal area in the Cascades—it has bubbling mud pots, steaming fumaroles, and pools of boiling water

A String of Volcanoes—Mobile Pieces

A String of Volcanoes—Mobile Pieces



A String of Volcanoes—Mobile Pieces



Mount Baker

fold

Mount Baker

Location _____

Elevation _____

Closest cities _____

Most recent volcanic activity _____

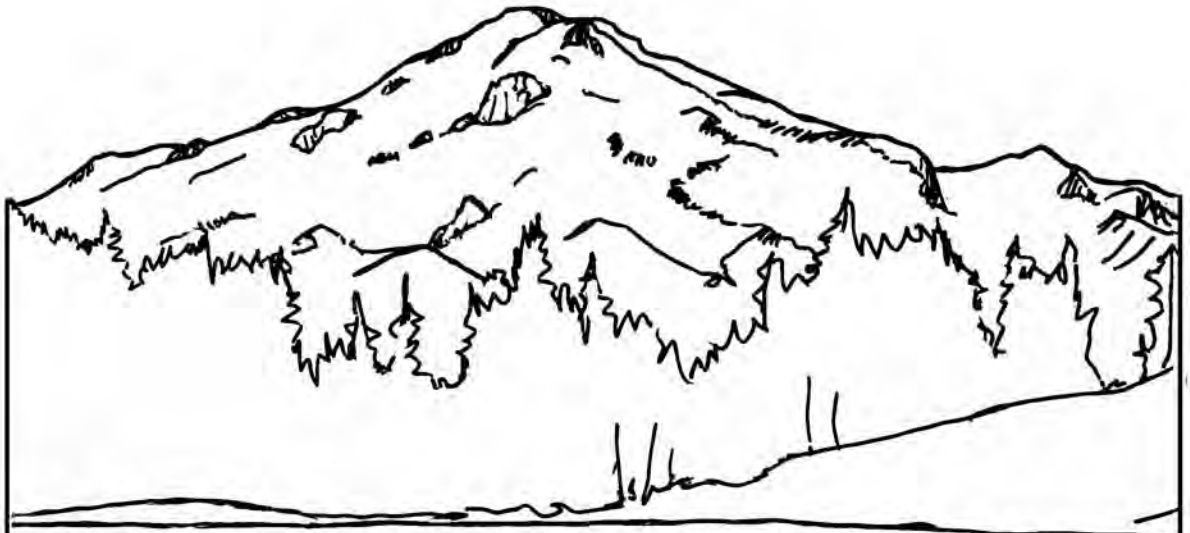
Most likely volcanic hazards _____

Another fact about this volcano _____

_____

fold

A String of Volcanoes—Mobile Pieces



Glacier Peak

fold

Location _____

Elevation _____

Closest cities _____

Most recent volcanic activity _____

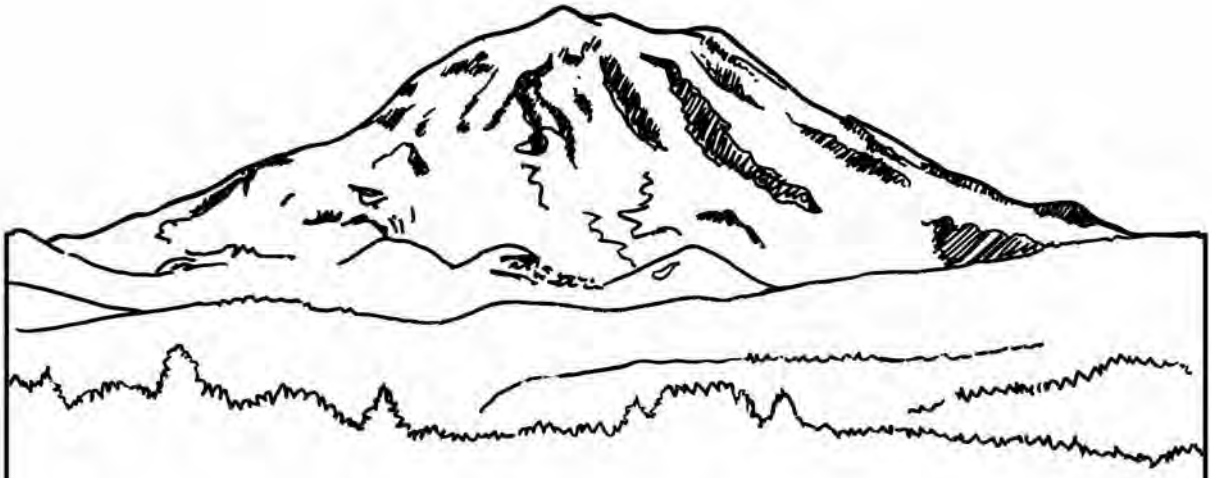
Most likely volcanic hazards _____

Another fact about this volcano _____

fold

Glacier Peak

A String of Volcanoes—Mobile Pieces



Mount Rainier

fold

Mount Rainier

Location _____

Elevation _____

Closest cities _____

Most recent volcanic activity _____

Most likely volcanic hazards _____

Another fact about this volcano _____

_____

fold

A String of Volcanoes—Mobile Pieces

fold

Mount St. Helens

Location _____

Elevation Location old dome _____ new dome _____

Closest cities _____

Most recent volcanic activity _____

Most likely volcanic hazards _____

Another fact about this volcano _____

_____

fold

A String of Volcanoes—Mobile Pieces

Mount Adams

fold

Mount Adams

Location _____

Elevation _____

Closest cities _____

Most recent volcanic activity _____

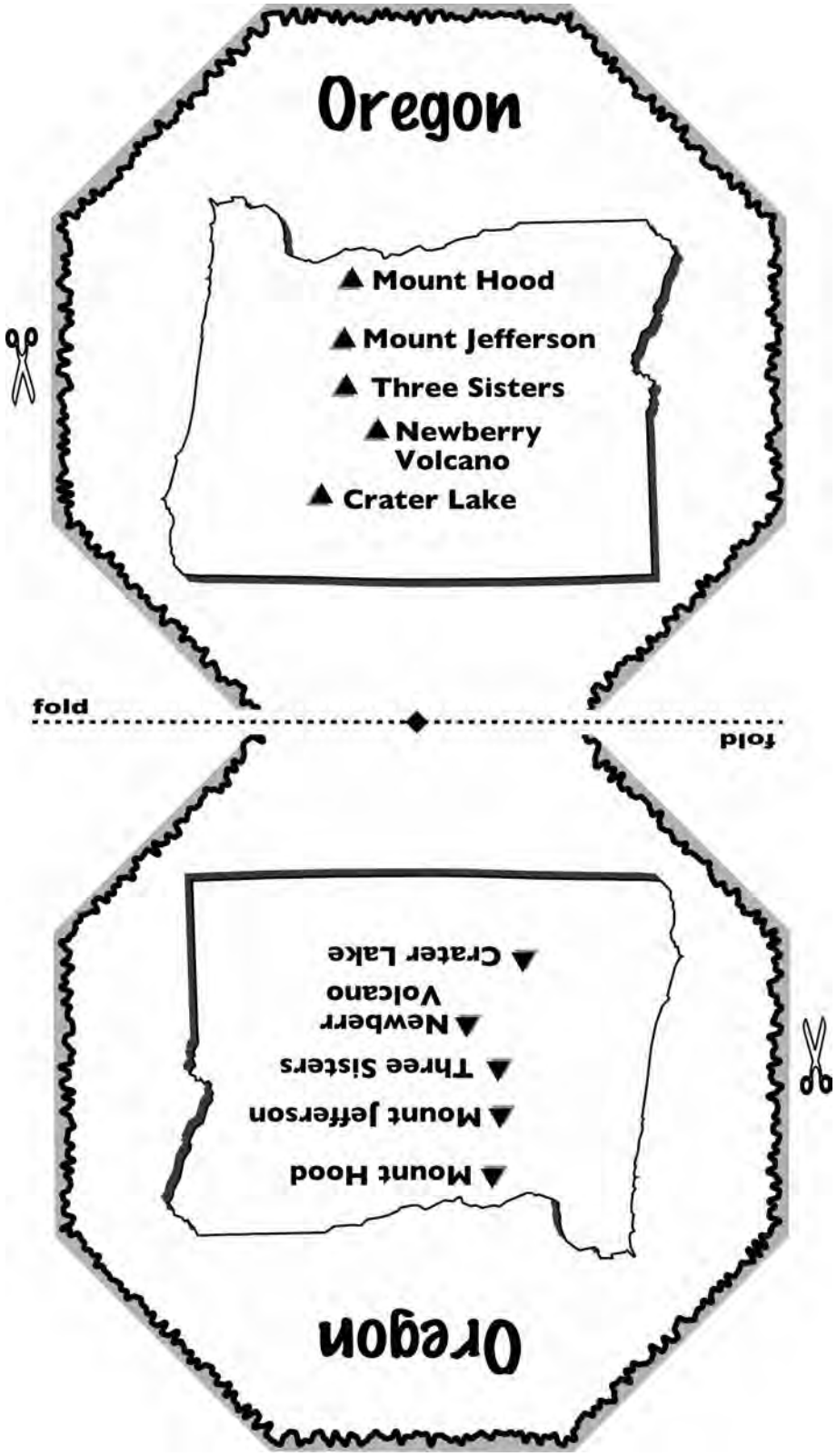
Most likely volcanic hazards _____

Another fact about this volcano _____

_____

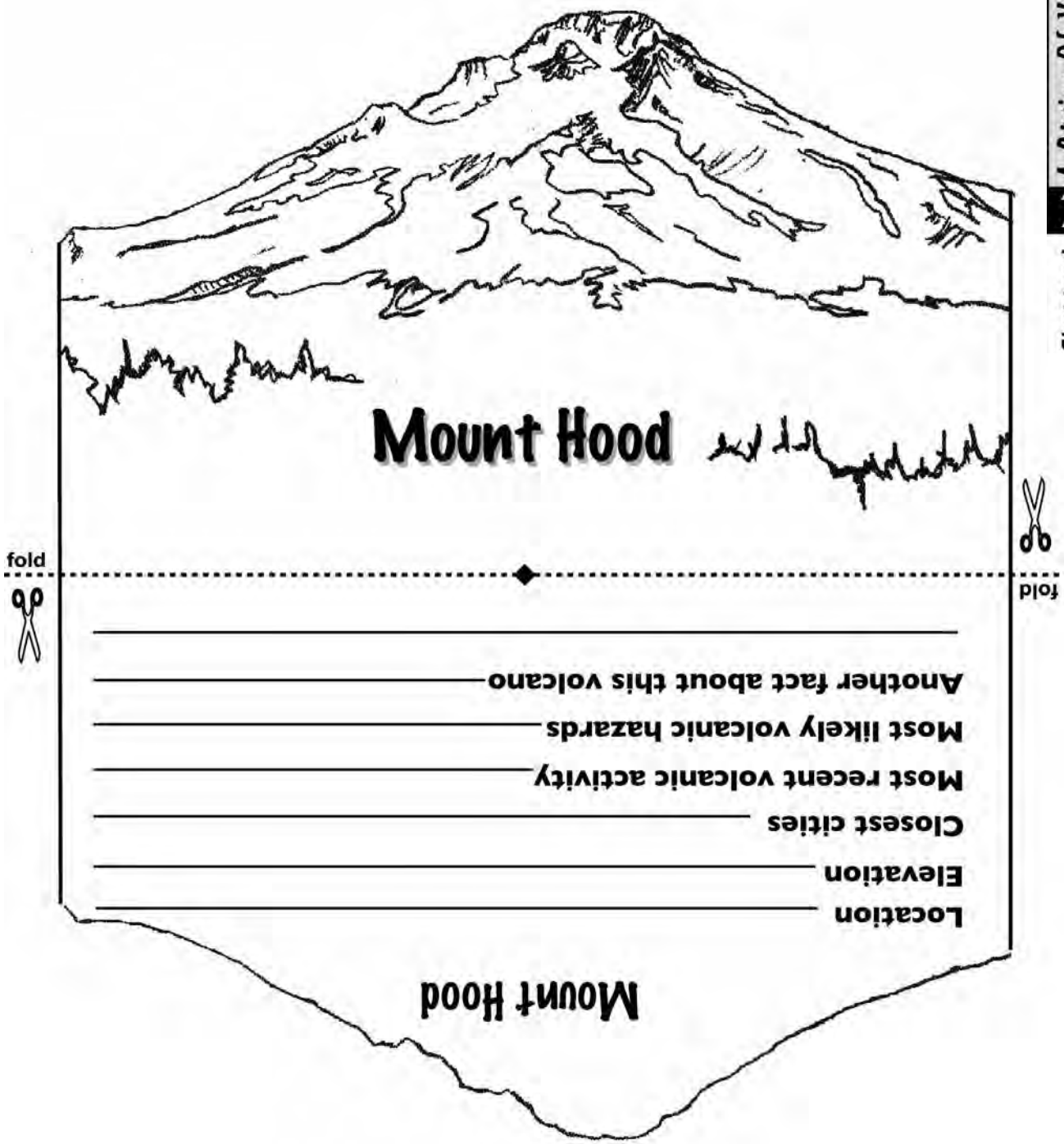
fold

A String of Volcanoes—Mobile Pieces



Student Page

A String of Volcanoes—Mobile Pieces



A String of Volcanoes—Mobile Pieces

Mount Jefferson

fold

Location _____

Elevation _____

Closest cities _____

Most recent volcanic activity _____

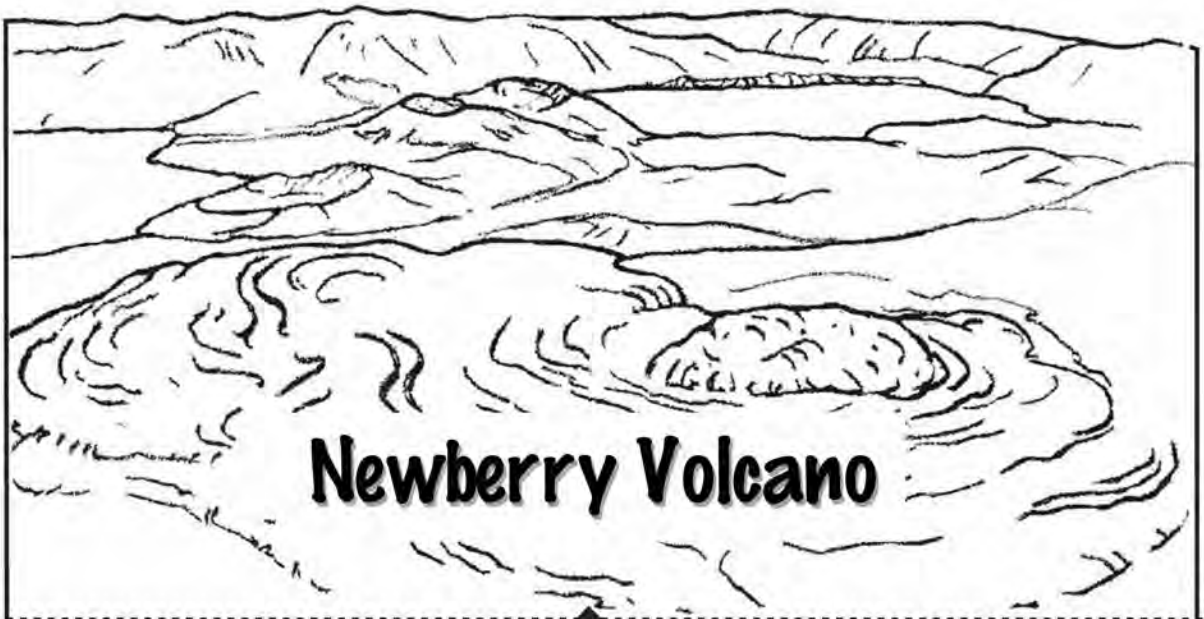
Most likely volcanic hazards _____

Another fact about this volcano _____

fold

Mount Jefferson

A String of Volcanoes—Mobile Pieces



fold

Newberry Volcano

Location _____

Elevation _____

Closest cities _____

Most recent volcanic activity _____

Most likely volcanic hazards _____

Another fact about this volcano _____

_____

fold

A String of Volcanoes—Mobile Pieces

Three Sisters

fold

fold

Three Sisters

Location _____

Elevation _____

Closest cities _____

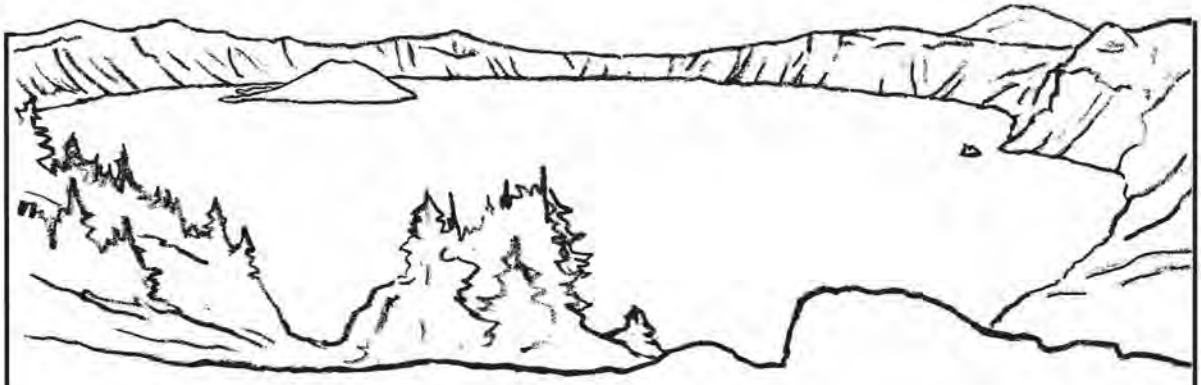
Most recent volcanic activity _____

Most likely volcanic hazards _____

Another fact about this volcano _____

_____

A String of Volcanoes—Mobile Pieces



Crater Lake

fold

fold

Crater Lake

Location _____

Elevation _____

Closest cities _____

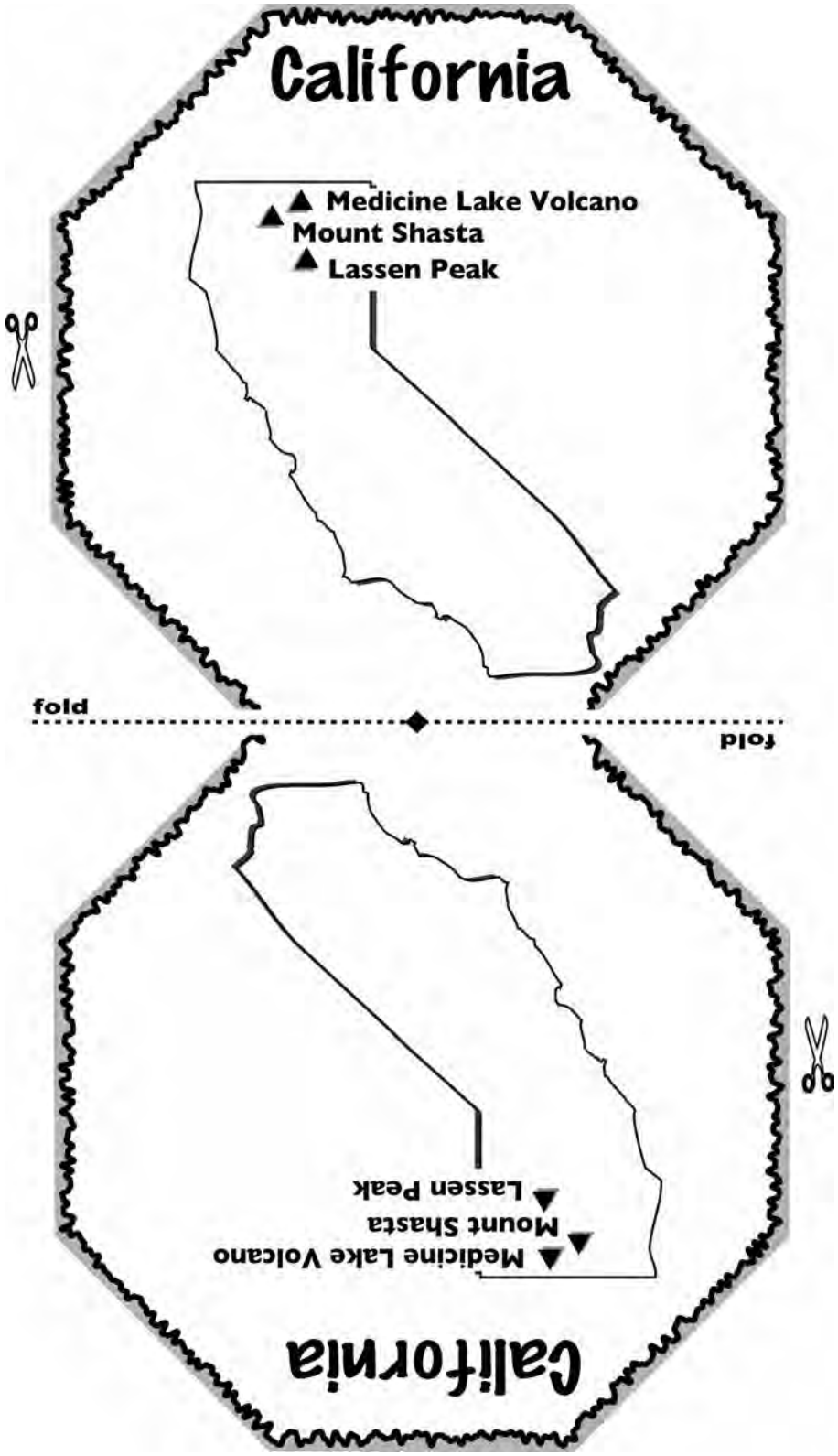
Most recent volcanic activity _____

Most likely volcanic hazards _____

Another fact about this volcano _____

_____

A String of Volcanoes—Mobile Pieces



A String of Volcanoes—Mobile Pieces

Medicine Lake Volcano

fold

fold

Medicine Lake Volcano

Location _____

Elevation _____

Closest cities _____

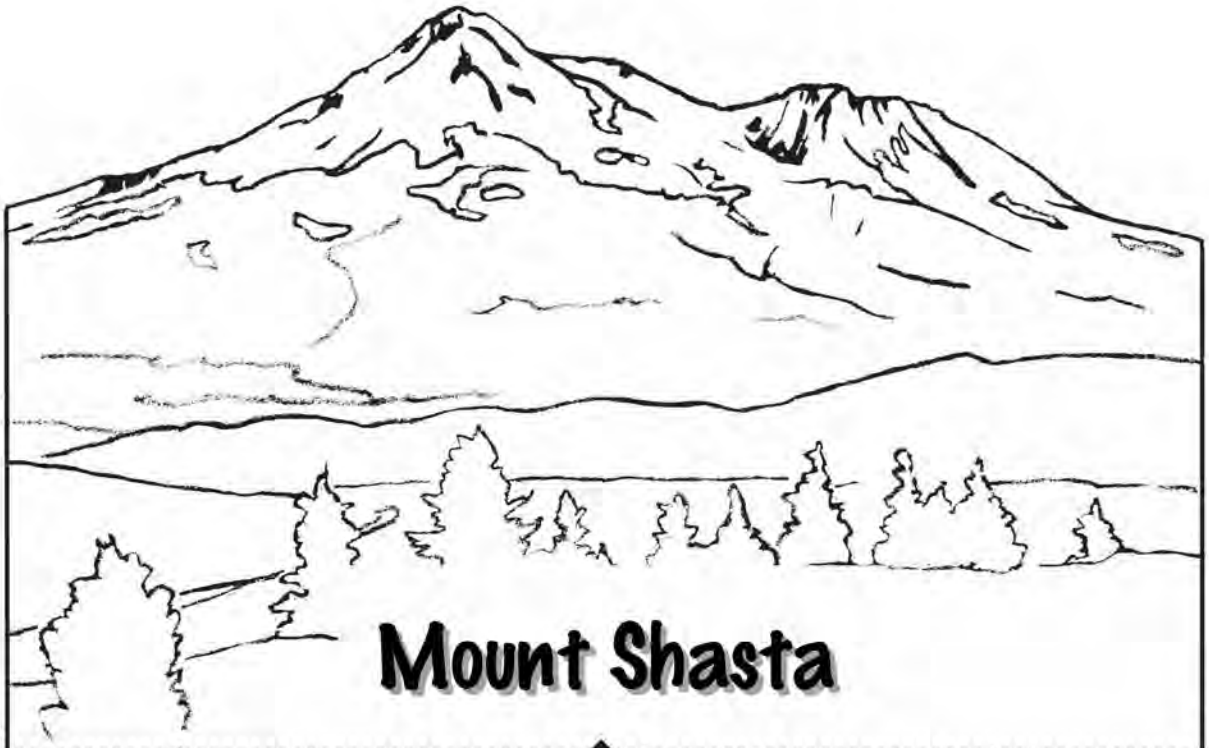
Most recent volcanic activity _____

Most likely volcanic hazards _____

Another fact about this volcano _____

_____

A String of Volcanoes—Mobile Pieces



Mount Shasta

fold

fold

Mount Shasta

Location _____

Elevation _____

Closest cities _____

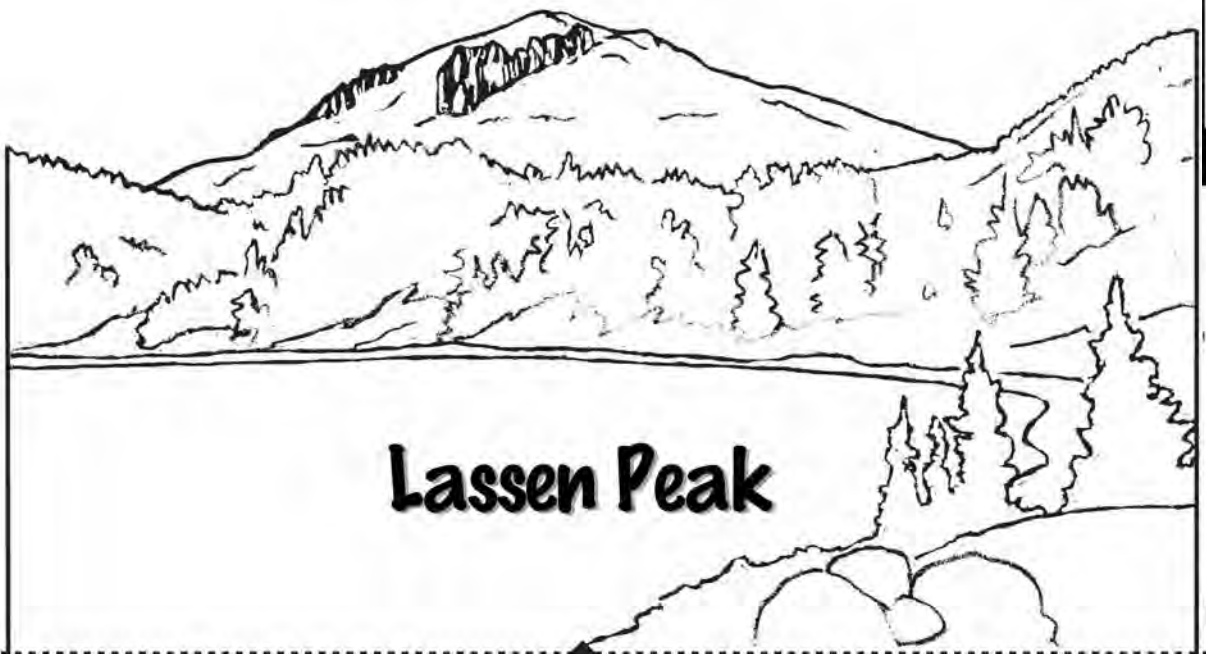
Most recent volcanic activity _____

Most likely volcanic hazards _____

Another fact about this volcano _____

_____

A String of Volcanoes—Mobile Pieces



fold

fold

Lassen Peak

Location _____

Elevation _____

Closest cities _____

Most recent volcanic activity _____

Most likely volcanic hazards _____

Another fact about this volcano _____

_____

Volcano Hall of Fame

Grade Level: 5–9

Learner Objectives:

Students will:

- Become familiar with important aspects about each of the Cascade volcanoes
- Identify sources of information about Cascade volcanoes
- Recognize the long-term interaction between people and Cascade Range volcanoes

Setting: Classroom

Timeframe: 30 minutes

Materials:

- Copies of *"Volcano Hall of Fame Cards"* student page
- Internet access or library resources
- USGS Volcano Fact Sheets (optional)

USGS
science for a changing world

Living with a Volcano in Your Backyard-An Educator's Guide with Emphasis on Mount Rainier

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

Students use fun facts to identify which Cascade volcano is being described.

Teacher Background

Refer to U.S. Geological Survey Fact Sheet 165–97 for general information about Cascade volcanoes and their locations in the Cascade Range. Find additional information at related activities, including **Cascade Volcano Timeline** and **Surrounded by Volcanoes**.

Procedure

Write a journal entry about a volcanic eruption to assess knowledge of volcanic processes and terms.

1. Give each student a "Volcano Hall of Fame" student page.
2. Explain procedure of matching facts to specific Cascade volcanoes.
3. Instruct students to use the Internet, library resources, or USGS Volcano Fact Sheets to match the facts to the correct volcano.

Adaptations

- Younger students can cut out the "***Hall of Fame***" cards and use as volcano trading cards.

Activity last modified: November 21, 2014

Vocabulary: Cinder cone, Klickitat, Kulshan, lahar, lava tube, obsidian, Loowit, Mazama, Modoc War, Pahto, shield volcano, stratovolcano, Tahoma, Tehama, tephra, volcanic ash, Wy'east

Skills: Communicating, creative writing

Benchmarks:

See benchmarks in Introduction.

Assessment

Use **A String of Volcanoes** as a learning tool, and **Volcano Hall of Fame** as an assessment of students' knowledge about important aspects of Cascade volcanoes. After completing these two activities, students should be able to identify important aspects of Cascade volcanoes and identify sources of information. Assess each student's ability to identify important aspects and to record them.

References

Dzurisin, D., Stauffer, P., and Hendley, J.W., II, 2003, Living with volcanic risk in the Cascades (revised March, 2008): U.S. Geological Survey Fact Sheet 165–97, 2 p.

Harris, S.L., 2005, Fire mountains of the West: the Cascade and Mono Lake volcanoes: Missoula, Mont., Mountain Press Publishing Company, 3rd ed., 454 p.

Tilling, R. I., Topinka, L., and Swanson, D.A., 1990, Eruptions of Mount St. Helens (revised edition): past, present, and future: U.S. Geological Survey General Interest Publication, 57 p.

Wright T.L., and Pierson, T.C., 1992, Living with volcanoes–The U.S. Geological Survey's Volcano Hazard Program: U.S. Geological Survey Circular 1073, 57 p.

Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

Student Page

Volcano Hall of Fame Cards

Instructions: *Use Internet or library resources to match the volcanoes in the Cascade Range (listed below) to the facts in the Volcano Hall of Fame. Write the name of the volcano below the number on each card.*

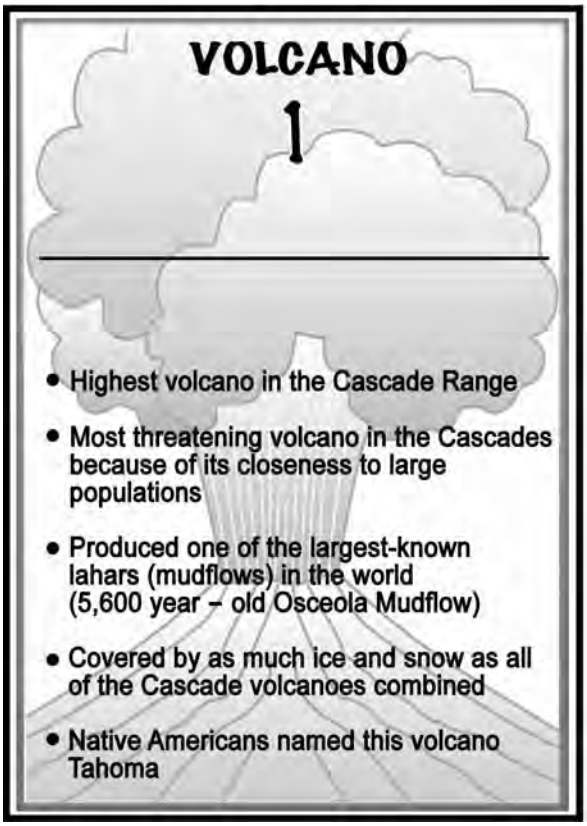
Crater Lake
Mount Baker
Mount Rainier

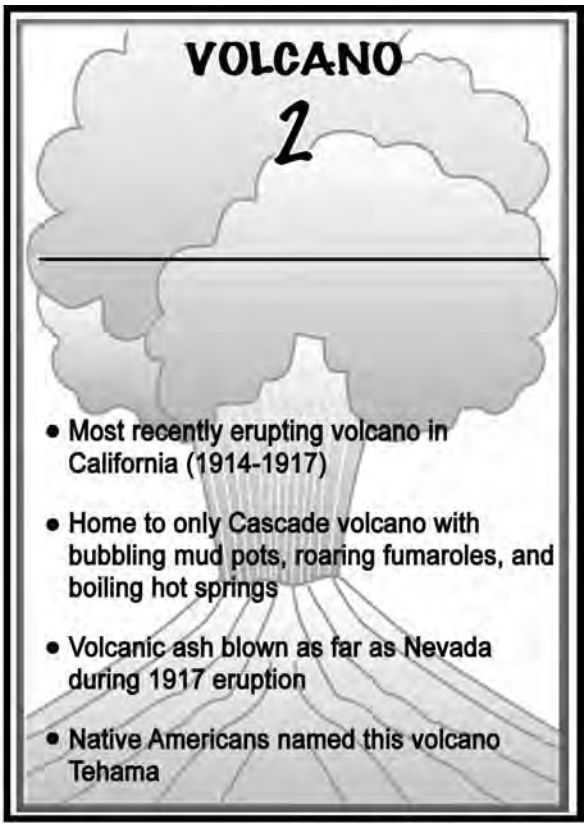
Glacier Peak
Mount Garibaldi
Mount Shasta

Lassen Peak
Mount Hood
Mount St. Helens

Medicine Lake Volcano
Mount Jefferson
Newberry Volcano

Mount Adams
Mount Meager
Three Sisters





Volcano Hall of Fame Cards-continued

VOLCANO 3

- A stratovolcano in southwestern British Columbia, Canada
- Ice-age glaciers confined lava and caused formation of thick lava layers–as much as 240 meters (800 feet) thick
- Melting of glacial ice could produce floods and lahars and endanger small communities in British Columbia

VOLCANO 4

- Cascade volcano that erupted most recently (1980-1986; 2004-2008)
- Most frequently active volcano in the Cascades during the past 4,000 years
- Eruptions and lahars caused $12 billion in damage–the most coslty volcanic event in United State history
- Known by Native Americans as Loowit

VOLCANO 5

- Large shield volcano–covers 1,300 square kilometers (500 square miles)
- Lava flows extend to the city of Bend, Oregon, and beyond
- More than 400 cinder cones dot the flanks of this volcano
- Produced a large glassy obsidian flow about 1,300 years ago

VOLCANO 6

- Largest shield volcano in California covers approximately 2,000 square kilometers (772 square miles)
- Well known for its extensive system of lava tube caves–at least 435
- Rugged volcanic landscape sheltered participants of the Modoc War of 1872-1873

Volcano Hall of Fame Cards-continued

VOLCANO 7

- Only volcanic area in Oregon where rising magma forces uplift of land surface
- Volcanoes span the horizon in a group of three west of Bend, Oregon
- These three volcanoes have the closest spacing of any stratovolcanoes in the Cascade Range
- Volcano group named by Methodist preacher

VOLCANO 8

- Second highest volcano in Washington
- Has the second largest lava volume of any stratovolcano in the Cascades
- Approximately 15 square kilometers (6 square miles) of lowland inundated by a lahar about 6,000 years ago and dammed a stream to form Trout Lake
- Known to Native Americans as Pahto or Klickitat

VOLCANO 9

- Oregon's most recently erupting volcano
- Highest peak in Oregon
- Only Oregon volcano to produce yearly earthquake swarms
- In 1805, Lewis and Clark observed quick-sand remaining from a lahar caused by an eruption that occurred about two decades earlier
- Named Wy'east by Native Americans

VOLCANO 10

- Largest eruptive volume of the Cascade Range volcanoes
- Viewed close-up from a nearby superhighway and railway in northern California
- Sustains Whitney Glacier, the largest glacier in California
- Partial volcano collapse about 300,000 years ago caused giant rock avalanche that came to rest as a field of small hills covering 174 square miles (450 square kilometers)

Volcano Hall of Fame Cards-continued

VOLCANO 11

_____

- Most remote of the Cascade volcanoes within the United States
- Produced one of the most explosive eruptions in the Cascades about 13,000 years ago
- Lahars threaten communities in river valleys of northwestern Washington

VOLCANO 12

_____

- Least active volcano in the Cascade Range–no known eruptions since the last ice age
- Erupted repeatedly for hundreds of thousands of years; last eruptive episode during the last ice age
- Lewis and Clark named this volcano in honor of America's third President

VOLCANO 13

_____

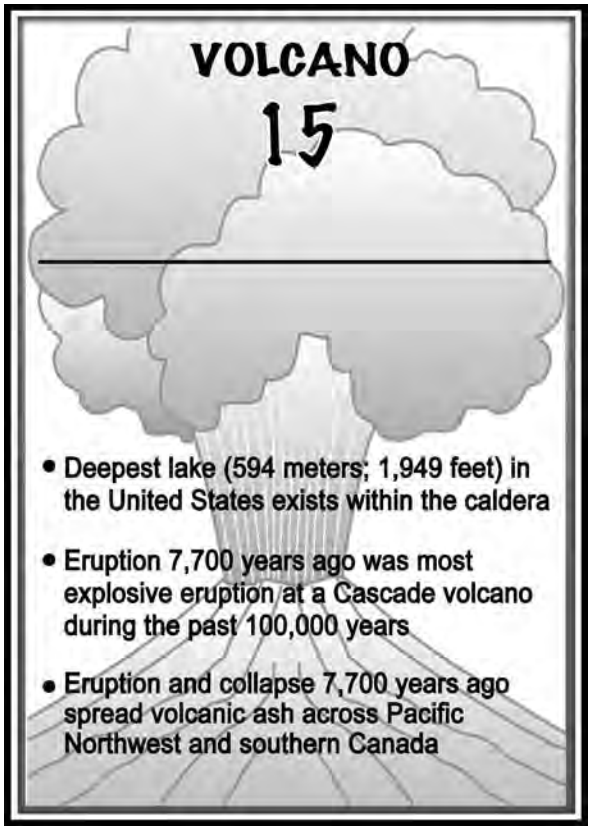
- Lahars from this volcano threaten communities in northwestern Washington and southern British Columbia
- Increased steam activity caused small mudflows in 1975
- 1843 eruption formed new crater that continues to steam
- Known by the Native people as Kulshan

VOLCANO 14

_____

- Volcano furthest north in the chain of volcanoes
- A complex of several volcanoes
- Widespread volcanic ash in southwestern Canada
- Most explosive eruption in Canada during past 10,000 years

Volcano Hall of Fame Cards-continued



Teacher Page

Volcano Hall of Fame—Answers

The following volcano names match the clues given in the Volcano Hall of Fame.

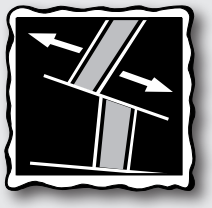
1. Mount Rainier
2. Lassen Peak
3. Mount Garibaldi

4. Mount St. Helens
5. Newberry Volcano
6. Medicine Lake Volcano

7. Three Sisters
8. Mount Adams
9. Mount Hood
10. Mount Shasta
11. Glacier Peak
12. Mount Jefferson
13. Mount Baker

14. Mount Meager
15. Crater Lake

Surrounded by Volcanoes



Grade Level: 5+

Learner Objectives:

Students will:

- Recognize individual Cascade volcanoes as part of an extensive volcanic mountain range, and as part of the circum-Pacific "Ring of Fire"
- Draw conclusions on relationships between tectonic plate movement and the occurrence of volcanic activity

Setting: Classroom, computer lab

Timeframe: Two 50-minute sessions

Session I:

Introducing Cascade Volcanoes as Links on the Ring of Fire

Exploring Earthquakes and Volcanoes at Plate Boundaries

Session II:

Discovering Volcanoes of the Cascade Range using Satellite Imagery

USGS science for a changing world

NATIONAL PARK SERVICE

Living with a Volcano in Your Backyard-An Educator's Guide with Emphasis on Mount Rainier

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

This multi-faceted activity leads students from a broad discussion about plate tectonics to specific information about volcanic peaks of the Cascade Range. "***Introducing Cascade Volcanoes as Links on the Ring of Fire***" explores the location of Cascade volcanoes on the "Ring of Fire." "***Exploring Earthquakes and Volcanoes at Plate Boundaries***" addresses associations of plate boundaries, earthquakes and the location of Cascade volcanoes. In "***Discovering Volcanoes of the Cascade Range using Satellite Imagery***" students investigate the location of Cascade volcanoes on a satellite photo using computer technology, or identify volcanoes on a conventional map.

Materials:

Introducing Cascade Volcanoes as Links on the Ring of Fire

- Copies of ***"Introducing Cascade Volcanoes as Links on the Ring of Fire"*** student page
- Graphic ***"Cascade Volcanoes Links on the Ring of Fire"*** (optional)
- Dynamic Planet map (optional)

Exploring Earthquakes and Volcanoes at Plate Boundaries

- Copies of ***"Plate Tectonics-Cascade Range"*** student page
- Copies of ***"Using Earthquakes to Find the Subduction Zone"***
- Graphic ***"Plate Tectonics Processes"***
- Graphic ***"Types of Tectonic Plate Boundaries"***
- Graphic ***"Plate Tectonics—Cascade Range"***

Activity last modified: July 22, 2015

- Graphic "*Using Earthquakes to Find the Subduction Zone*" (student page)
- Graphic "*Using Earthquakes to Find the Subduction Zone*" (teacher page)

Discovering Volcanoes of the Cascade Range using Satellite Imagery

- Student-use computers
- Graphics or word processing program and the provided satellite image file installed on student computers
- *"Surrounded by Volcanoes—Satellite Image"* student page (digital file of same name) or *"Map of Cascade Volcanoes"* as low-tech adaptation
- Graphic *"Map of Cascade Volcanoes"*

Vocabulary: Asthenosphere, Cascadia Subduction Zone, convergent plate boundary, divergent plate boundary, hot spots, lithosphere, mafic, magma, magma chamber, mantle, Ring of Fire, spreading ridge, subduction, tectonic plates, transform plate boundary

Skills: interpreting, mapping, observing, relating spatially, synthesizing

Benchmarks:

See benchmarks in Introduction.

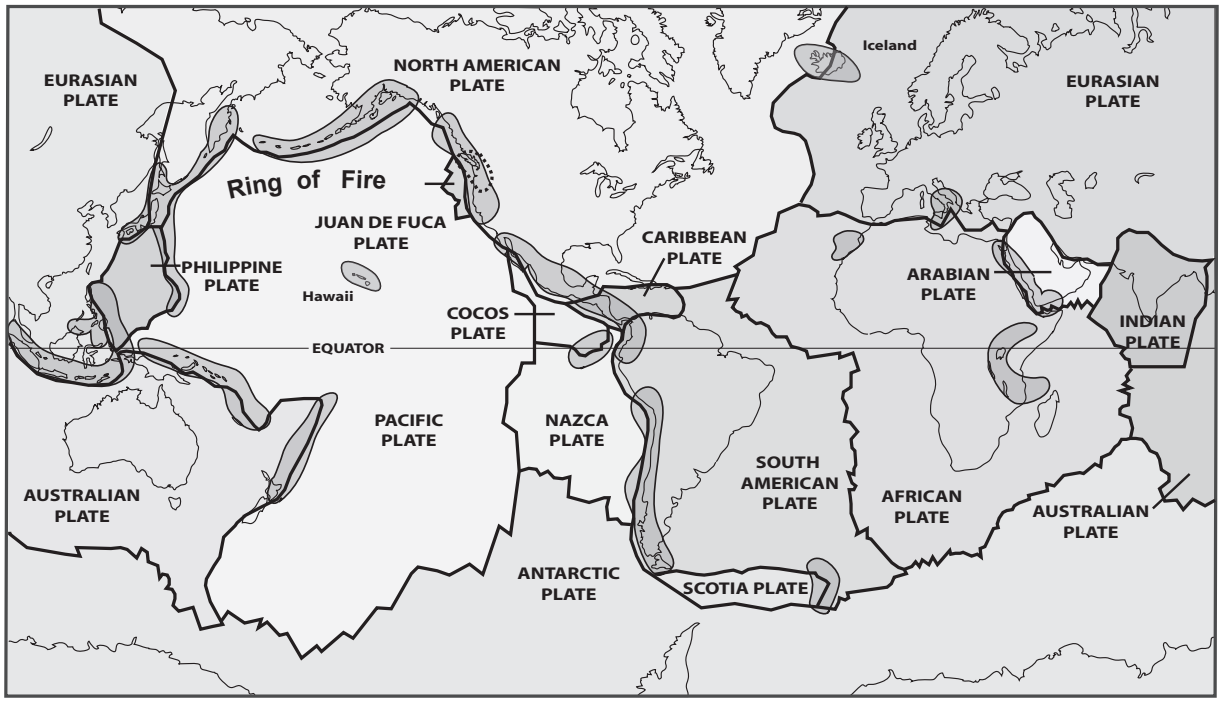
Teacher Background

Tectonic plates move like choreographed dancers

Earth's lithosphere is fragmented into more than a dozen tectonic plates that glide across the soft ***mantle*** of the Earth like carefully choreographed dancers. Some plates glide past each other horizontally as transform plate boundaries. Other plates dance away from one another, as divergent plate boundaries. Some plates move toward each other and meet at ***convergent plate boundaries***. The distribution of earthquakes and volcanoes on the Earth reveals the boundaries of these plates. In the same way, knowledge about plate boundaries helps scientists understand the potential for earthquakes and volcanoes around the world.

Cascade volcanoes are part of Earth's "Ring of Fire"

The collection of hundreds of volcanoes encircling the Pacific Ocean is known as the ***"Ring of Fire***." In this zone, plate boundary interactions set the stage for volcano and earthquake activity in regions as diverse as New Zealand, Indonesia, Alaska, Mexico and the western United States. The Cascade volcanoes are part of this "Ring of Fire." Each volcano is a link in the chain.



Modified from Tilling, Heliker, and Wright, 1987, and Hamilton, 1976

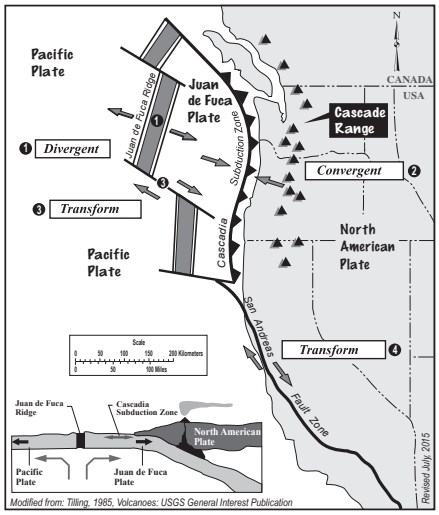
EXPLANATION

- Regions of earthquakes and volcanic activity
- Plate boundaries
- Location of Cascade Volcanoes

Three plate boundary types exist in the Pacific Northwest

All three plate boundary types exist off the coast of the Pacific Northwest. The Pacific and Juan de Fuca Plates originate as a slab of hot volcanic at the divergent ***spreading ridge (1)***. At a convergent plate boundary eighty kilometers (fifty miles) from the coast in an area named the ***Cascadia Subduction Zone (2)*** the Juan de Fuca begins its downward dive called ***subduction***, at a rate of approximately 5 centimeters (2 inches) per year at an angle of as much as 60 degrees. Transform plate boundaries separate the plates on their north and south sides ***(3)***.

Plate Tectonics—Cascade Range



Modified from: Tilling, 1985, Volcanoes: USGS General Interest Publication

Subduction of the Juan de Fuca Plate sets the stage for volcanism

The Juan de Fuca Plate consists of dense oceanic plate rock that is relatively thin compared to most of the North American Plate. The Juan de Fuca Plate originates as a slab of hot volcanic rock at the spreading ridge. As it moves eastward, it cools, becomes denser and sinks into ***asthenosphere***, the soft, highly viscous rock of the upper mantle beneath the western edge of the North American Plate. Eventually, temperatures are hot enough to break down water-bearing minerals within the sinking Juan de Fuca Plate. Water is released into the overlying mantle, where it lowers the melting temperature of rock and causes the mantle rock to melt. By this complex combination of physical and chemical processes, ***magma*** forms**.** The upward movement of magma, caused by magma being less dense than surrounding solid rocks, also forces melting of crustal rocks and the formation of ***magma chambers*** that feed Cascade volcanoes.

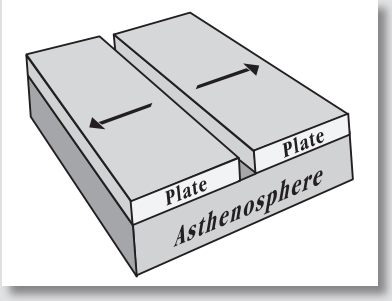
Cascade volcanoes erupt above the Cascadia Subduction Zone

The roughly linear string of volcanoes in the Cascade Range is not an accident of nature. Volcanoes stand directly above the subducted slab (80 to 120 kilometers deep) where conditions for magma formation are roughly uniform. This string of volcanoes exists inland from the edge of the North American Plate and parallel to the Cascadia Subduction Zone. The 3,000-kilometer-long (1,600-mile-long) chain of active volcanoes stretches from Mount Meager in British Columbia to Lassen Peak in northern California. As with humans, each Cascade volcano possesses its own “personality” and “life story.” Some volcanoes display explosive behavior while others erupt more placidly. Several have erupted frequently in historical time while others remain quiescent. Most major Cascade volcanoes support active glaciation. All sustain complex ecosystems and supply water for recreation, agriculture, and human consumption. All present potential geological hazards.

Sidebar 1 Tectonic Plates set the Stage for Earthquakes and Volcanoes

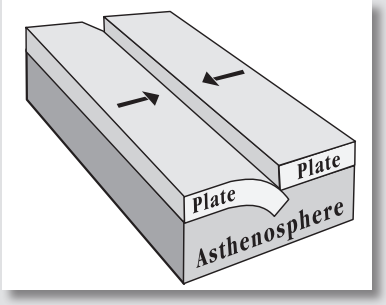
DIVERGENT PLATE BOUNDARIES

About seventy-five percent of Earth's volcanism occurs sight unseen at the ocean bottom, where plates pull apart along divergent plate boundaries. Magma rises in the gap between the separating plates and erupts—building volcanoes as a spreading ridge on the sea floor. The recently (1998) erupting Axial Seamount located on the west edge of the Juan de Fuca Plate, 480 kilometers (300 miles) west of Cannon Beach, Oregon, is one of the best documented examples. Another well-known illustration is the spreading ridge of volcanoes along the Mid-Atlantic Ridge, which pulls apart at a rate of about 2.5 centimeters per year (1 inch per year) and which rises above sea level as Iceland.



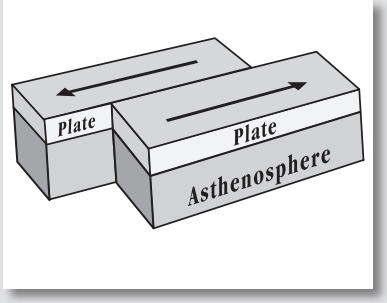
CONVERGENT PLATE BOUNDARIES

Converging tectonic plates are frequently of different densities. While both plates are in motion, commonly the denser plate moves beneath the other in a process known as subduction. The grinding together of these plates generates a tremendous stress that causes the subducting plate to crack, fracture and shake. Thus, the pattern of earthquakes delineates the position of the subducting slab. Approximately 400 kilometers (250 miles) in depth, temperature and pressure are so high that the subducting plate ultimately loses physical identity and continuing movement fails to produce earthquakes.



TRANSFORM PLATE BOUNDARIES

At transform faults, plates slide past one another horizontally and produce earthquakes, though rarely cause volcanoes. The San Andreas Fault Zone in California, where the Pacific Plate slides past the North American Plate at a rate of 5 centimeters (2 inches) per year, is one of the best known examples of a transform plate boundary. In the Pacific Northwest, a transform plate boundary separates the Juan de Fuca Plate on the north side from the Pacific Plate on the south side.



INTRA-PLATE VOLCANISM

The Hawaiian volcanoes and the Yellowstone volcanic area are two examples of regions where magma rises beneath a tectonic plate rather than at plate margins. Continuing plate movement carries the land surface across a persistent source of rising magma called a *hot spot*. Through time, plate motion across the hot spot allows formation of a line of volcanoes. Not all intra-plate volcanoes are caused by hot spots. Researchers note that the gradual east-west spreading of western North America to form the Basin and Range province is responsible for volcanoes in eastern California, Nevada, Arizona and New Mexico, Utah and southern Idaho, too.

Sidebar 2 The Difference Between Crust and Lithosphere

Researchers use two classification systems for categorizing Earth's internal structure

CLASSIFICATION BY ROCK TYPE

- *Crustal rocks* are distinguishable by their silica-rich composition

  Underlying mantle rocks contain dark and dense minerals that are abundant in magnesium and iron *(mafic rocks)*.

CLASSIFICATION BY ROCK FLOW PROPERTIES

- *Lithosphere* includes crustal rocks and the comparatively rigid rocks of the upper mantle. Together, they form a rigid shell, which breaks into pieces (tectonic plates), and moves around like floating puzzle pieces on more mobile mantle rock below.
- *Asthenosphere* describes the soft, highly viscous rock of the upper mantle, which supports tectonic plates of the lithosphere.

Both systems recognize the existence of a liquid outer and rigid inner core within the earth.

Teacher Tips

Actual plate tectonics are more complex than generally portrayed, with many plates being a combination of continental and oceanic rock. In this activity we portray plates solely as oceanic or continental for the sake of simplicity.

Procedure

What to do before class begins:

Introducing Cascade Volcanoes as Links on the Ring of Fire

1. Make copies of student page "***Introducing Cascade Volcanoes as Links on the Ring of Fire***."

2. Prepare to show graphic "***Cascade Volcanoes—Links on the Ring***" teacher page (optional).

Exploring Earthquakes and Volcanoes at Plate Boundaries

1. Make copies of "***Plate Tectonics—Cascade Range***" and "***Using Earthquakes to Find the Subduction Zone.***"

2. Prepare to show graphics "***Plate Tectonic Processes,***" "***Types of Tectonic Plate Boundaries***," and "***Plate Tectonics—Teacher Page.***"

Discovering Volcanoes of the Cascade Range using Satellite Imagery

1. Review capability of your students' computers and determine which graphics or word processing programs are suitable for students' electronic labeling of features on the digital map provided. The satellite image is in .jpeg format and can be downloaded in almost any graphics program.

2. Download the "***Surrounded by Volcanoes—Satellite Image***" student page file. Import the image to a blank text document, or use a graphics program if available. Place file in a directory that is accessible to students.

3. If you are using the adaptation option, make copies of "***Map of Cascade Volcanoes***."

4. Prepare to show graphics "***Discovering Cascade Volcanoes with Satellite Imagery***" teacher and student pages.

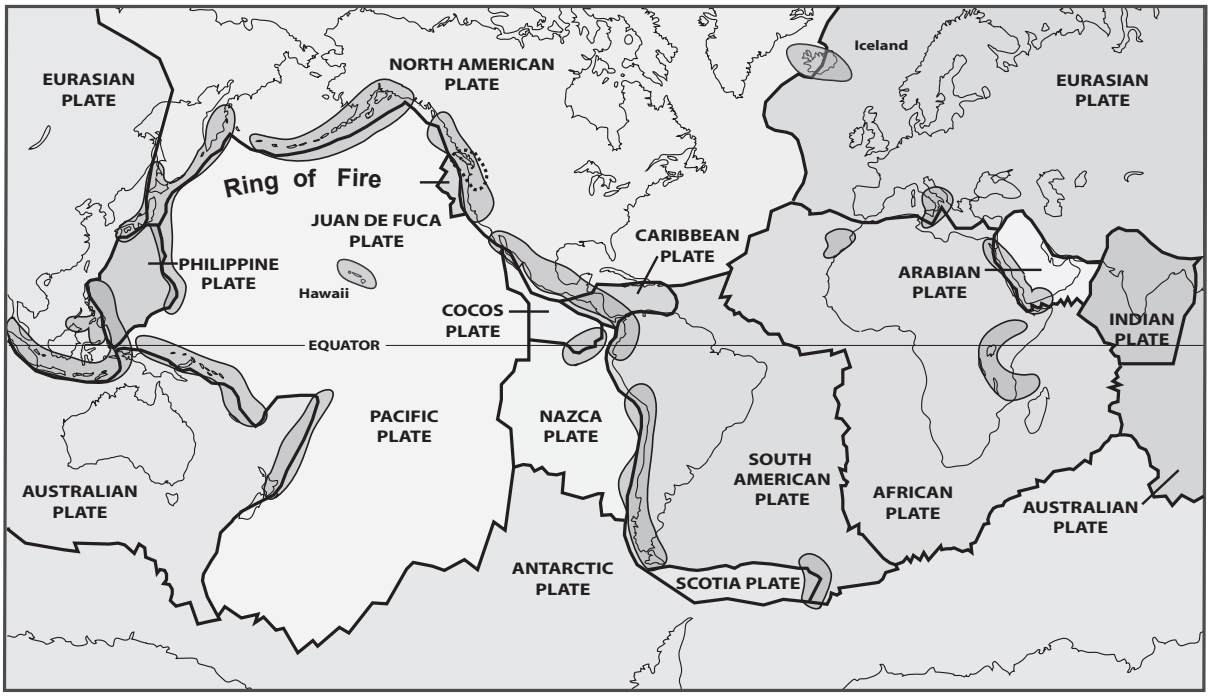
Introducing Cascade Volcanoes as Links on the Ring of Fire

Students view map of Earth's tectonic plates, such as the "***Cascade Volcanoes—Links on the Ring of Fire***," or the optional "***Dynamic Earth***" map (see References) or other map. They note the region's tectonic plate boundaries relative to the zones of earthquakes and volcanoes, and then answer questions.

1. Provide each student with the student page "***Cascade Volcanoes—Links on the Ring of Fire***," You can display the color graphic version overhead.

2. Instruct students to answer questions.

3. Discuss answers with the class, focusing attention on the relationship of tectonic plate boundaries to the patterns of distribution of volcanoes and earthquakes.



Modified from Tilling, Heliker, and Wright, 1987, and Hamilton, 1976

EXPLANATION

- Regions of earthquakes and volcanic activity
- Plate boundaries
- Location of Cascade Volcanoes

Exploring Earthquakes and Volcanoes at Plate Boundaries

Perform a quick demonstration of plate boundaries, and then make information relevant to the Pacific Northwest with two student pages.

1. Read background to review your knowledge of plate tectonics and positions of Cascade volcanoes.

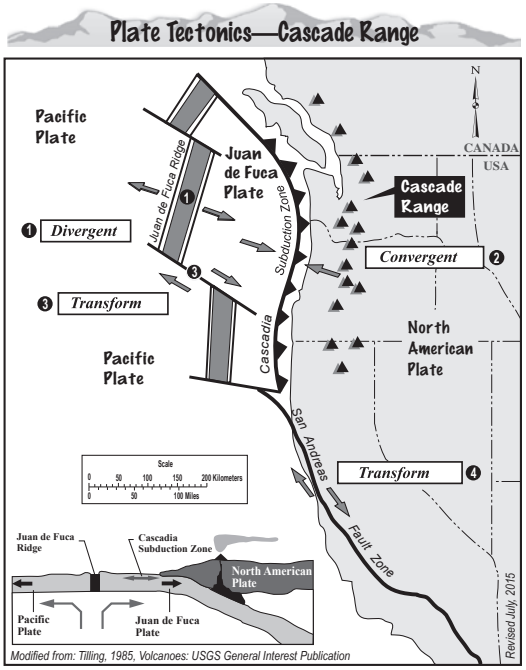
2. Review the basic concepts of plate tectonics with your students.

3. Demonstrate the three types of plate boundaries by first asking for six student volunteers (smaller numbers of students work as well).

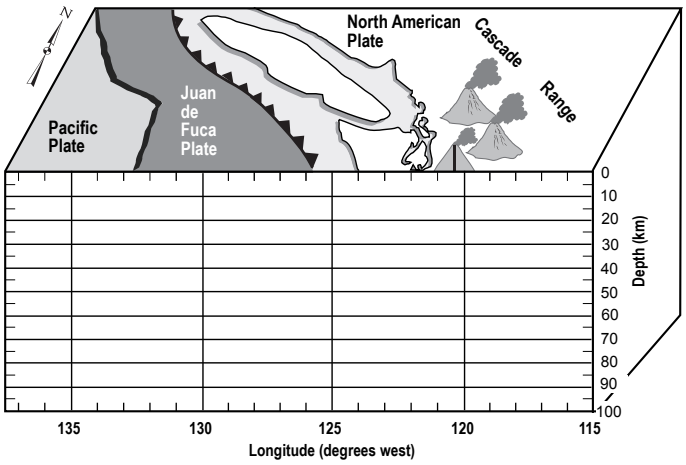
- ***For a Convergent Plate Boundary:*** Instruct volunteers to form two lines of three—about 3 feet apart and facing each other. The three volunteers on the right represent an oceanic plate, which is dense and thin; and the other three volunteers on the left signify the less dense but thicker continental plate. Volunteers hold their arms out toward the person directly across from them. Students move towards each other and their hands collide. Then the oceanic plate volunteers "dive" their arms beneath the continental plate to illustrate subduction.
- ***For a Divergent Plate Boundary:*** Instruct volunteers to form two lines of three and to stand toe to toe. Instruct volunteers to grasp the hands of the person across from them. Tell students to move away from each other, slowly releasing their grasp as they inch farther and farther apart.
- ***For a Transform Plate Boundary:*** Instruct volunteers to form two parallel lines of three students. Ask the groups to face each other and to take three sideways steps to their respective lefts such that they glide past one another.
  Optional: Line up students who participated in the demonstration and some additional students. Call each forward and introduce them individually, from north to south, as representative of a Cascade volcano.

4. In further discussion use the graphic "***Plate Tectonics Processes***" and "***Types of Tectonic Plate Boundaries***" to illustrate plate boundaries.

5. Provide each student with a copy of "***Plate Tectonics—Cascade Range***" student pages. Students label the three tectonic plate boundary types—convergent, divergent and transform.



6. Distribute "***Using Earthquakes to find the Subduction Zone***." Students use depth and longitude data to plot locations of earthquakes. The resulting pattern indicates the location of the Cascadia Subduction Zone. Students answer questions on each student page. Teachers should note the extension activity about earthquakes associated with the Cascadia subduction zone.



7. As a class, review answers and summarize concepts learned.

Discovering Volcanoes of the Cascade Range Using Satellite Imagery

Students use library and Internet resources to find the location of volcanoes and nearby features on the satellite image. This activity can be accomplished using a variety of graphics or word processing computer programs depending on the computer literacy of your students, or in a low-tech manner by copying the graphic and having the students label each volcano by hand. Use student page "***Map of Cascade Volcanoes***" as a low-tech alternative (See Adaptations).

1. Explain to students that they will be importing a satellite image of volcanoes in the Cascade Range onto their computer and labeling it. The image was taken by either the Aqua or Terra satellites on June 13, 2002, using an instrument called MODIS (MODerate-resolution Imaging Spectroradiometer). This instrument is able to measure different wavelengths of light so that scientists can study oceans and land features. This image was originally used to spot forest fires, but it also provides a great view of volcanoes in the Cascades.

2. Divide students into small groups or instruct them to work individually.

3. Provide each student or group of students with a student page "***Discovering Volcanoes of the Cascade Range Using Satellite Imagery***."

4. Open the satellite image in an appropriate program. Review computer tools available for drawing and labeling features on the digital satellite image. In word processing programs, use drawing bar and text boxes.

5. Instruct students to identify and label state and national borders and the location of population centers. Using the Internet and (or) an atlas, students should identify the location of the volcanoes listed on the student activity sheet and circled on the satellite image. Students should label volcanoes on the satellite image.

6. Invite them to explore other land features—snow covered mountains, lakes, rivers, distinct vegetative zones, clouds, and the ocean. They will also note many smaller, less prominent volcanoes.

Adaptations

- ***Introducing Cascade Volcanoes as Links on the Ring of Fire***. Use the "***This Dynamic Planet***" map (see References and Internet Resources) as a more detailed visual to answer questions on the student pages. Explore other volcano issues: the pairing of earthquake zones to regions of volcanism. Ask students to investigate why not all volcanoes exist at plate boundaries. Use "This Dynamic Earth" booklet as resource for this guided exploration (see References and Internet Resources).

- ***Alternative to Exploring the Volcanoes of the Cascade Range using Satellite Imagery.*** Use a non-technical approach. Students use library and or Internet resources to research location of Cascade volcanoes, then identify and label each on the ***Map of Cascade Volcanoes***.

Extensions

You may want to expand the Internet research goals for this activity.

- Use sandwich creme cookies to illustrate convergent, divergent and transform plate boundaries. Distribute one cookie to each student. Explain how the bottom cookie piece represents Earth's core, the creme in the center illustrates plastic mantle rock, and the top cookie piece represents Earth's crust and part of the upper mantle. Instruct students to twist off the cookie top and break it in half, then place the two halves back on top of the creme. Coach students through the following steps: use thumbs to move the two top halves towards each other to model convergent plates, away from each other for divergent plates, and back and forth, parallel to each other for a transform plate boundary. *Used Courtesy of Dr. Robert Lillie, Oregon State University.*

- Instruct students to find several facts about each volcano and add them to the information on the satellite image.

- Divide students into groups and tell them to become experts about one volcano. Students can later present the information to the class.

- Tell students to find information about the Cascade Range and to put it on the satellite image to make a poster.

- Instruct students to research the three types of earthquakes associated with the Cascadia subduction zone. They should explain the hazards of each type of earthquake.

- **Volcano Hall of Fame** activity. Students explore the individual personalities of volcanoes in the Cascade Range by reading facts and matching them to the appropriate volcano.

- **String of Volcanoes** activity. This activity is meant for younger grades (3 to 6). Students construct a mobile that represents volcanoes of the Cascade Range. Students use "Fun Facts" to identify and label the volcanoes.

Assessment

Cascade Volcano Timeline addresses the temporal aspect of eruptions in the Cascades, while **Surrounded by Volcanoes** addresses the spatial aspect. Assess students' ability to think of volcanic events in the Cascades on a global scale. For example, at the beginning of the activity, students may have recognized the presence of Cascade volcanoes as isolated topographic features. As the activity progresses, they may have added to their knowledge about how the movement of tectonic plates leads to the development of earthquakes and volcanoes in the Pacific Northwest. They might recognize the names of volcanoes closest to their community, but now they comprehend that the volcanoes are part of a larger pattern. Plate tectonics built the landscape of the Pacific Northwest.

References

Dzurisin, D., Stauffer, P., and Hendley, J.W., II, 2003, Living with volcanic risk in the Cascades (revised March, 2008): U.S. Geological Survey Fact Sheet 165–97, 2 p.

Harris, S., 2004, Fire mountains of the West: the Cascade and Mono Lake volcanoes: Missoula, Mont., Mountain Press Publishing Company, 3rd ed, 454 p.

Kious, J.W., and Tilling, R.I., 1996, This dynamic earth: the story of plate tectonics: U.S. Geological Survey General Interest Publication, 77 p.

Lillie, R.J., 2005, Parks and Plates: The geology of our national parks, monuments and seashores: New York, N.Y., W.W. Norton and Company, 298 p.

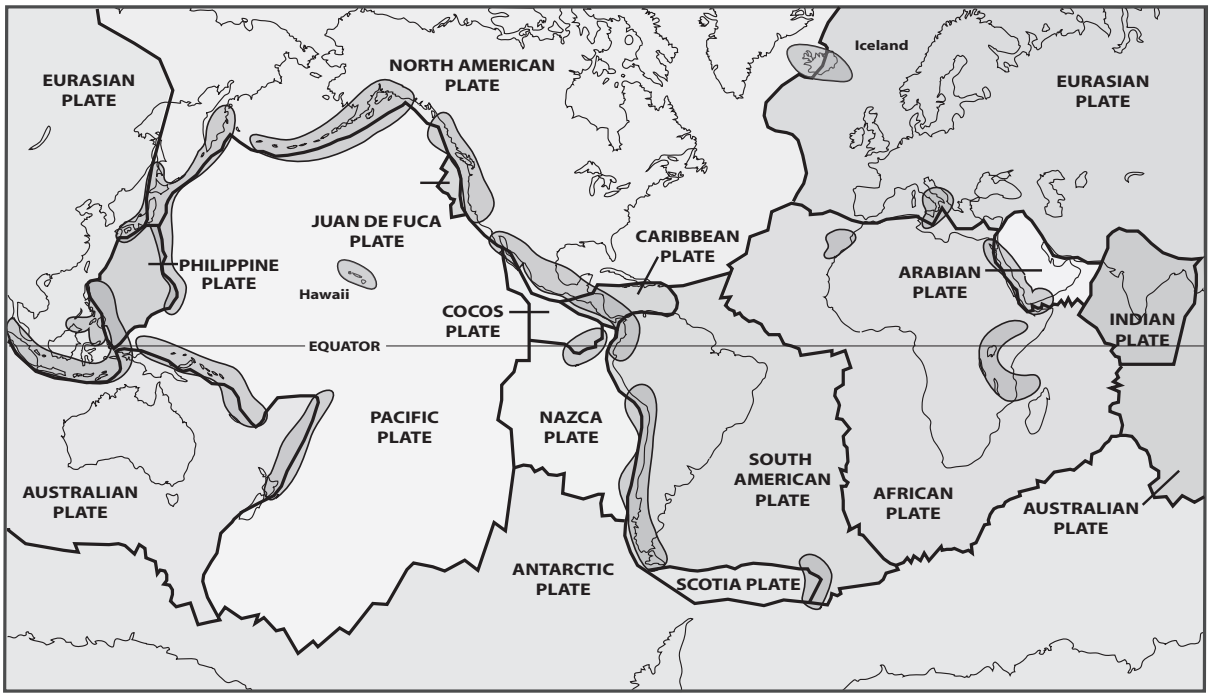
Simkin, T., Tilling, R., Vogt, P., Kirby, S., Kimberly, P., and Stewart, D., 2006, This dynamic planet: world map of volcanoes, earthquakes, impact craters, and plate tectonics: published by The Smithsonian, U.S. Naval Research Station and the U.S. Geological Survey as Geological Investigations Map I-2800, 1 plate, front and back.

Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

Name _____

Introducing Cascade Volcanoes as Links on the Ring of Fire

*The **Ring of Fire** describes a zone of frequent earthquakes and volcanic eruptions that encircle the Pacific Ocean. The Ring of Fire exists along the edges of tectonic plates, often at the edges of continents. It stretches from the southern tip of South America to Alaska, then across the Pacific Ocean to Japan, Indonesia and New Zealand. Volcanoes of the Cascade Range are part of the Ring of Fire. Each Cascade volcano represents one link of this long chain of volcanoes.*



Modified from Tilling, Heliker, and Wright, 1987, and Hamilton, 1976

EXPLANATION

Regions of earthquakes and volcanic activity

Plate boundaries

1. Examine the map of Earth's tectonic plates. Name some of the larger plates that touch the Pacific Plate.

2. Look for patterns in the distribution of volcanoes and earthquakes on the map. Describe them.

3. Name the plate that is surrounded on three sides by a ring of earthquakes and volcanoes.

4. Label the "Ring of Fire" on your map.

5. Place a circle around the general location of the Cascade Volcanoes.

Introducing Cascade Volcanoes as Links on the Ring of Fire—Answers

*The **Ring of Fire** describes a zone of frequent earthquakes and volcanic eruptions that encircle the Pacific Ocean. The Ring of Fire exists along the edges of tectonic plates, often at the edges of continents. It stretches from the southern tip of South America to Alaska, then across the Pacific Ocean to Japan, Indonesia and New Zealand. Volcanoes of the Cascade Range are part of the Ring of Fire. Each Cascade volcano represents one link of this long chain of volcanoes.*

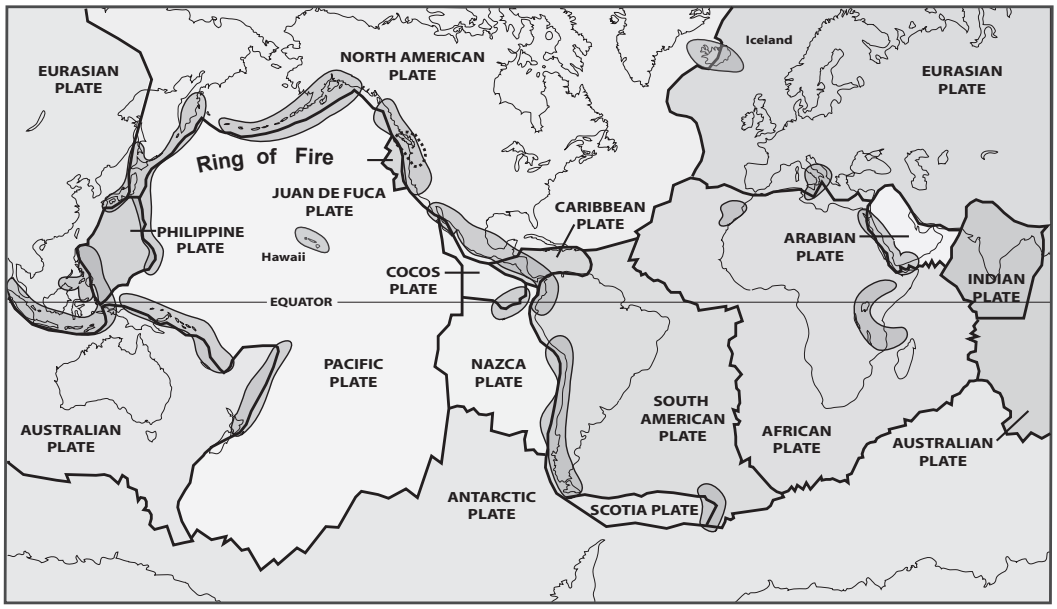
1. Examine the map of Earth's tectonic plates. Name some of the larger plates that touch the Pacific Plate. ***Antarctic, Australian, Philippine, North American, Juan de Fuca, Cocos, Nazca***

2. Look for patterns in the distribution of volcanoes and earthquakes on the map. Describe them. ***Earthquakes and volcanoes occur along or near the boundaries of tectonic plates.***

3. Name the plate that is surrounded on three sides by a ring of earthquakes and volcanoes. ***The Pacific Plate.***

4. Label the "Ring of Fire" on your map.

5. Place a circle around the general location of the Cascade Volcanoes.



Modified from Tilling, Heliker, and Wright, 1987, and Hamilton, 1976

EXPLANATION
- Regions of earthquakes and volcanic activity
- Plate boundaries
- Location of Cascade Volcanoes

Plate Tectonics—Cascade Range

The Pacific Ocean may look calm on its surface, but the floor beneath it moves eastward continuously off the coast of the Pacific Northwest at a rate of approximately 5 centimeters (2 inches) each year. In the Pacific Northwest, the Pacific and North American Plates are separated by a small tectonic plate called the Juan de Fuca Plate. As the Juan de Fuca Plate inches eastward it pulls away from the Pacific Plate, opening a gap that enables magma to rise and construct submarine volcanoes on the Juan de Fuca Ridge. Scientists refer to this pulling apart as a divergent plate boundary or spreading ridge. Further east, the Juan de Fuca and North American Plates move toward each other at a convergent plate boundary. Dense rock of the Juan de Fuca Plate sinks beneath the North American Plate in a process called subduction. We call this region the Cascadia Subduction Zone. The north and south edges of the Juan de Fuca Plate slide past neighboring plates at transform plate boundaries.

On the Plate Tectonics—Cascade Range map, the shaded triangles indicate the location of Cascade Volcanoes. Triangles on the line show the location of the Cascadia Subduction Zone.

Instructions:
Label the diagram as instructed and answer the questions below.

1. *On the Plate Tectonics—Cascade Range map, label the divergent, convergent and transform plate boundaries on the map above. Notice that one boundary type appears twice.*

2. *Does the eastern boundary of the Juan de Fuca Plate lie parallel to the Cascade Range?*

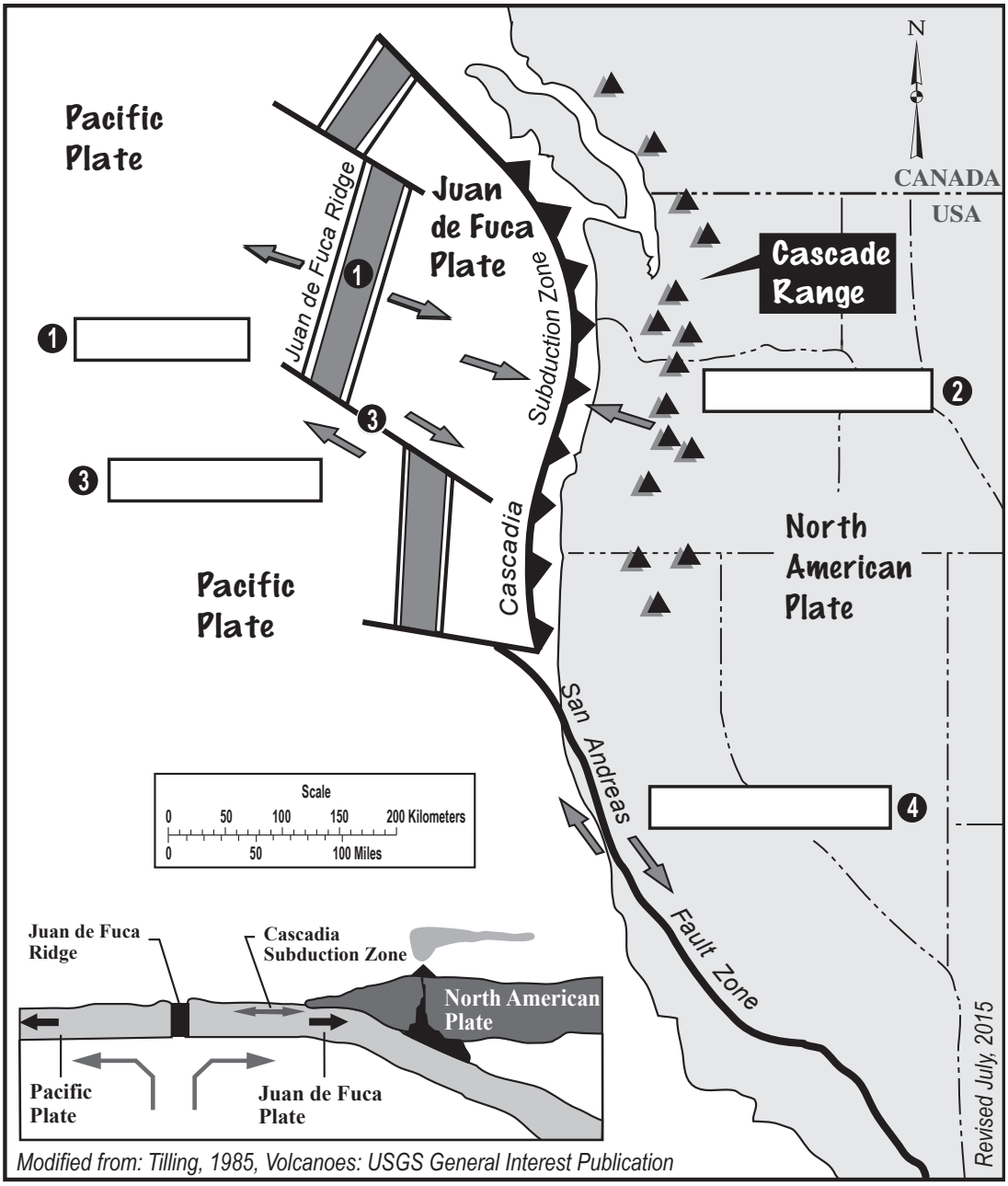
3. *Does the line of volcanoes extend north and south of the converging plates? Make a hypothesis that explains your answer.*

Name _____

Plate Tectonics—Cascade Range

Instructions: *Label the plate boundary types. Note that one boundary appears twice. Arrows indicate direction of movement.*

Plate Tectonics—Cascade Range



Modified from: Tilling, 1985, Volcanoes: USGS General Interest Publication

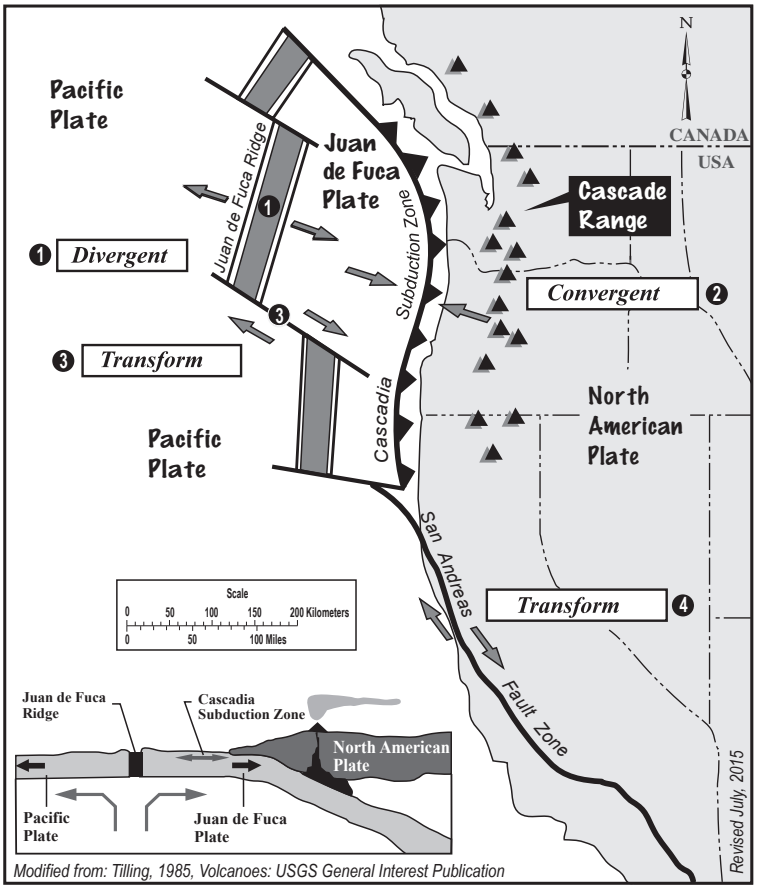
Plate Tectonics—Cascade Range —Answers

1. On the Plate Tectonics—Cascade Range map, label the divergent, convergent and transform plate boundaries on the map above. Notice that one boundary type appears twice.

2. Does the eastern boundary of the Juan de Fuca Plate lie parallel to the Cascade Range? ***Yes.***

3. Does the line of volcanoes extend north and south of the converging plates? Make a hypothesis that explains your answer. ***No, the volcanoes do not extend beyond the converging plates. The converging plates are responsible for formation of the Cascade Volcanoes.***

Plate Tectonics—Cascade Range



Modified from: Tilling, 1985, Volcanoes: USGS General Interest Publication

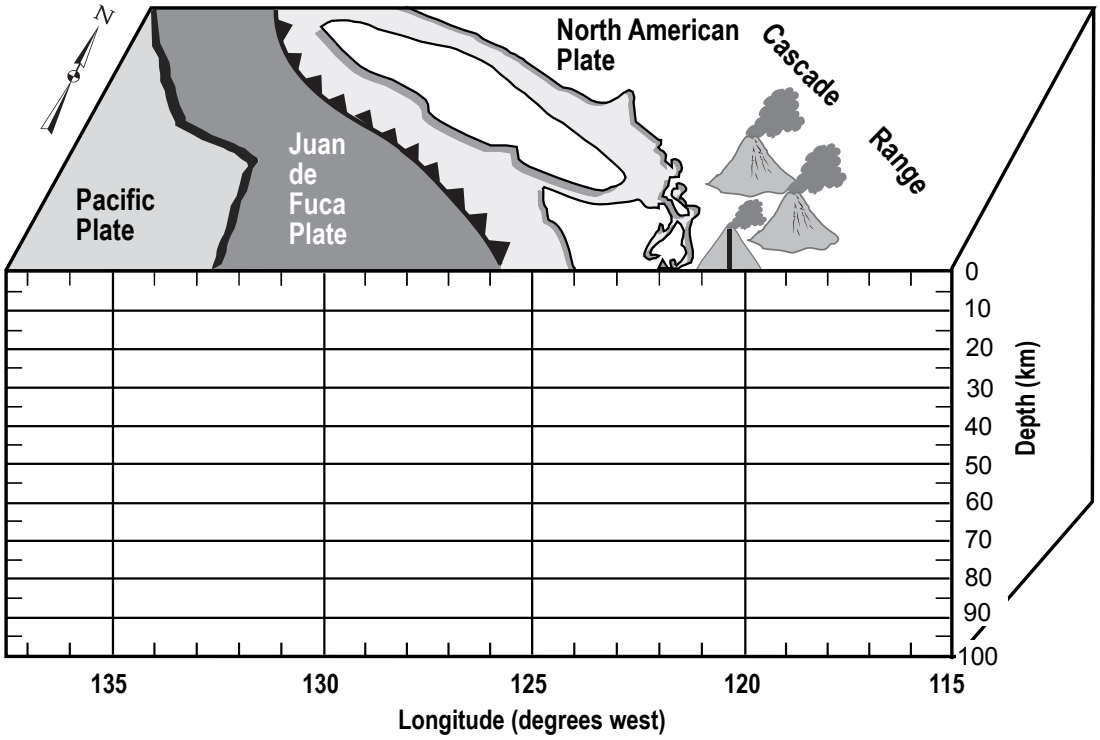
Name _____

Using Earthquakes to Find the Subduction Zone

Instructions: *The Table "**Some Pacific Northwest Earthquakes 1970–2003**" provides information about a small percent of earthquakes that occurred in the Pacific Northwest between 1970 and 2003. Follow the instructions and answer the questions in each step below.*

Some Pacific Northwest Earthquakes 1970-2003

Depth below sea level (km)	Longitude (degrees west)	Depth below sea level (km)	Longitude (degrees west)
10.0	128.2	51.9	122.7
10.0	128.4	57.0	122.4
10.0	128.6	61.8	122.5
22.0	125.6	64.7	122.3
25.1	125.0	68.7	122.3
25.7	124.8	71.4	121.8
28.8	124.6	72.5	122.2
33.0	124.7	74.8	121.9
33.0	124.5	77.4	121.6
34.7	124.4	78.6	121.5
37.0	123.8	82.4	121.4
40.4	123.4	87.0	121.6
43.1	123.2	91.4	120.9
50.3	122.8		



Using Earthquakes to Find the Subduction Zone—Questions

1. Explain why earthquakes can occur in abundance at this plate boundary.

2. Make a prediction about the location of earthquakes on the graph. Predict the pattern of earthquakes at this convergent plate boundary. Trace the predicted pattern lightly pencil on the graph.

3. Plot the location of earthquakes on the graph using the depth and location data provided.

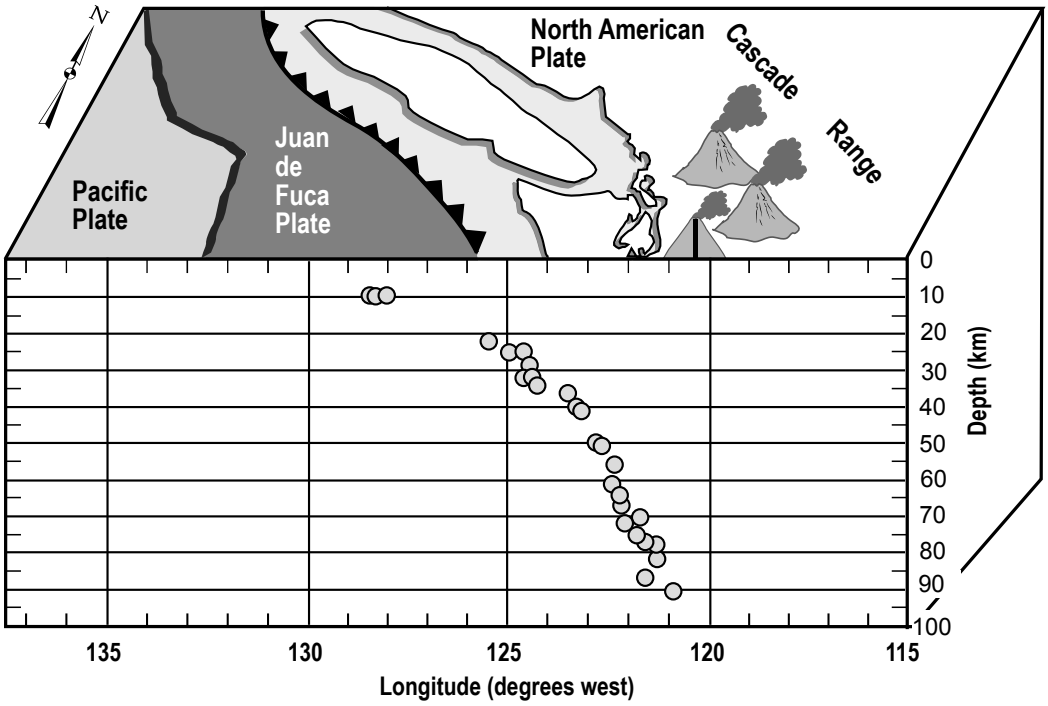
4. Examine the pattern of earthquakes on the diagram. Does the pattern of plotted earthquakes confirm your prediction? Explain how the depth of earthquakes varies across the region shown on the graph.

5. In the previous section, you discovered that Cascade volcanoes are positioned parallel to the plate boundary between the Juan de Fuca and North American Plates. Use this information to form a hypothesis that explains the location of the volcanoes.

6. Use the information in the text to calculate how long it will take for the newly formed Juan de Fuca Plate to subduct beneath North America.

Table of some Pacific Northwest Earthquakes 1970–2003 Subduction Zone Earthquakes

The Subduction Zone



Depth below sea level (km)	Longitude (degrees west)	Depth below sea level (km)	Longitude (degrees west)
10.0	128.2	51.9	122.7
10.0	128.4	57.0	122.4
10.0	128.6	61.8	122.5
22.0	125.6	64.7	122.3
25.1	125.0	68.7	122.3
25.7	124.8	71.4	121.8
28.8	124.6	72.5	122.2
33.0	124.7	74.8	121.9
33.0	124.5	77.4	121.6
34.7	124.4	78.6	121.5
37.0	123.8	82.4	121.4
40.4	123.4	87.0	121.6
43.1	123.2	91.4	120.9
50.3	122.8		

Teacher Page

Using Earthquakes to Find the Subduction Zone—Answers

1. Explain why earthquakes can occur in abundance at this plate boundary.
   The Juan de Fuca plate pushes under the North American Plate causing rocks in the brittle crust and mantle to crack and break.

2. Make a prediction about the location of earthquakes on the graph. Predict the pattern of earthquakes at this convergent plate boundary. Trace the predicted pattern lightly pencil on the graph.
   Students might predict that volcanoes occur in a pattern that descends from left to right, and this would be correct.

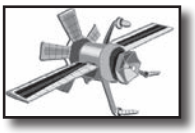
3. Plot the location of earthquakes on the graph using the depth and location data provided.
   (see completed table).

4. Examine the pattern of earthquakes on the diagram. Does the pattern of plotted earthquakes confirm your prediction? Explain how the depth of earthquakes varies across the region shown on the graph.
   Students will notice that earthquakes descend from left to right. Earthquakes occur within and above the subducting slab of oceanic lithosphere.

5. In the previous section, you discovered that Cascade volcanoes are positioned parallel to the plate boundary between the Juan de Fuca and North American Plates. Use this information to form a hypothesis that explains the location of the volcanoes.
   The interaction of the two plates creates conditions conducive to magma formation.

6. Use the information in the text to calculate how long it will take for the newly formed Juan de Fuca Plate, at the spreading center, to subduct beneath North America.
   Approximately 10 million years.

Student Page



Discovering the Volcanoes of the Cascade Range Using Satellite Imagery

Instructions: *Use library resources or Web pages to help identify and label the Cascade Range volcanoes (circled) on the satellite image. The items you need to label are listed below.*

Volcanoes:

Crater Lake
Glacier Peak
Lassen Peak
Medicine Lake Volcano
Mount Adams
Mount Baker
Mount Garibaldi
Mount Hood
Mount Jefferson
Mount Meager
Mount Rainier
Mount St. Helens
Mount Shasta
Newberry Volcano
Three Sisters

Major Cities:

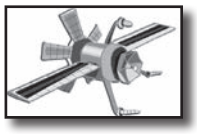
Bellingham
Bend
Chehalis
Eugene
Everett
Klamath Falls
Longview
Olympia
Portland
Redding
Salem
Seattle
Spokane
Tacoma
Vancouver, B.C
Vancouver (USA)
Yakima

National and State Borders:

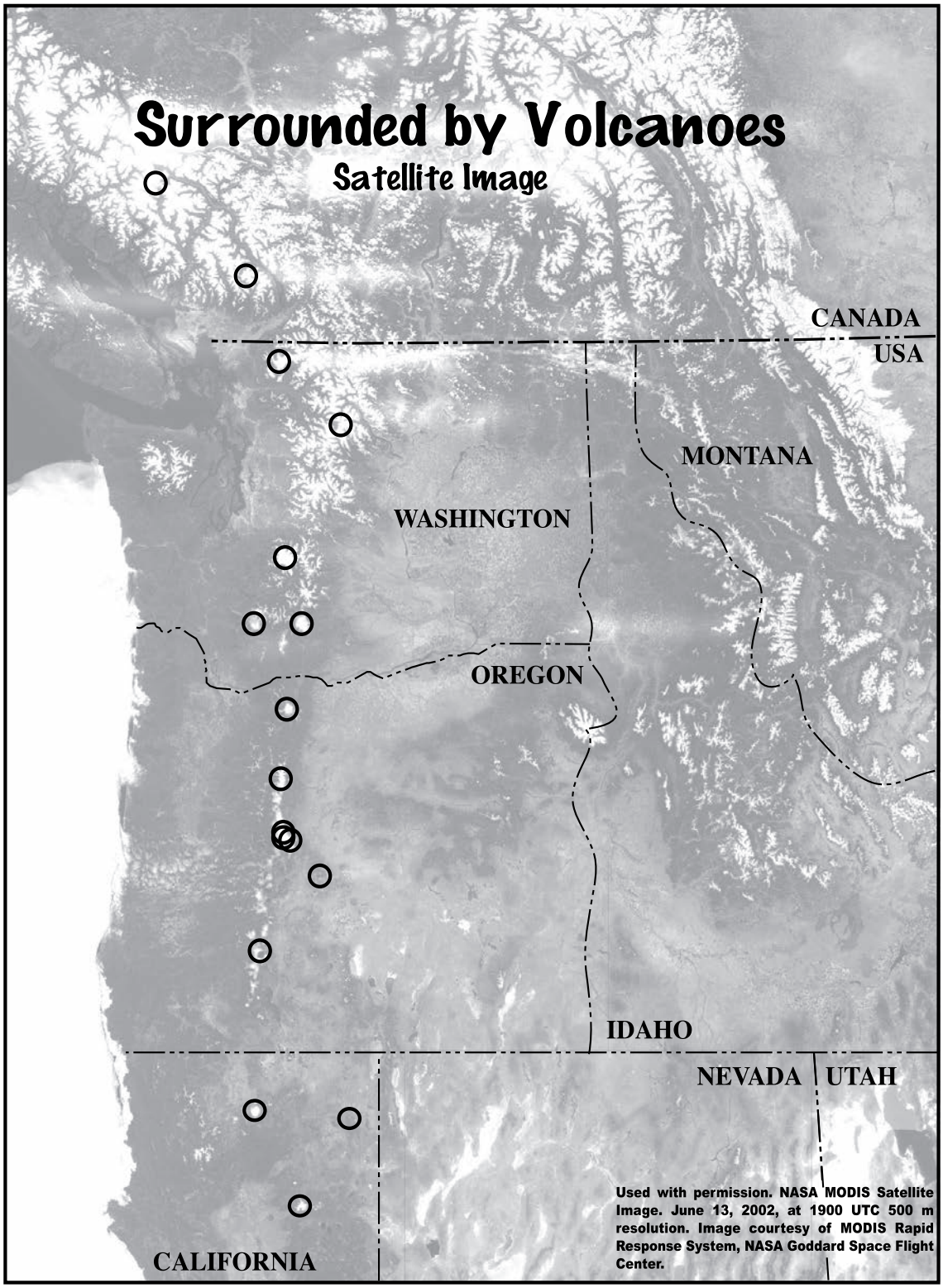
California
Oregon
Washington
U.S.A. and Canada

Student Page

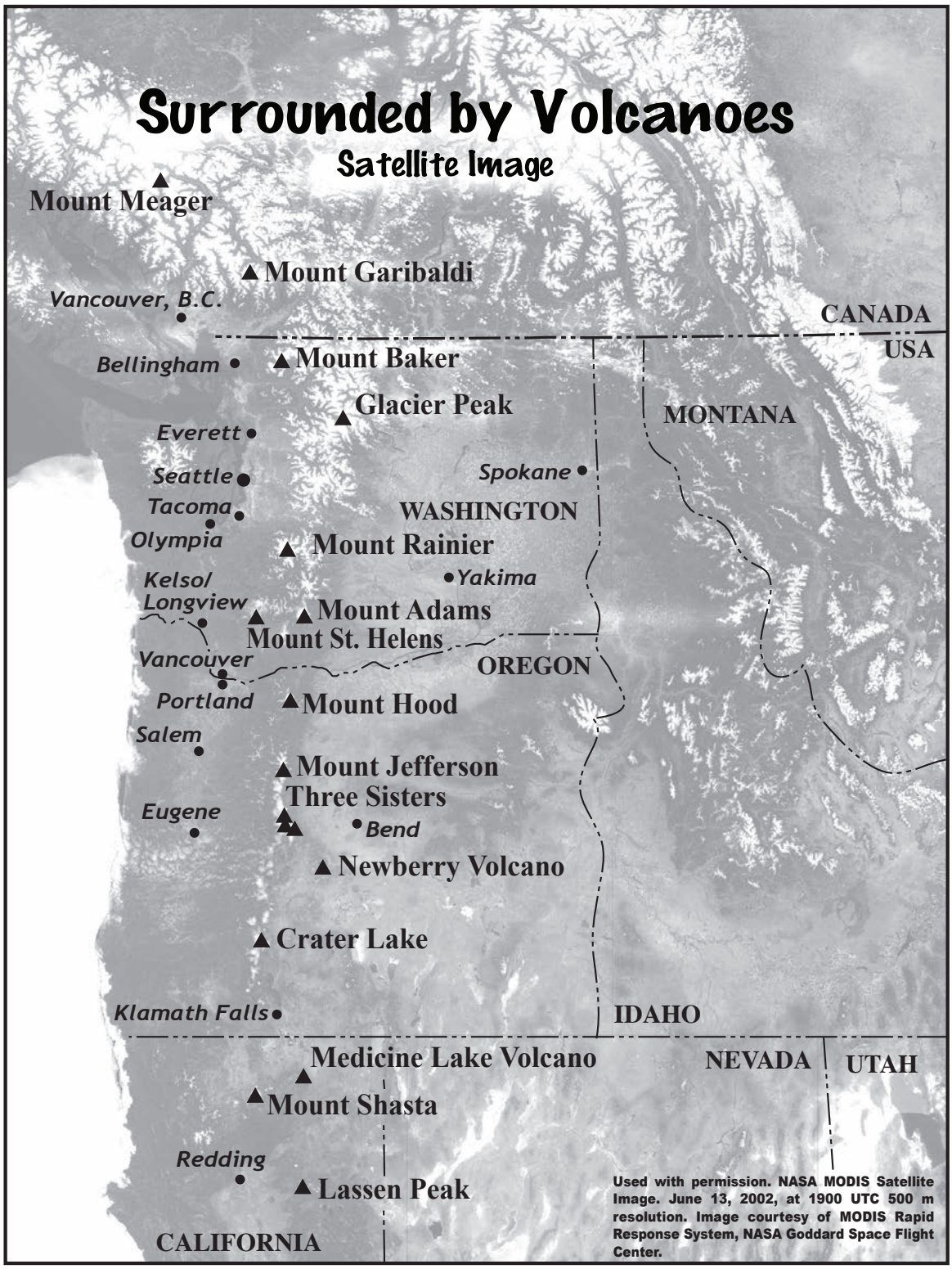
Name _____



Discovering the Volcanoes of the Cascade Range Using Satellite Imagery

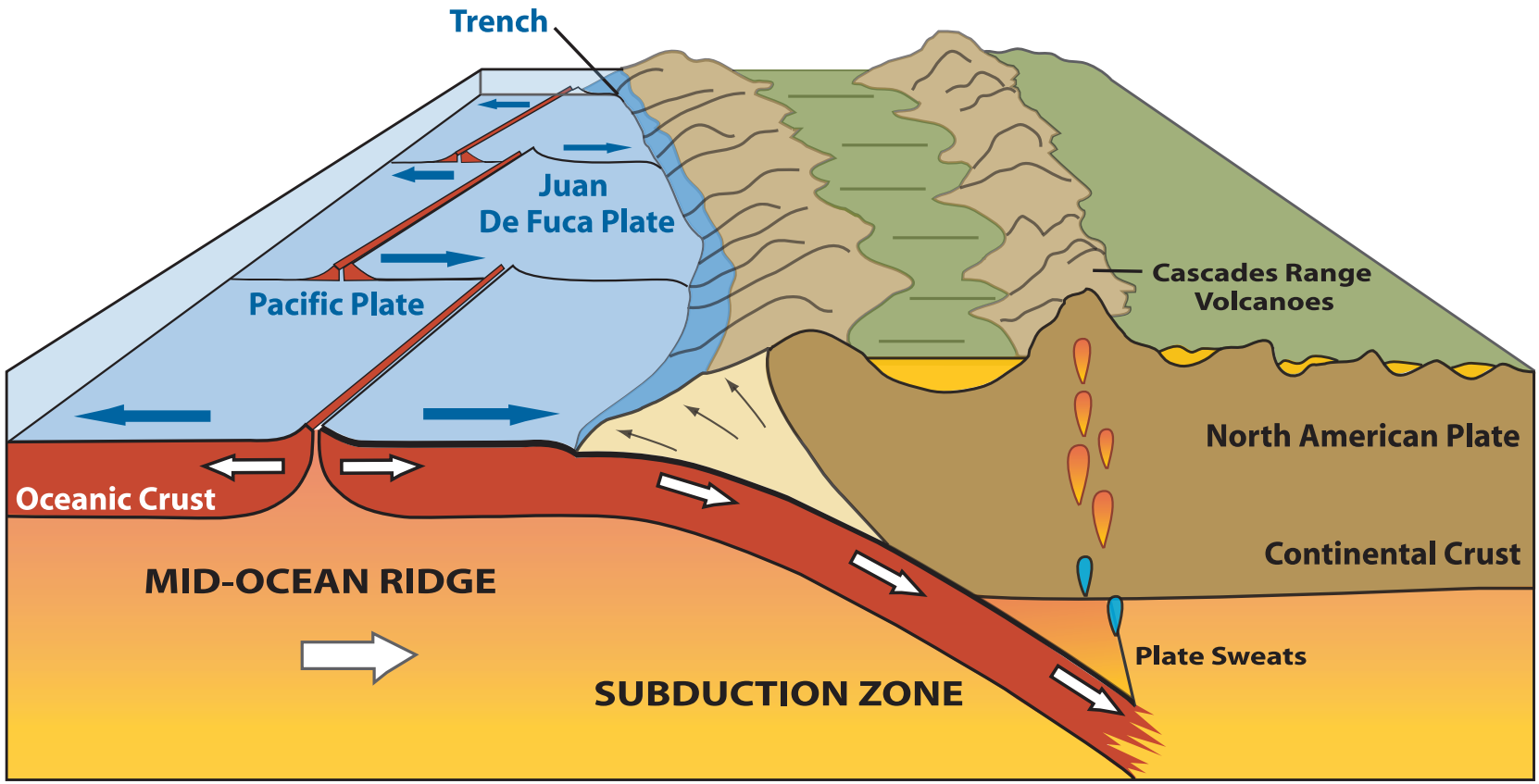


Discovering the Volcanoes of the Cascade Range Using Satellite Imagery



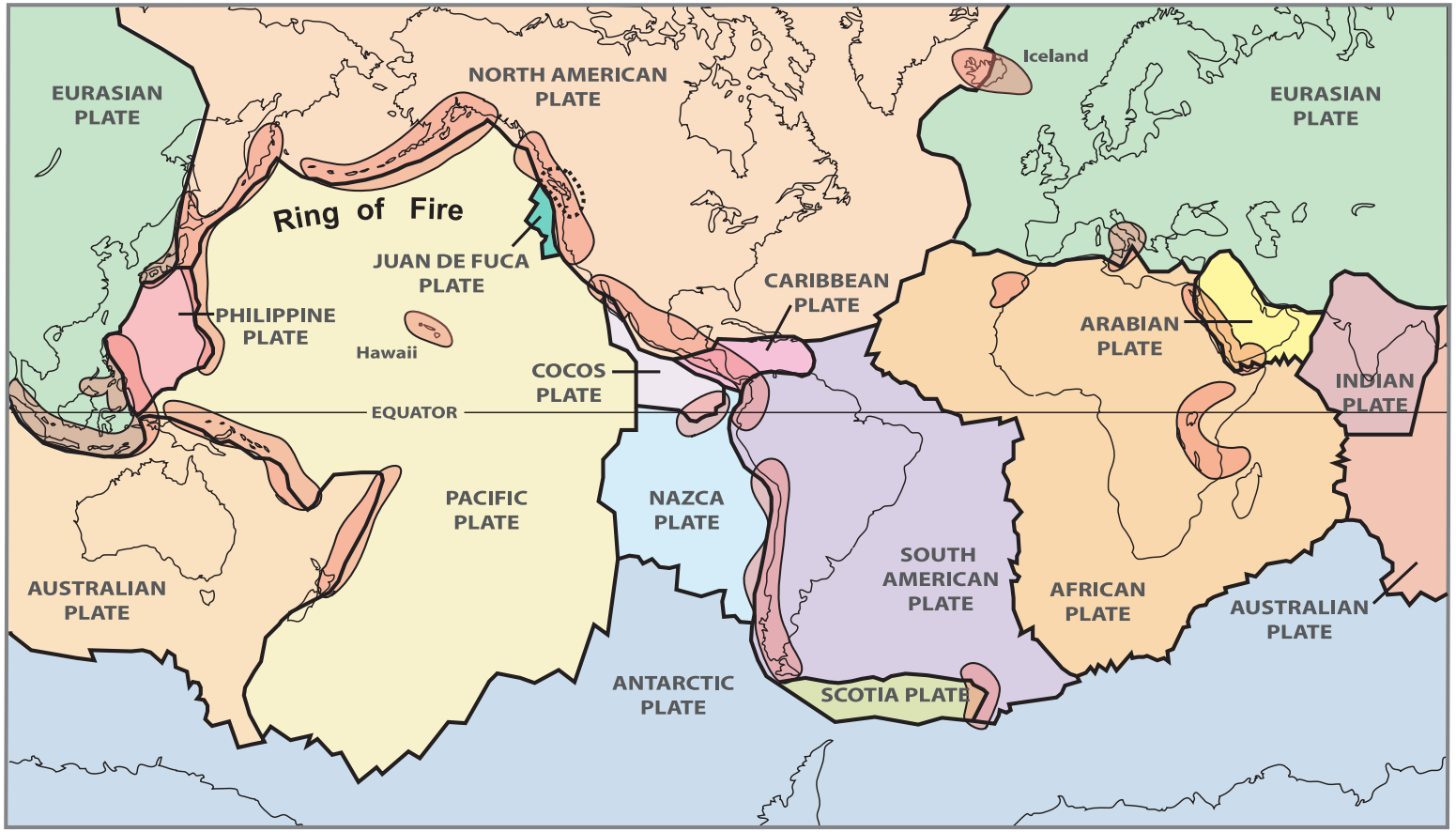
Used with permission. NASA MODIS Satellite Image. June 13, 2002, at 1900 UTC 500 m resolution. Image courtesy of MODIS Rapid Response System, NASA Goddard Space Flight Center.

Plate Tectonic Processes



Modified from Subduction in the Pacific Northwest by Robert J. Lillie.

Cascade Volcanoes—Links on the Ring of Fire



Modified from Tilling, Heliker, and Wright, 1987, and Hamilton, 1976

EXPLANATION

- Regions of earthquakes and volcanic activity
- Plate boundaries
- Location of Cascade Volcanoes

Student Page

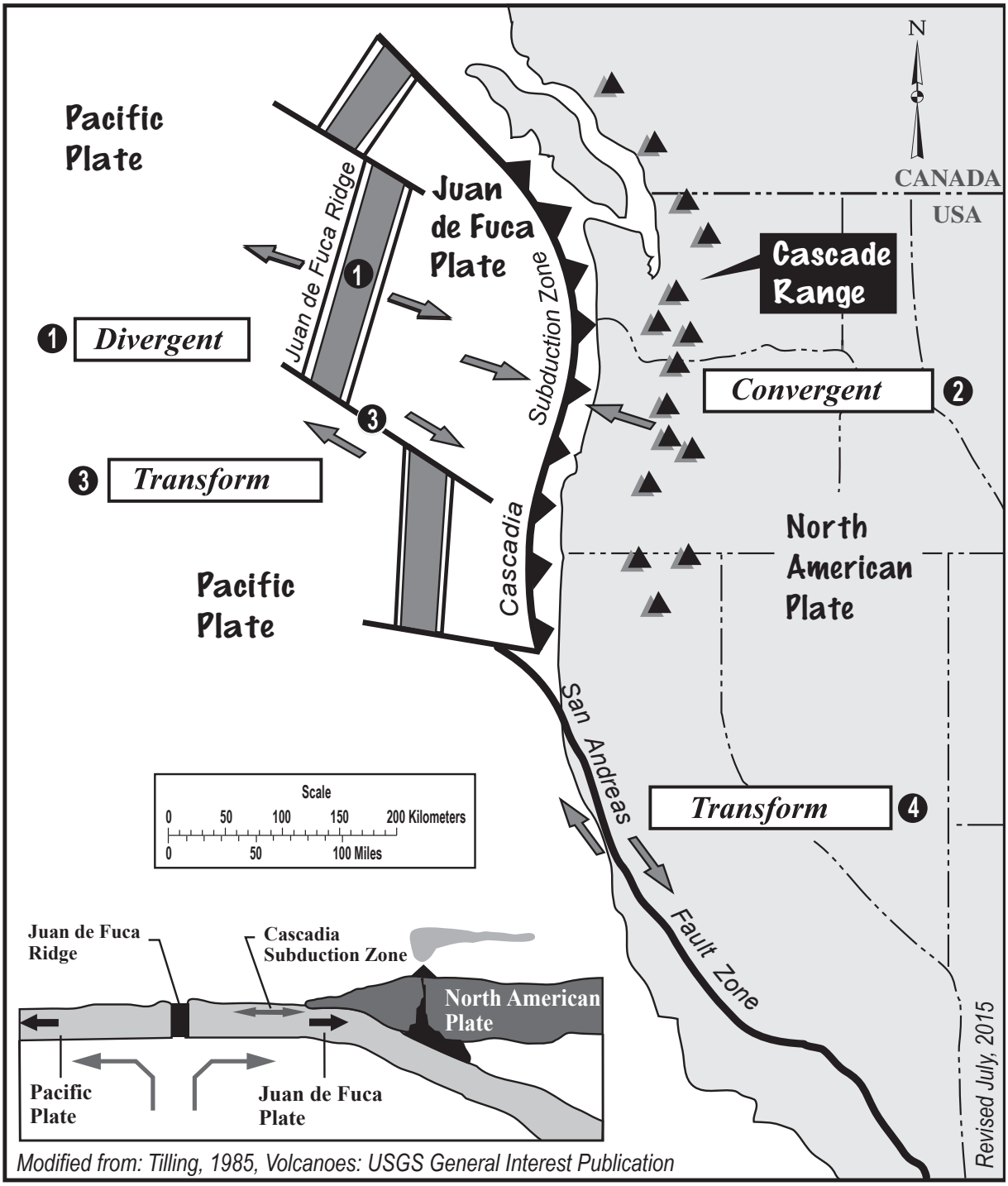
Name _____

Map of Cascade Volcanoes

Teacher Page

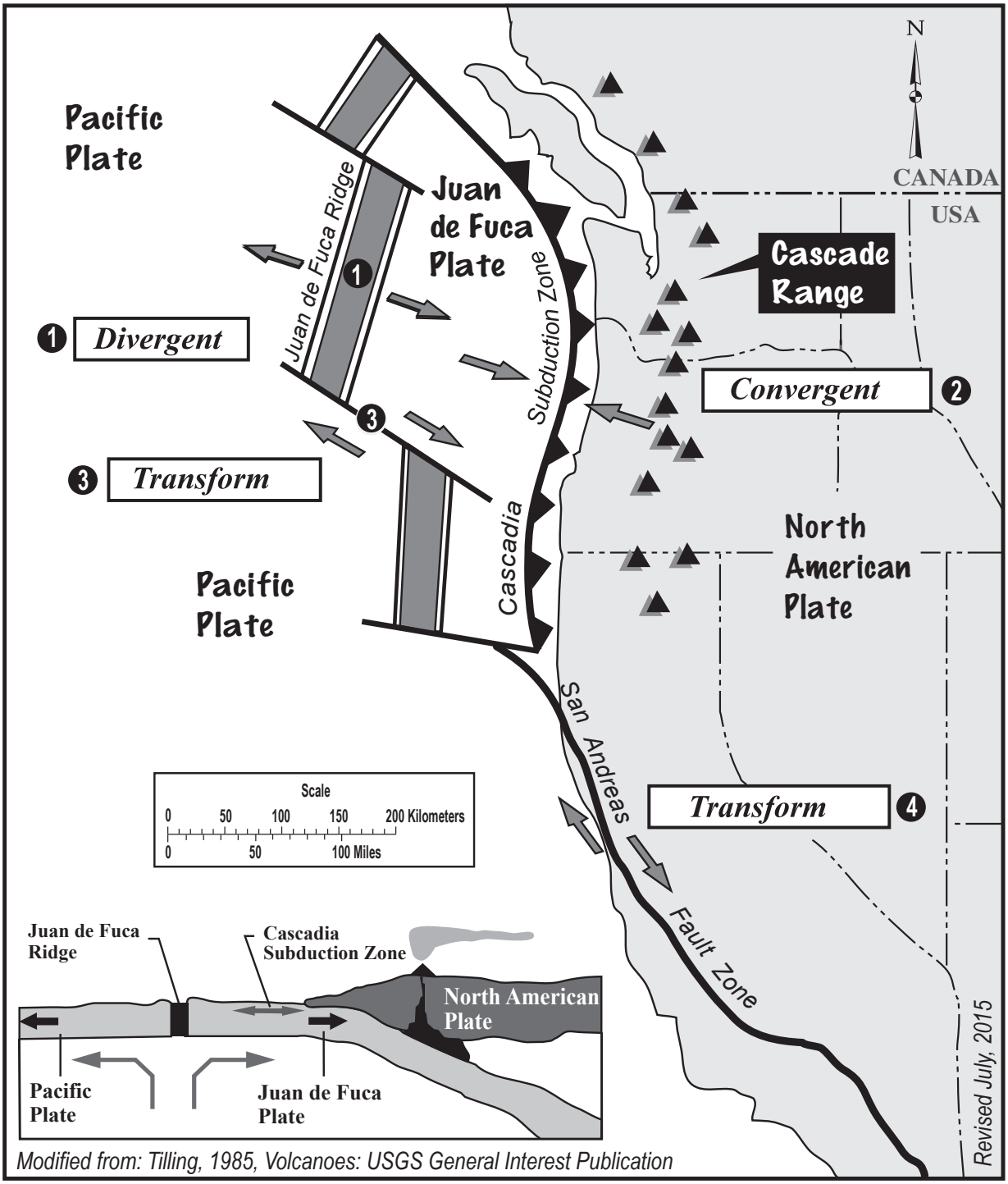
Map of Cascade Volcanoes

Plate Tectonics—Cascade Range



Modified from: Tilling, 1985, Volcanoes: USGS General Interest Publication

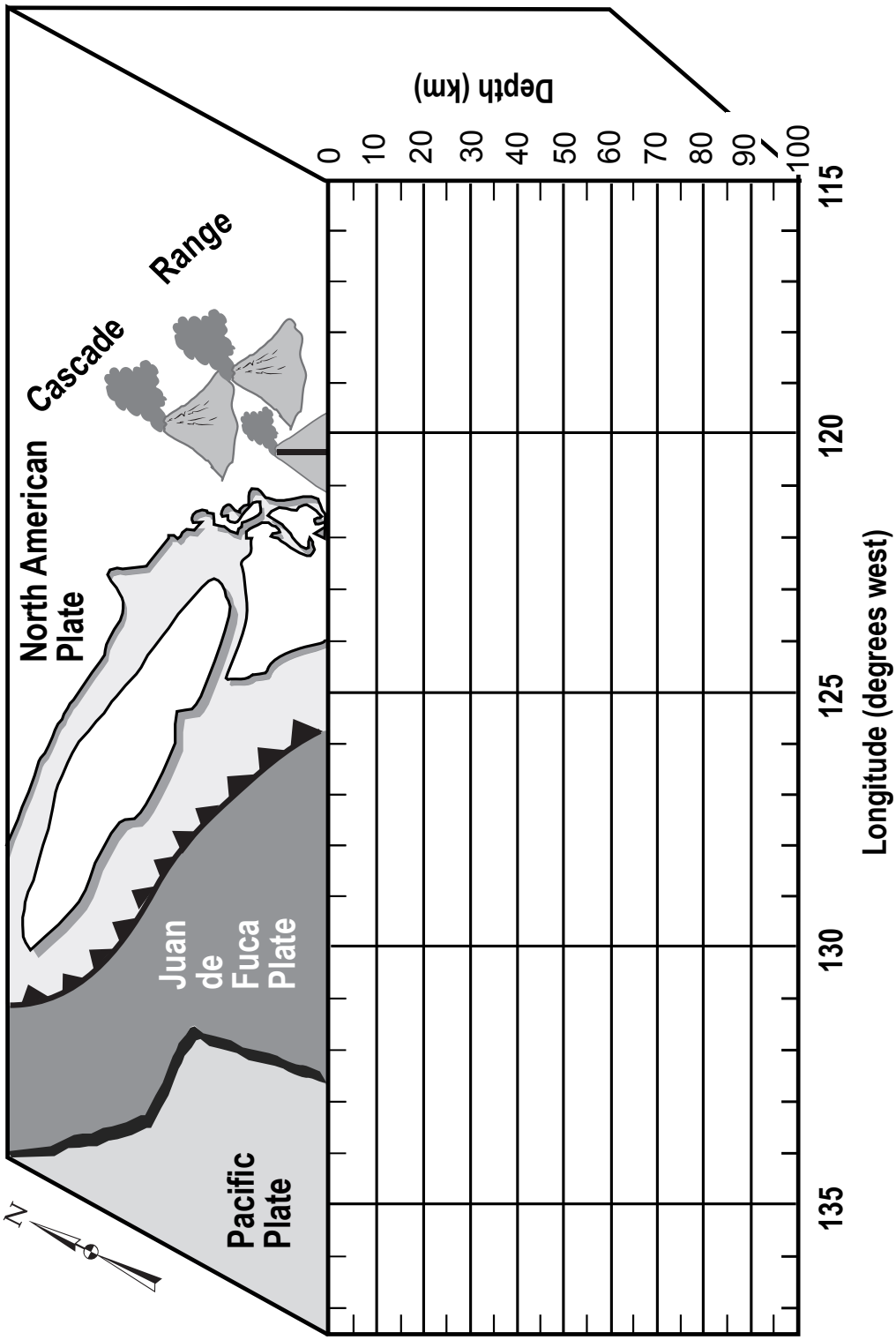
Plate Tectonics—Cascade Range



Modified from: Tilling, 1985, Volcanoes: USGS General Interest Publication

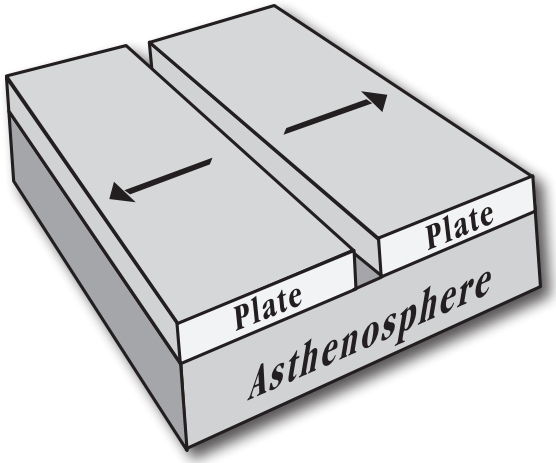
Graphic Page

Using Earthquakes to find the Subduction Zone

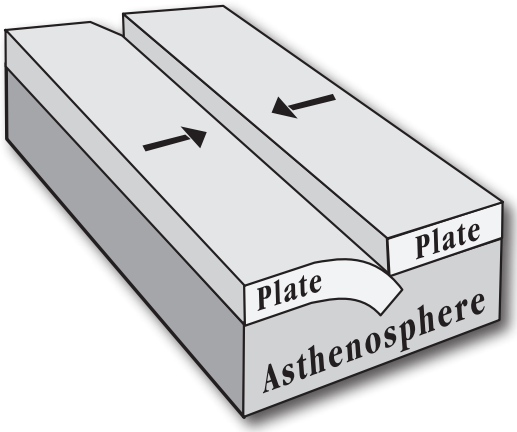


Types of Tectonic Plate Boundaries

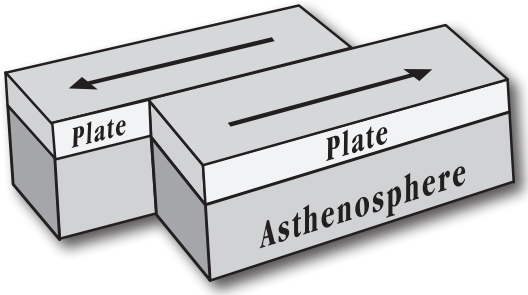
Divergent Plate Boundary



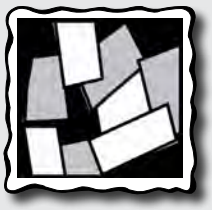
Convergent Plate Boundary



Transform Plate Boundary



Magma Mash



Grade Level: 4–8

Learner Objectives:

Students will:

- Recognize and record differences and similarities of rock samples with similar chemical compositions
- Hypothesize about methods of rock formation
- Understand the effect of cooling rates the appearance of igneous rocks

Setting: Large open area and classroom lab

Timeframe: 20 minutes; 30 minutes

Discovering How Magma Makes Rocks

Making Observations Using Mount Rainier Rock Samples

Materials:

Discovering How Magma Makes Rocks

- Colored tokens (poker chips, craft sticks, etc.) For a class of thirty students—twelve each of two different colors—and six of a third color.

USGS
science for a changing world

Living with a Volcano in Your Backyard-An Educator's Guide with Emphasis on Mount Rainier

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

In an exploration of magma behavior, students role play minerals that are cooling at different rates, and then examine rock samples

Teacher Background

Upward ho!—Magma ascent

All ***igneous*** rocks originate underground in the molten state as magma. ***Magma*** is hot molten rock containing chemical elements from melted ***mantle*** rock and ***oceanic plate***. It also contains dissolved gases such as water, carbon dioxide, sulfur dioxide, and possibly a few crystals.

Magma forms in the mantle where the subducted oceanic plate has sunk to great depths. At Mount Rainier, magma forms from rocks about 80 kilometers (50 miles) below Earth's surface. Temperatures and pressures at such depths are sufficiently high to cause water within the oceanic plate to sweat into the mantle rock. The addition of water to hot mantle rocks causes rock to melt and form magma. This magma begins to rise because it is less dense than surrounding solid mantle rock.

Rock flows at great pressure and temperature

Rock flows like putty in this inhospitable environment of great pressure and temperature. Rock that surrounds rising magma deforms, allowing passage of the magma. This partially molten magma eventually rises to the base of the ***continental crust***. The upper continental crust is more rigid than the mantle, so the magma must force its way upward through

- Colored pencils (3 for each student)

Making Observations Using Mount Rainier Rock Samples

- Sample of andesite and granodiorite or graphic *"Mount Rainier Rocks"* for each student or small student group
- Graphic *"Magma Cooling Rates"*
- Graphic *"Elements to Rocks"*
- Copies of *"Rock Sample Observations"* student page
- Colored pencils (3 for each student)
- Ruler
- Hand lens (1 for each student, or per class)
- Sample of obsidian (optional)

Vocabulary: Andesite, chemical elements, continental crust, extrusive, granite, granodiorite, igneous, intrusive, lava, magma, magma chamber, mantle, mineral, obsidian, oceanic plate, plutonic, solidus, tephra

Skills: Classifying, comparing, demonstrating, describing, listing, sketching

Benchmarks:

See benchmarks in Introduction.

cracks or by melting surrounding crustal rocks. The magma creeps upward like giant fingers. By the time magma reaches Earth's crustal rocks, its density often is comparable to that of the surrounding crustal rock. Here the ascent of magma ceases. This stagnant mass of magma forms a reservoir called a ***magma chamber.*** From here, magma may cool and solidify in place, or continue its ascent to erupt eventually onto Earth's surface through a volcano. Once magma reaches Earth's surface, it is known as ***lava***.

What happens inside the magma chamber?

You may have heard the expression that "birds of a feather flock together." In a similar way, individual ***chemical elements*** combine and form distinct ***minerals***. They bond to each other and form complex structures with specific chemical patterns or crystalline structures (see table 1 below). Individual minerals combine to form large masses as illustrated in this activity.

Minerals often look like small cubes, spheres and many-faced crystals. The longer it takes for magma to cool, the more time is available for crystals to grow and become larger mineral grains. Eventually, magma cools and crystallizes completely and becomes solid rock. Most magma cools slowly enough that all the liquid is used to form minerals. Some magmas cool so fast that the liquid hardens into glass. The ***solidus*** is the temperature at which all liquid in the magma becomes completely crystalline.

Table 1—Elements to Rocks

Building Blocks	Mount Rainier Examples
Chemical Elements	Si, Na, Ca, Al, Ti, K, O, Fe, Mg
Bond to become Minerals	Olivine $(Mg,Fe)_2SiO_4$ Pyroxene $(Ca,FeMg)Si_2O_6$ Feldspar $(Ca, Na, K)\ AlSi_3O_8$ Amphibole $Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2$ Magnetite Fe_3O_4 Quartz SiO_2
Become Rocks	Andesite 60% SiO_2: fine-grained Granodiorite 60% SiO_2: coarse-grained

Cooling rates of magma

Magma that cools slowly over thousands of years develops minerals throughout its entire mass. These minerals continue to grow larger until all liquid has changed to crystal. We call these igneous rocks ***intrusive,*** or ***plutonic***, in commemoration of Pluto, the Greek god of the Underworld. ***Granite*** and ***granodiorite*** are common plutonic rocks.

Some magma ascends through cracks and breaks through the surface during a volcanic eruption. The resulting ***extrusive*** rock, called ***lava*** cools quickly, providing little or no time for chemical elements to group together and form minerals. Volcanic rocks form in this way. Minerals in some volcanic rocks can be so small they are difficult to identify without magnification. These miniature mineral grains form the background, groundmass, or matrix that creates the principal color of a rock. Magmas that cool before chemical elements bond to form minerals solidify to a glass. ***Obsidian*** is one example of a volcanic glass.

Teacher Tips

Before class begins, assemble samples of andesite and granodiorite or make copies of the graphic "Mount Rainier Rock Photos" for each student or small student group. Learn more about andesite and lava flow features in Lava: Building Blocks of a Volcano activity; see Soda Bottle Volcano and Riding the Magma Elevator for more information about eruption dynamics.

Sidebar 1 The Magma Chamber Beneath Mount Rainier

This magma chamber occupies part of a zone a few kilometers wide and eight to ten kilometers (5 to 6 miles) beneath the volcano. How do we know this? Seismologists measure the velocity of earthquake waves passing through the Earth below Mount Rainier. These waves travel slower through molten rocks and hot fluids than through solid rock. Seismologists found that earthquake waves slowed beneath Mount Rainier. The magma chamber occupies part of this zone.

Sidebar 2 Rocks Made from Magma at Mount Rainier

Granodiorite and andesite are common rocks found at Mount Rainier. Both rock types originated from magmas with similar chemical composition; however, each has a very different appearance. They appear dissimilar because they cooled at different rates and the rate of cooling controls crystal sizes and, hence, rock textures.

Andesite is a common volcanic rock at Cascade Volcanoes, formed by magma that ascended to Earth's surface and cooled quickly. At Mount Rainier, andesite erupted as thick lava flows and tephra. The matrix of andesite is made of microscopic minerals and some glass and usually appears gray. Andesite typically contains a sprinkling of small rectangular black or white crystals of minerals that can be seen without magnification. The light-colored minerals are feldspar and the dark minerals are pyroxene and (or) amphibole (see Table 1, Elements to Rocks for chemical formulas). In Mount Rainier andesite, these black and white crystals are usually smaller than 5 millimeters (0.2 inch) and make up thirty percent of the rock. Andesite that cools quickly often traps bubbles of volcanic gas.

Granodiorite, a plutonic rock, is formed by magma that cooled slowly below the surface of the Earth. The crystals in granodiorite, the bubbles have been squeezed out. These black and white crystals are commonly 5 millimeters (0.2 inch) across and make up one hundred percent of the rock. The Tatoosh Range, a neighbor to Mount Rainier, is composed of granodiorite. The magma that formed the Tatoosh Range solidified 13 to 16 kilometers (8 to 10 miles) below the surface. Subsequent erosion of overlying rocks has exposed this granodiorite at the surface. Slow cooling allowed the minerals to grow large.

Granodiorite has a black and white speckled appearance. The minerals in granodiorite include: quartz (clear to light gray), feldspar (white to pink), and pyroxene or amphibole (black) (see table for chemical formulas).

Procedure

Discovering How Magma Makes Rocks

This activity illustrates how the sizes of mineral grains increase with cooling time. Students role play as minerals that have already formed from elements, and now move within a magma chamber. They "search" for like minerals during teacher-designated short, medium, and long "cooling periods." At the end of each cooling period, students drop colored tokens (colored craft sticks, or other colored tokens) to the ground, and then map positions of the tokens on the "***Magma Mash***" student page.

When introducing this activity, emphasize to students that the composition of magma in an actual magma chamber is more complex as it consists of a mixture of unattached chemical elements, minerals, and mineral clumps. These components migrate through the magma chamber and chemically bond to make larger clusters of minerals. This activity simplifies the situation by assigning students only as minerals.

1. Designate an area, 6 meters x 6 meters (20 feet x 20 feet), as a "magma chamber." Students stand in a circle that outlines the magma chamber as you provide instructions. Inform students that they will now simulate the process of rapid cooling of magma from molten to solid rock. When called upon, they will enter the magma chamber, and when told to do so, will move randomly within the circle. Over the next two cooling periods, they will search and stand beside other minerals of same type.

2. Provide each student with a copy of the "***Magma Mash***" student page. Then, distribute colored tokens, one per student, in the following percentages: feldspar–55 percent; pyroxene–30 percent; olivine–10 percent; magnetite–5 percent. Provide each student with colored pencils—one color for each mineral assigned (matching colored pencils work best). Encourage students to draw a legend that correlates mineral to color of token. Be sure that each student knows the name of the mineral that they represent.

3. Introduce each "mineral" that enters the magma chamber. Once in the magma chamber, each student "mineral" should remain in place until you have given instructions to "mingle" in search of students with like token color. Optional: Enhance your introduction. Olivine, a green-colored silicate mineral is first to crystallize because it "freezes" as a solid at high temperatures. It is followed by pyroxene, a dark-green or brown colored silicate, then by feldspar, a common mineral that can be white or pink in color. Finally, magnetite, a black or metallic iron-oxide mineral that is naturally magnetized, is one of the last minerals to crystallize from the magma.

4. Follow the cooling period instructions below. Remember to begin each cooling period by shouting "mingle," end each cooling period with "freeze."

Cooling Period 1 (Rapid Cooling)

- Lasts for a few seconds (or when students have had time to disperse).
- Students step back and map the position of all colored tokens on "***Magma Mash***" student page.
- Students look for patterns in the distribution of each mineral. Minerals will be randomly distributed with little recognizable pattern.

Cooling Period 2 (Medium-length Cooling)

- Lasts for 10 to 15 seconds (or when some "minerals" have assembled beside one another).
- Students step back and map the position of all colored tokens on "***Magma Mash***" student page.
- Students look for patterns in the distribution of each mineral. Minerals will be show some clumping into groups.

Cooling Period 3 (Slow Cooling)

- Lasts for 20 seconds or more (give all minerals time to associate with one another).
- Students step back and map the position of all colored tokens on "***Magma Mash***" student page.
- Students look for patterns in the distribution of each mineral. All like minerals should be grouped together.

5. Assemble students so that they can analyze their diagrams on the "***Magma Mash***" student page. Instruct students to look for patterns in the distribution of each mineral.

6. Did this rock cool slowly enough to allow time for mineral growth?

- Is it possible for rocks of the same composition to have different crystal sizes?
- Which cooling period produced the largest mineral groupings?
- Which cooling period produced the smallest mineral groupings?
- How is cooling rate related to the size of minerals?
- What characteristics would you expect of a rock that has cooled in just a few hours? For thousands of years?

Making Observations Using Mount Rainier Rock Samples

Examine similarities and differences in samples or photos of an extrusive rock (andesite) and an intrusive rock (granodiorite), two rock types commonly found at Mount Rainier National Park. These rocks are similar, though not identical in chemical composition (granodiorite cooled over a longer time, allowing the formation of crystals of quartz and two dark-colored minerals called biotite and hornblende).

1. Direct small groups of students to observe samples of andesite and granodiorite from your school collection. You can use the "***Mount Rainier Rock Photos***" graphic provided in this activity if rock samples are unavailable.

2. Instruct students to compare the two rock samples using a ruler and hand lens. On the "***Rock Sample Observations***" student page, direct students to draw and describe each sample with enough detail that they could locate the sample in a box of rocks. Instruct students to observe the overall texture and appearance of the mineral crystals.

3. Next, instruct students to record the similarities and differences between these rocks on the student page. Provide enough time for observation of the finer details of each rock.

4. Students and teacher compile a list of students' observations, then review results.

5. Review the composition of igneous rocks from Mount Rainier using "***Table 1—Elements to Rocks***." Explain that andesite and granodiorite have similar chemical compositions and mineral assemblages, yet they look distinctly different. Allow students to hypothesize why this may be true based on what they learned from first part of the activity.

6. Show the graphic "***Magma Cooling Rates***" to show actual cooling times for volcanic rocks, and to summarize what students learned.

Adaptations

- Examine, compare and classify other igneous rocks in your school's rock collection.

- Direct younger students to assemble a four-page book called "How a Rock Forms." On page one, students draw a picture of magma inside a volcano. On page two, write "Magma that cools fast has small minerals," and have students draw a rock with small minerals. On page three, write "Magma that cools slowly has large minerals" and have students draw a rock with large minerals. Page four, is a drawing by students of their favorite rock.

- For younger students, instruct them to make rocks from construction paper. Draw two rock outlines on a piece of paper. On one rock, students glue small pieces of colored construction paper so that the paper pieces are separated by some space. This represents a rock that was cooled quickly, so only small minerals formed. On the other rock, students glue larger pieces of paper, until no blank paper is showing. This represents a rock that cooled slowly and has large minerals.

- For younger students, have them do the "Magma Mash" to music. Use slow music for slower cooling and fast music for faster cooling.

Extensions

- ***The Rock Candy Experiment***. Make rock candy to demonstrate how crystals develop in magma. To show how rapid cooling effects the development of crystals, spoon some of the hot candy mixture into cold water before dispensing the remainder into the container for cooling. The candy mixture that cooled quickly should show no crystal development, while the slowly cooled mixture will create rock candy crystals.

- ***Rock and Mineral Classification***. This activity can be used as part of a unit on rocks and minerals or to prepare students for scientific observations during a planned visit to Mount Rainier.
  1. Take students on a field trip to a local streambed to collect a variety of different rocks.
  2. Instruct students to make up classification categories for the collected rocks. With a grid on the floor or on a large sheet of paper, ask students to arrange the rocks into different categories based on the classification system they developed. Afterwards, instruct students to arrange the rocks using the rock classification system commonly used by geologists.

- ***Shoe Classification.*** Students learn about classification systems by sorting shoes. Each student takes off one shoe and places it in a pile with their classmates' shoes. Students then define categories to sort the shoes into different piles (smelly versus non-smelly, white versus other colors, big versus little, etc.). Once the shoes are sorted, they make up subcategories to sort them even more. Continue to do this until each shoe has been sorted into its own pile and can be identified as one particular person's shoe. This is similar to how geologists sort rocks into categories and eventually identify the rock and give it a name.

- ***Rock Stories.*** Ask students to write a creative story illustrating the formation of a rock from magma to a solid.

Assessment

As this activity progresses, pay attention to student's understanding of the effect of cooling rates on the appearance of igneous rocks. Note how students' thinking progresses from basic observations of appearance to the causes of appearance and how the causes are related to volcanic processes. Use students' results on student pages "***Magma Mash***" to assess their ability to observe and record experimental results; use "***Rock Sample Observations***" to assess ability to apply the concepts to identifying the source of igneous rocks in the real world.

References

Francis, P., and Oppenheimer, C., 2003, Volcanoes: New York, N.Y., Oxford University Press, 536 p.

Harris, S.L., 2005, Fire mountains of the west: the Cascade and Mono Lake volcanoes: Missoula, Mont., Mountain Press Publishing Company, 3rd ed., 454 p.

Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

Credits

Photos by U.S. Geological Survey.

Student Page

Name _____

Magma Mash

Instructions: *Use colored pencils or crayons to draw the arrangement of the colored tokens after each period of movement.*

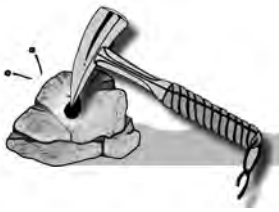
Freezing Point	Diagram of Colored Tokens
Cooling time 1	
Cooling time 2	
Cooling time 3	

Student Page

Name _____

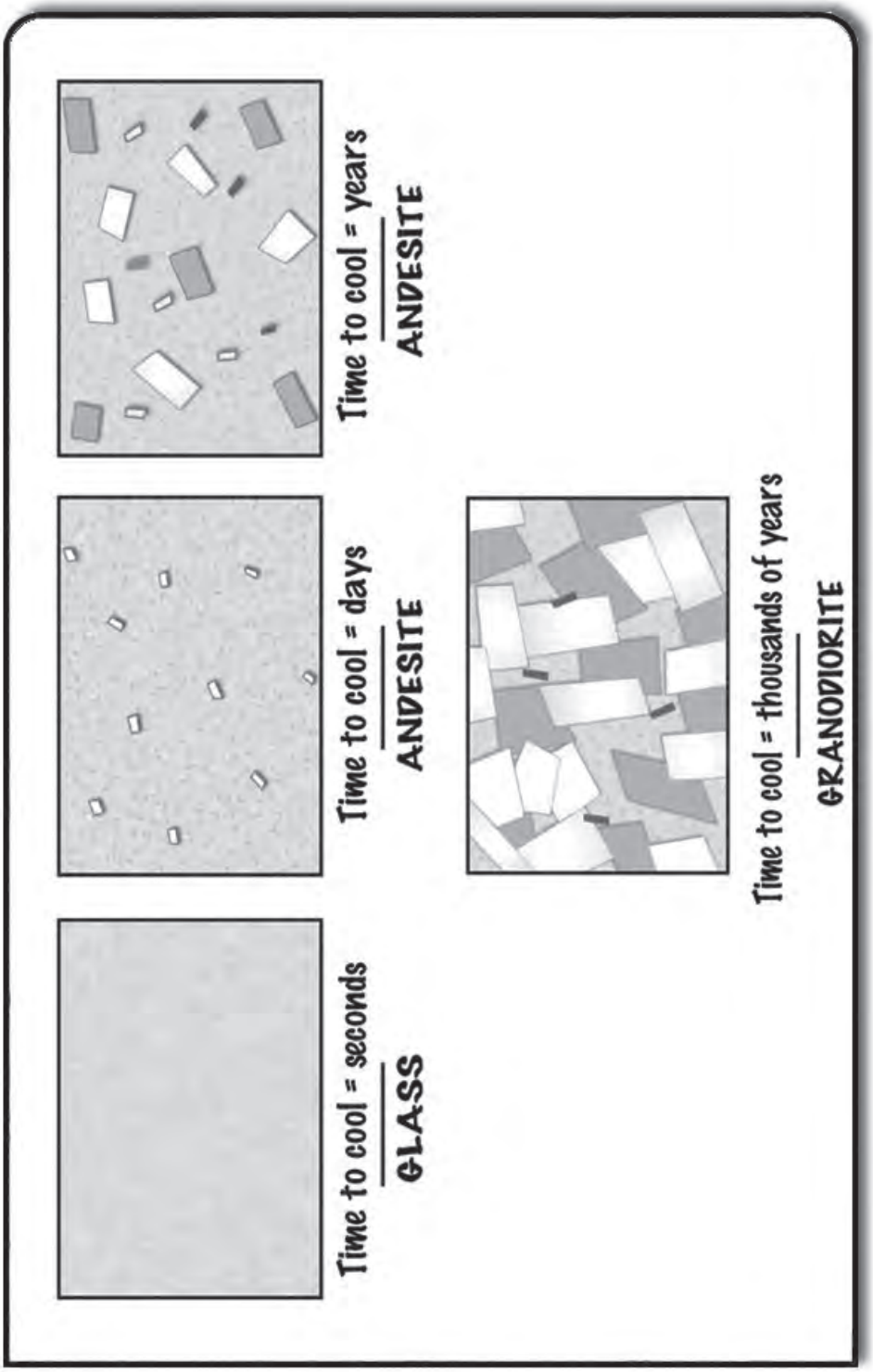
Rock Sample Observations

Rock Sample 1	Rock Sample 2
Draw, color and label sample 1	**Draw, color and label sample 2**
Using words, describe the characteristics of sample 1	**Using words, describe the characteristics of sample 2**
Examine the rock samples. In the space below, list the characteristics that are similiar and different in each sample	
Similarities	**Differences**



Mount Rainier Rocks

Magma Cooling Rates



Riding the Magma Elevator

Grade Level: 6+

Learner Objectives:

Students will:

- Understand how the subducting plates trigger melting of mantle to form magma
- Identify how gas pressure initiates the ascent of magma into the magma chamber

Setting: Classroom

Timeframe: 20 minutes

Materials:

- Narrative *"Riding the Magma Elevator"*
- Graphic *"Elevator Overview"*
- Graphic *"Level 1—Subduction Zone"*
- Graphic *"Level 2—Basement of Earth's Crust"*
- Graphic *"Level 3—The Magma Chamber"*
- Graphic *"Level 4—Inside the Volcano"*

Vocabulary: Bar, crust, conduit, dike, eruption, granodiorite, lava, mantle, magma, magma chamber, subduction zone, Pascal, vent, volcanic ash, volcanic gases, volcano, volcanologists

USGS
science for a changing world

NATIONAL PARK SERVICE

Living with a Volcano in Your Backyard-An Educator's Guide with Emphasis on Mount Rainier

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

Examine the processes leading to a volcanic eruption, including mantle melting, magma formation, and magma ascent. During this activity, the students will ride an imaginary elevator from the subduction zone to volcanic vent.

Teacher Background

The query "What triggers a volcanic ***eruption***?" is one of the most common questions pondered by ***volcanologists***. They have explored this question for years and developed some sound theories about the processes at work beneath a ***volcano***. The most common understanding is displayed in the narrative and graphics of this activity.

Sidebar 1 — Measures of Pressure

Pressure is a critical factor that influences how volcanoes behave. It is expressed in terms of force per unit area; in English units, for example we measure pressure in pounds per square inch (psi); in metric or SI units, pressure is measured in Pascals, where one Pascal is a Newton of force applied over a square meter of surface area. (An older metric unit of pressure is the bar, which equals 100 kilopascals (kPa)). The pressure of the atmosphere at sea level is roughly 14.7 psi, or 101.3 kPa. Within the Earth, pressure increases with depth due to the weight of rock; the rate of increase is about 100 kilopascals (kPa) per kilometer, or 400 atmospheres per mile. Water vapor and other gases dissolve into the magma because of extreme pressure exerted by overlying and surrounding rocks.

Activity last modified: September 5, 2014

Skills: Inference, discussion, listening

Benchmarks:

See benchmarks in Introduction.

Procedure

1. Use the graphic "***Elevator Overview***" to show the pathway that the "elevator" will be following. Introduce the concept of mantle melting, magma rising into the magma chamber and erupting through the magma conduit.

2. Distribute "***Riding the Magma Elevator***" narrative to every student. For each level, display the appropriate graphic.

3. Read or paraphrase, or ask a student to read the narrative for each level of the magma rising process. At each level, review whether pressure is increasing or decreasing and why.

4. For assessment, at the end of the narrative, ask students for a quick review of what processes occur at each level shown on the graphics.

Adaptations

- Read the text from this activity and have the students draw their own rendition of what magma might look like at each stage.

Extensions

- Create a play in which students act out all the elements and processes involved in a volcanic eruption.
- Direct students to explore Internet–based computer programs that simulate volcanic eruptions. Note the list of selected computer programs in **Internet Resources**.

Assessment

Look for students' recognition of the following concepts: subducting plates trigger melting of mantle to form magma; water lowers the melting of rocks for magma formation; magma rises into Earth's crust and remains in the magma chamber for extended periods of time. Some, but not all magma will move up the conduit to Earth's surface and erupt at a volcano. As the activity progresses, look for evidence that students understand that volcanoes of the Cascade Range originate in this manner, and that volcanoes in similar settings around the Ring of Fire own their origins to the same processes. To assess students' understanding, instruct students to explain the processes as noted in procedure number 4 above.

References

Decker, R., and Decker, B., 1998, Volcanoes: New York, N.Y., W.H. Freeman and Company, 321 p.

Francis, P., and Oppenheimer, C., 2003, Volcanoes: New York, N.Y., Oxford University Press, 536 p.

Kious, J.W., and Tilling, R.I., 1996, This dynamic earth: The story of plate tectonics: U.S. Geological Survey General Interest Publication, 77 p.

Rosi, M., Papale, P., Lupi, L., and Stoppato, M., 2002, Volcanoes: Buffalo, N.Y, Firefly Books, 335 p.

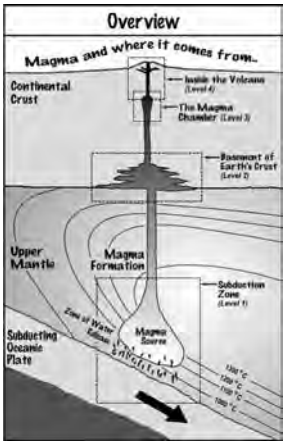
Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

Student Page

Riding the Magma Elevator

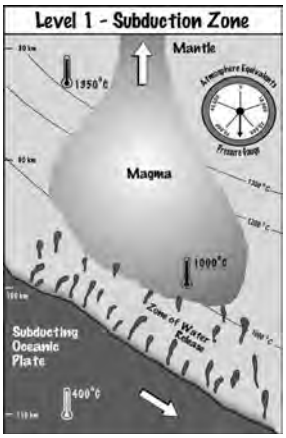
Narrative

Overview



No one has been—nor will likely reach the center of a volcano to examine directly the inner workings of an eruption. However, we can interpret what is going on by using scientific instruments—and a bit of imagination! We'll use an imaginary elevator in this activity to explore four locations crucial to the making of ***magma***: the ***subduction zone*** at **level 1**; basement of Earth's ***crust*** at **level 2**; the ***magma chamber*** at **level 3**; and inside the volcano at **level 4**. We'll make a descent down to level 1, the upper mantle and subduction zone, and then work our way upward to a Cascade volcano on Earth's surface. Put on your hard hats, this elevator's heading down!

Level 1—Subduction Zone



After a hot and dark trip downward, our elevator arrives safely in the upper ***mantle***, just above the subducting Juan de Fuca Plate, 80 to 120 kilometers (50 to 75 miles) below Earth's surface. Looking out our elevator porthole, we view dense ocean floor sediments that have sunk beneath North America. On the way down, we passed through the less dense upper portion of sediments that scraped against the continent and accumulated as great piles of rock—the Olympic Mountains and the Coast Range.

These sediments move quickly—at a speed of approximately 5 centimeters per year (more than 2 inches per year), a rate equivalent to that of your annual fingernail growth! Cold water from the Pacific Ocean helps keep temperatures comparatively cool in the subduction zone—that is, below 400° Celsius (750° Farenheit); however, temperatures here in the surrounding upper mantle are considerably hotter.

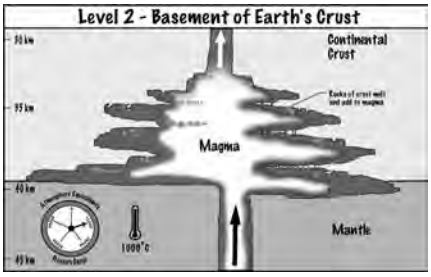
Our elevator is well-equipped with temperature and pressure sensors. We note that the pressure is extreme 2.5 gigapascals (GPa). That pressure is 25,000 times greater than pressure exerted by Earth's atmosphere at sea level, and the equivalent of 1.5 million cars stacked one upon the other, and sufficient to make mantle rock flow like road tar exposed to the warm sun. The thermometer indicates an outside temperature of 1,350°Celsius (2460°Farenheit)—sufficiently hot to warm the water within the subducting Juan de Fuca Plate. Water from the subducting slab rises into the mantle rocks. The addition of water to hot mantle rocks causes rock to melt and form magma. This magma begins to rise because it is less dense than surrounding solid mantle rock.

"All aboard," as we head upward to our next stop, the basement of Earth's crust—the Crustal Melting Zone.

Riding the Magma Elevator

Narrative-continued . . .

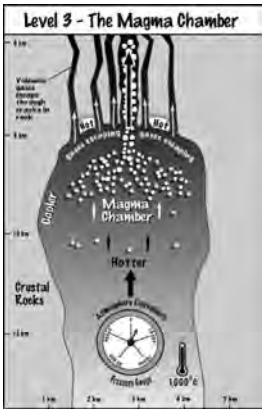
Level 2—Basement of Earth's Crust—Crustal Melting Zone Graphic



The crustal melting zone is 40 kilometers (24 miles) below Earth's surface and is the boundary between the mantle and the overlying continental crust. Our pressure gage shows a pressure of 1 GPa, or 10,000 Earth atmospheres. To our sense of touch, the magma is hot 1,000° Celsius (1,800° Farenheit). Even with oven mitts, you wouldn't want to touch this rock! The rock is pliable, unlike the hard continental crust with which we are familiar at Earth's surface. Rising magma collects at the base of the crust, slowly melting a pathway upwards—perhaps at a rate of 1 meter (3 feet) per year. From our porthole windows we note that the magma rises as a plume of hot rock, completely molten at the plume's center, and partially molten around the edges. This plume of ascending magma melts some surrounding crustal rocks, enabling bits of crustal material to hitchhike upward and form new combinations of elements within the magma.

Now it is time for our elevator to climb upward again. We're headed to the top of the magma chamber.

Level 3—Magma Chamber



We are now at the top of the magma chamber, a zone of partially to completely molten rock. At Mount Rainier, the magma chamber is located approximately 8 to 10 kilometers (5 to 6 miles) below the Earth's surface and extends several kilometers (approximately 2 miles) in width. Why does the magma accumulate here? The upward migration of magma stalls when its density equals that of the surrounding solid continental rock. Here, pressure within the magma chamber approximates 0.3 GP, the equivalent of 3,000 Earth atmospheres, and to the pressure of 180,000 cars stacked one on top of the other! The temperature remains at about 1,000° Celsius (1,800° Farenheit). In the center of the magma chamber the rock is molten and has the consistency of a hot slushy crystal mix. Temperatures and textures vary progressively from the center to the margins; a viscous (mushy) liquid that flows under pressure in the center to cooler solid rock at the chamber's outer edges.

Minerals and still uncombined chemical elements mix and mingle like at a square dance, where atoms change partners and new minerals and element patterns emerge. While the minerals and elements are square dancing, the gases separate from the magma and rise to the top of the magma chamber in search for the quickest and easiest route of escape to Earth's surface.

Teacher Page

Riding the Magma Elevator

Narrative-continued . . .

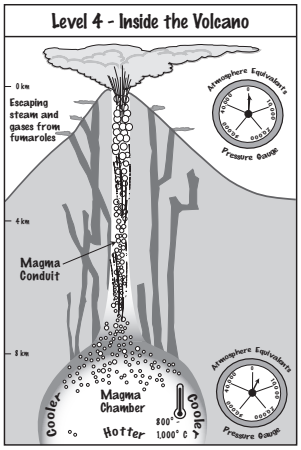
Here the magma rests, often for thousands of years, while it continues to cool, crystallize, form minerals, and receive replenished magma from below. Minerals mix and mingle with crustal rocks. Hot magma remains trapped beneath Earth's surface until the pressure within the magma chamber exceeds the strength of surrounding crustal rocks, forcing a volcanic eruption.

Some magma never makes the journey to the volcano above. It cools and hardens in place, and after thousands of years, the minerals within grow large and form a rock called ***granodiorite***. We see it at Earth's surface today, exposed by erosion.

Our elevator will follow magma as it erupts from the volcano. So hold on, here we go!

Level 4—Inside the Volcano

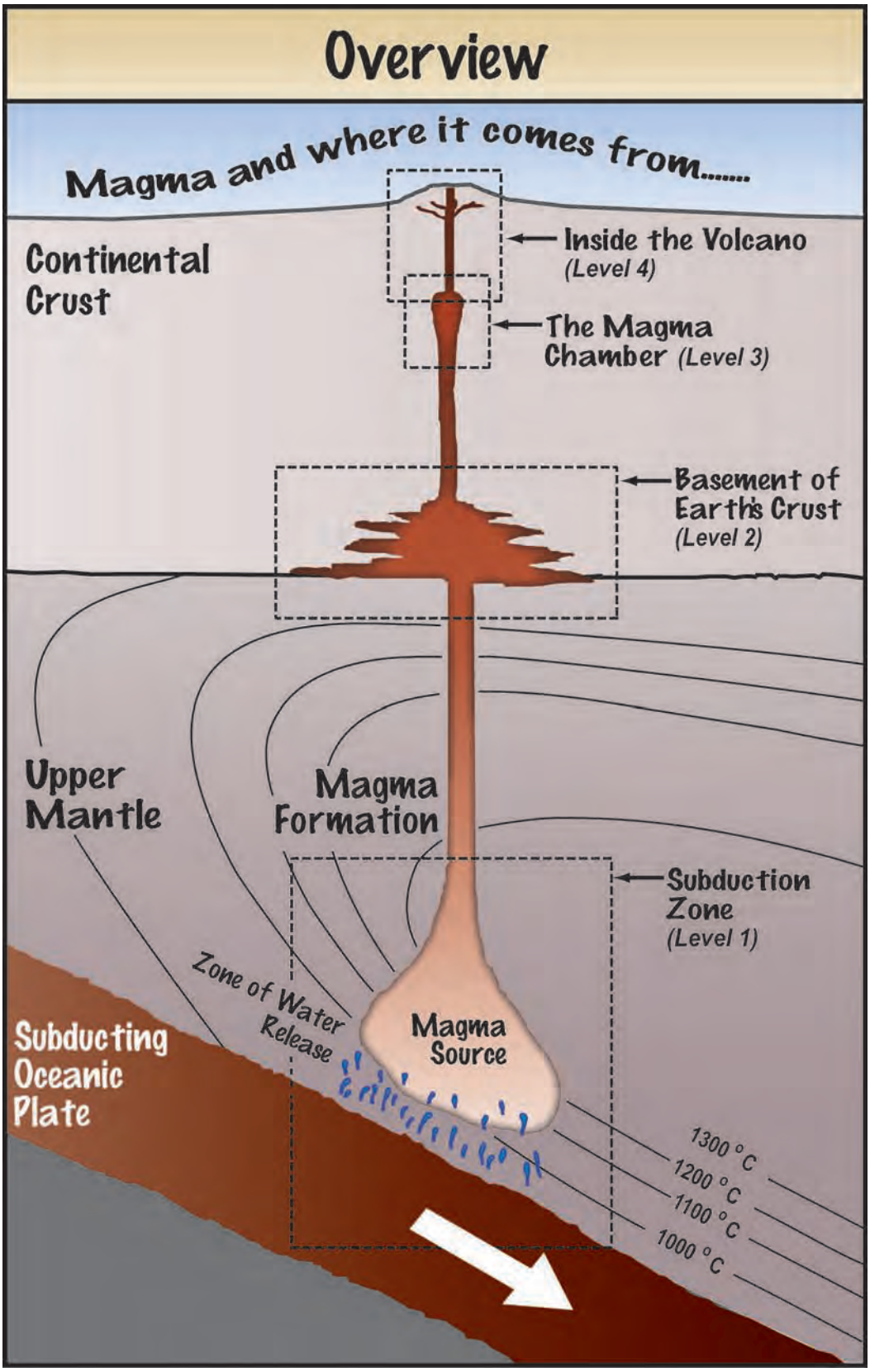
When pressure in the magma chamber is sufficient, magma forces open a narrow pathway that extends up to the Earth's surface, called a ***conduit***. During non-eruptive times, the conduit is filled with solid rock and debris from previous eruptions, which traps debris, ***volcanic gas*** and magma like a cork in a bottle. This conduit acts as a superhighway for magma erupting from the volcano. Magma can reach speeds of 50 to 100 meters per second (160 to 300 feet per second) as it rushes upward.

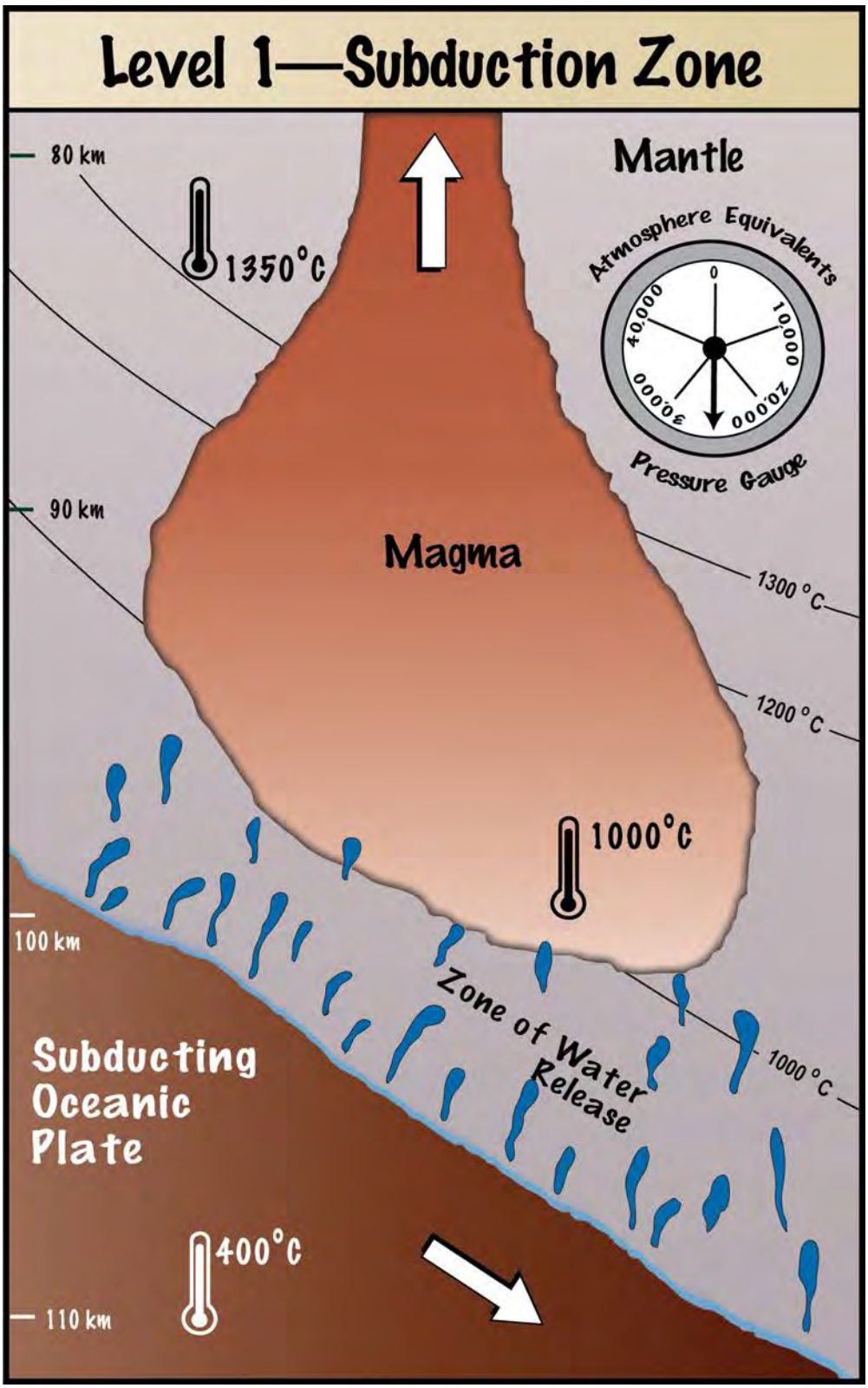


It takes only a few minutes for magma to rush from the magma chamber to the ***vent*** of the volcano during an explosive eruption, a distance of 8 to 10 kilometers (5 to 6 miles). Gas-rich magma escapes first, often blasting surrounding magma into billions of shards of ***volcanic ash***. ***Lava*** then squeezes or flows from the vent. The conduit sometimes overflows, and magma squeezes into cracks within the volcano forming ***dikes***.

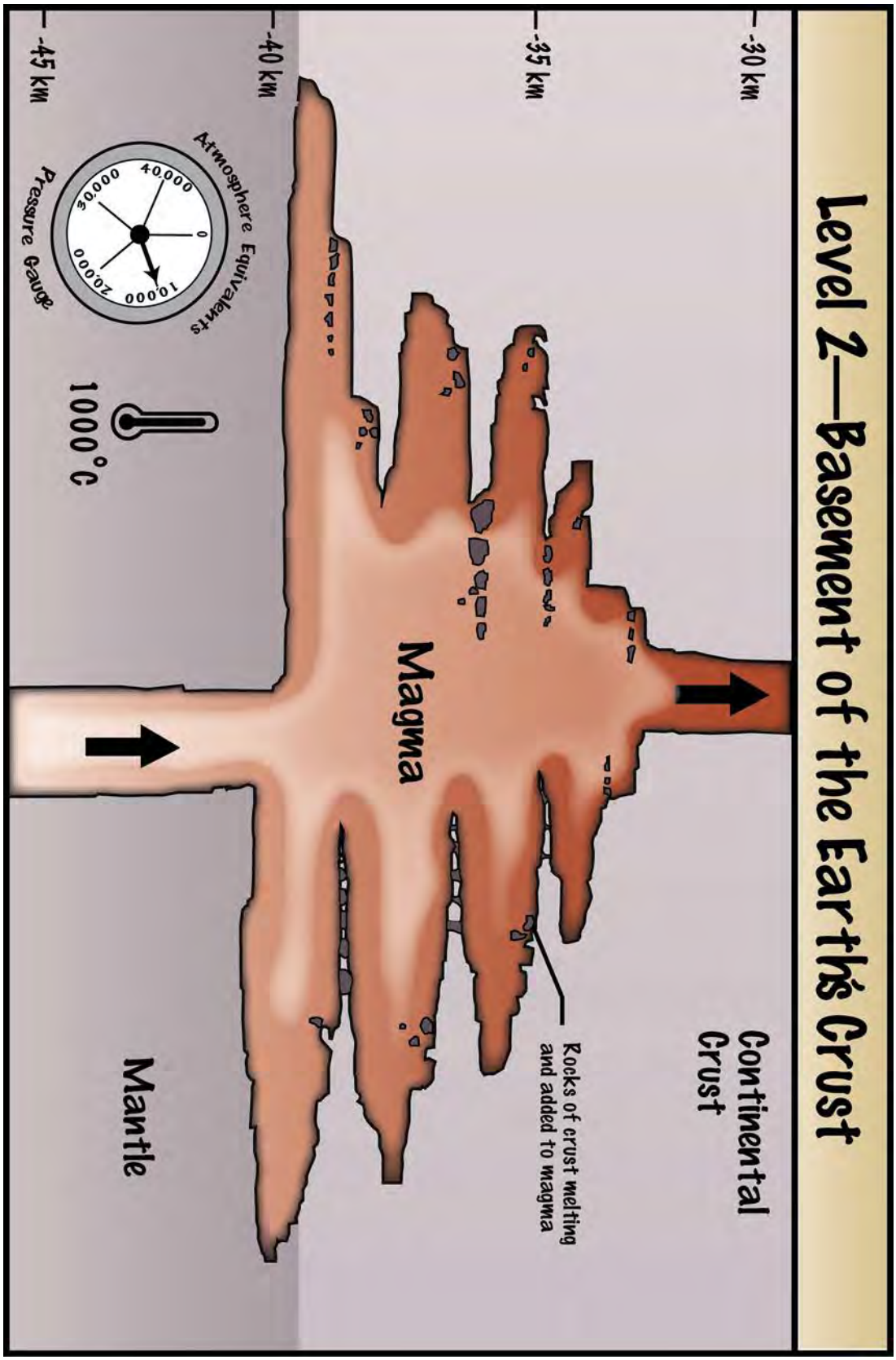
Hold on, because we are about to explode out of the volcano along with lava, ash, and gases. Here we go!

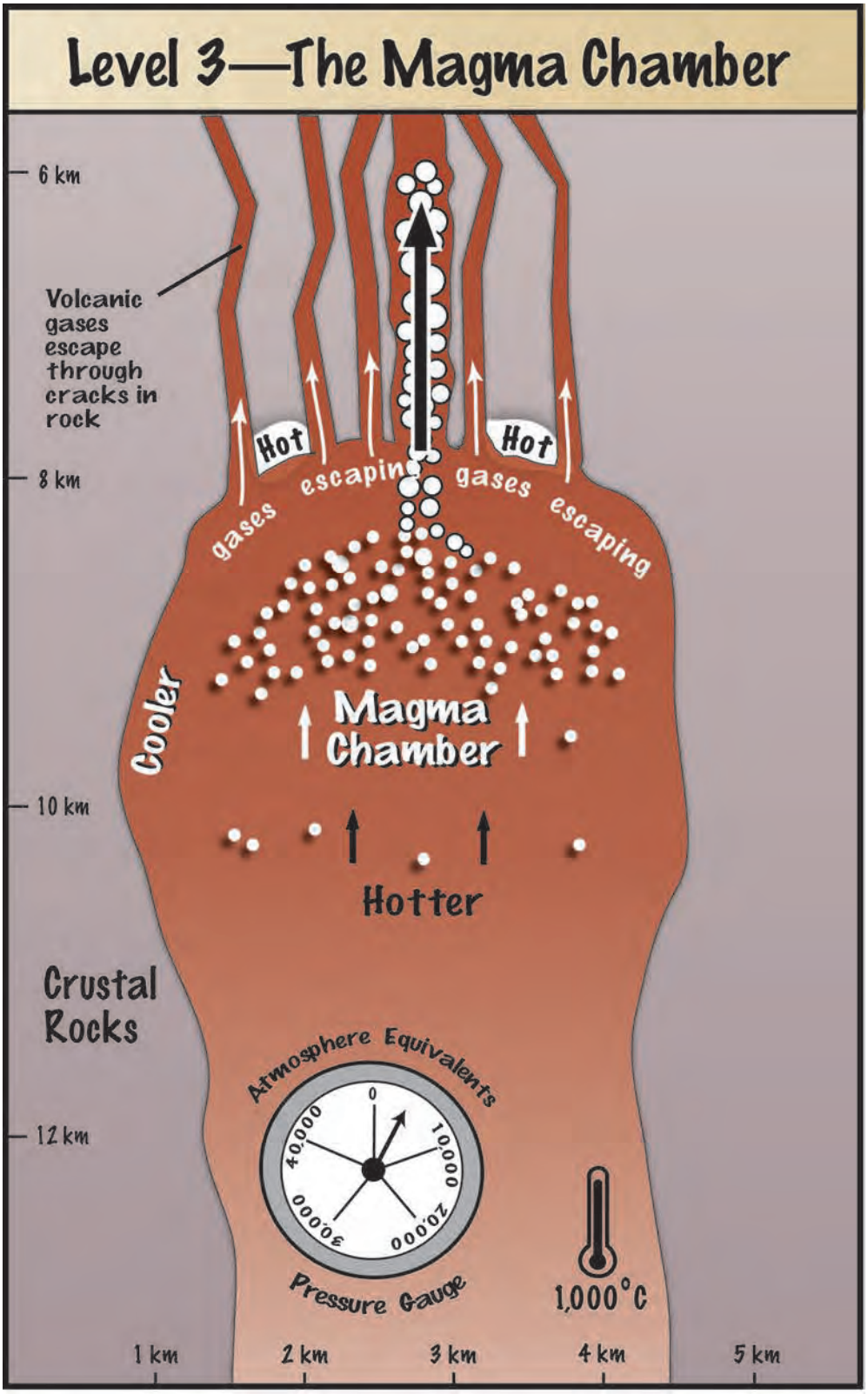
To learn what happens after an eruption, move on to **Soda Bottle Volcano** and Chapter 2 activities of this guide.


Overview
Magma and where it comes from.....
Continental Crust
Inside the Volcano (Level 4)
The Magma Chamber (Level 3)
Basement of Earth's Crust (Level 2)
Upper Mantle
Magma Formation
Subduction Zone (Level 1)
Zone of Water Release
Magma Source
Subducting Oceanic Plate
1300 °C
1200 °C
1100 °C
1000 °C

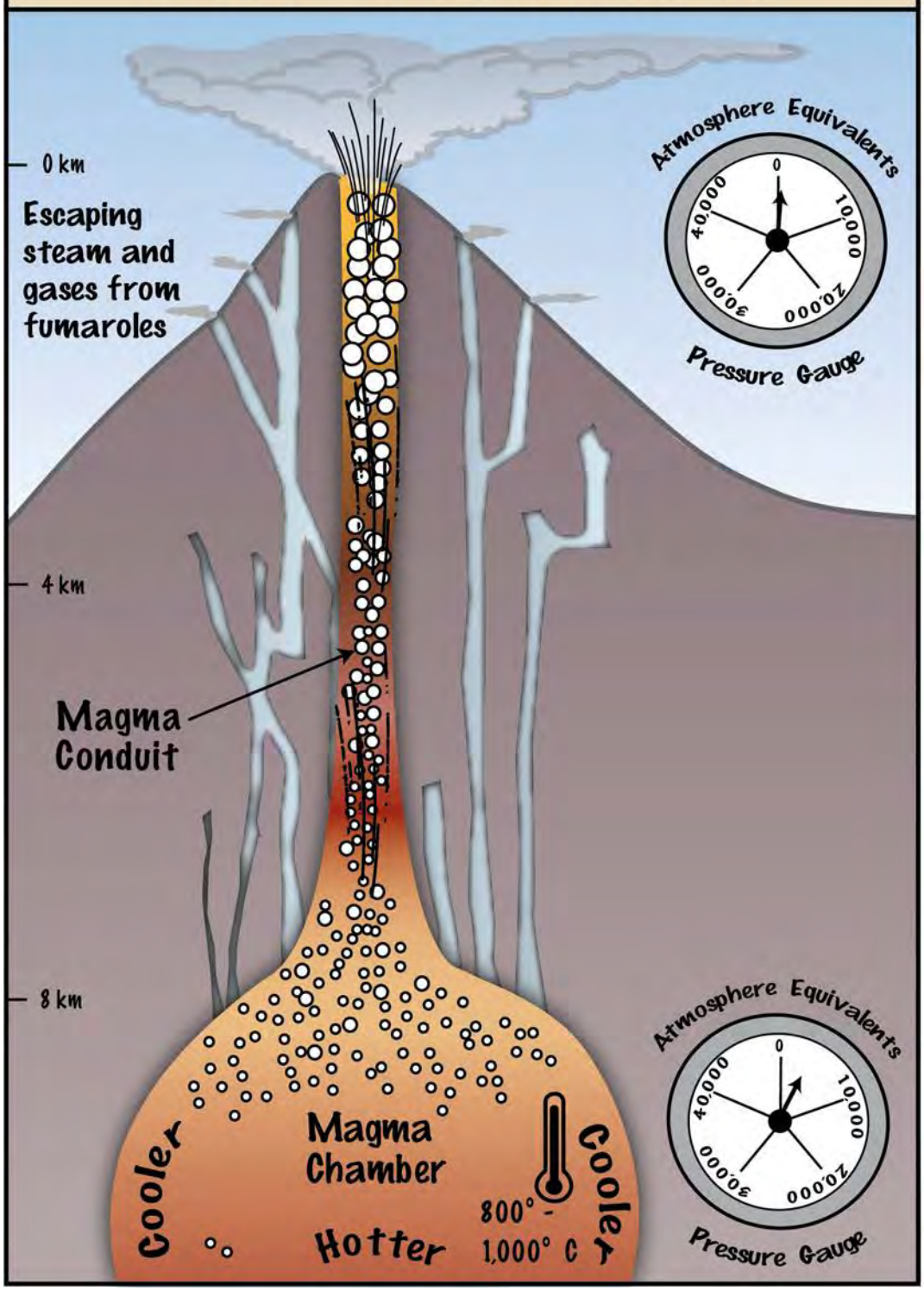

Level 1—Subduction Zone
80 km
1350°C
Mantle
Atmosphere Equivalents
0
10,000
20,000
30,000
40,000
Pressure Gauge
90 km
Magma
1300 °C
1200 °C
1000°C
100 km
Zone of Water Release
1000 °C
Subducting Oceanic Plate
400°C
110 km

Graphic Page

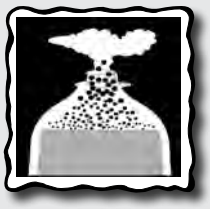



Level 3—The Magma Chamber
6 km
8 km
10 km
12 km
Volcanic gases escape through cracks in rock
Hot
Hot
gases escaping
gases escaping
Cooler
Magma Chamber
Hotter
Crustal Rocks
Atmosphere Equivalents
0
10,000
20,000
30,000
40,000
Pressure Gauge
1,000°C
1 km
2 km
3 km
4 km
5 km

Level 4—Inside the Volcano



Soda Bottle Volcano



Grade Level: 5–8

Learner Objectives:

Students will:

- Understand the important role of gases in providing energy for explosive volcanic eruptions
- Understand how pressure affects gases
- Learn how gases influence the texture and appearance of volcanic rocks

Setting: Outdoors or uncarpeted class-room with a tarp or plastic floor covering

Timeframe: 15 minutes; 25 minutes

Human Molecules—Studying the Role of Gas Bubbles in an Explosive Eruption

Making Your Own Volcanic Eruption—Option 1 or Option 2

USGS
science for a changing world

Living with a Volcano in Your Backyard-An Educator's Guide with Emphasis on Mount Rainier

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

Examine how gases provide for explosive volcanic eruptions by making comparisons to gases in a soda bottle and by conducting a carefully controlled "eruption" of baking soda and vinegar, or soda water.

Teacher Background

Water—The surprisingly essential ingredient in explosive volcanic eruptions

Hot ***magma*** and water vapor seem incompatible. Yet, water vapor (H_2O), carbon dioxide (CO_2), sulfur dioxide (SO_2), and lesser amounts of rarer gases take up as much as ten percent of the magma (by weight) that lies beneath some Cascade volcanoes. These gases are important because their expansion provides the energy that blasts magma to Earth's surface during an explosive volcanic eruption.

About 80 kilometers (50 miles) below the Earth's surface, water sweats off the subducted oceanic plate and promotes the formation of magma, which then rises into the Earth's crust (see **Surrounded by Volcanoes** for further detail). Water vapor and other gases, elements and minerals coexist as a mixture of molten or partially molten magma having a texture similar to hot oatmeal (see **Magma Mash** background section for further details).

A magma chamber is like a pot of dessert pudding

Imagine magma as home-cooked pudding bubbling in a pot topped by a tight lid. Some of the ingredients in the pot combine as they cool; this is similar to the process

Materials:

Human Molecules—Studying the Role of Gas Bubbles in an Explosive Eruption

- Graphic "***The Role of Gas Bubbles in an Eruption***"
- Teacher Page—Narrative ***"What Makes a Volcano Erupt?"***

Making Your Own Volcanic Eruption—Option 1

- Graphic ***"Soda Bottle Volcano"***
- Clear plastic bottle of tonic or seltzer water or other sugarless clear soda (those containing sugar are sticky)
- Paper towels
- Tarp or other plastic floor covering (optional)

Making Your Own Volcanic Eruption—Option 2

- Graphic ***"Soda Bottle Volcano"***
- 8 or 9 ounce clear plastic soda bottle for each student
- Permanent ink marker pen
- 1 box baking soda
- 2 gallons vinegar
- 1 box tissue
- Spoon
- Paper towels
- Tarp or other plastic floor covering (optional)

Vocabulary: **Conduit, magma, magma chamber, exsolution, fumaroles, pumice, scoria, throat, volcanic ash**

Skills: **Demonstrating, inferring, observing, predicting**

of elements combining to form minerals. During this process, tiny bubbles of gas separate from their more solid surrounding neighbors. Since gases are lighter, they rise to the top of the pudding (or magma). As gases separate progressively from the pudding, bubbles rise, expand, and form a gas-rich layer at the top of the pot (or ***magma chamber***).

The pot boils over

The pressure of rising gases eventually forces the pot lid to vibrate. Puffs of steam break out between the pot and lid in the same way that volcanic gases escape the top of a magma chamber through cracks and openings in surrounding rocks.

The upward pressure of gases eventually exceeds the downward pressure exerted by the lid, and the pudding and gases pour over the side of the pot and onto the stovetop. This is the same concept as lava escaping across the slopes of an erupting volcano. Some of the pudding propels explosively out of the pot and splatters everywhere, similar to magma erupting from a volcano as rock fragments or ash.

Teacher Tips

For more information on how minerals form in magma, see the* Magma Mash *activity.

Benchmarks:

See benchmarks in Introduction.

Gas bubbles determine the texture of volcanic rock

During an explosive volcanic eruption, gases escape into the atmosphere; however, some become trapped in the quickly cooling magma. The erupted magma, in the form of ash and lava, may contain bubble holes from the former presence of gases. The resulting rocks appear similar to foam from a bottle of soda. These rocks are called ***pumice*** and ***scoria***. Sometimes the gas-rich magma erupts so explosively that it breaks into tiny fragments known as ***volcanic ash***.

Sidebar 1 Fumaroles at Mount Rainier

Hot gases often mix with groundwater before venting to the surface as fumaroles. Steam and gases that spew from the fumaroles make the air smell unpleasant and deposit colorful minerals on Earth's surface. Active fumaroles are found at most Cascade volcanoes.

Fumaroles are evidence that Mount Rainier is an active volcano. Inside Mount Rainier's summit craters, heat from fumaroles has melted out a system of narrow ice caves and a sub-ice lake, possibly the highest lake in the United States. Temperatures at the hottest fumaroles range between 70–90° Celsius (150°–200° Farenheit) and produce enough heat to keep some parts of the summit craters snow-free year round. Early climbers used the ice caves as shelter. They described huddling around the fumaroles and feeling scalded on one side and frozen on the other! Fumaroles exist also on the upper flanks of Mount Rainier at Disappointment Cleaver, Willis Wall, Sunset Amphitheater, the South Tahoma headwall and the Kautz headwall. These fumaroles have lower temperatures due to increased dilution by groundwater. Some gases rise to the surface through thermal springs near Winthrop and Paradise Glaciers, the Nisqually and Ohanapecosh Rivers, and Longmire Springs.

Teacher Tips

For more information on volcanic ash, pumice, and scoria, see the Tephra Popcorn activity.

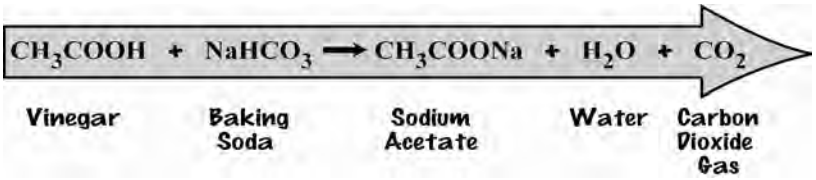
How the soda water experiment is like a volcano

The wide body and narrow neck of a soda bottle roughly resemble the shape of a magma chamber and the ***conduit*** or ***throat*** within a volcano. The pressurized soda water represents gas-rich magma that is under pressure from overlying rocks.

Carbonated beverages get their fizz from the gas carbon dioxide. When the bottle is capped, carbon dioxide dissolves within the soda from the pressure exerted on it. It also occupies the void between the surface of the liquid and the cap. Shaking the bottle adds energy and causes gas in the soda water to separate, forming tiny bubbles throughout the liquid. Formation of the bubbles increases pressure inside the bottle. Quickly removing the cap releases this pressure, and the bubbles immediately expand. Forced up the narrow neck, the fluid and bubbles burst from the high-pressure environment of the bottle to the lower pressure of the atmosphere. Bubbles of water vapor and other gases within magma undergo a similar progression. They are initially dissolved in magma, then depressurization of the magma chamber frees the bubbles from the magma in a process called ***exsolution***. The bubbles rise to the top of the ***magma chamber***. Pressure from the gas bubbles propels both the magma and gas up the conduit. The gas bubbles now rapidly expand to thousands of times their original volume when escaping up the conduit to the top of the erupting volcano.

How is the vinegar and baking soda eruption unlike a volcano?

Combining baking soda and vinegar causes a chemical reaction that quickly produces carbon dioxide bubbles:



This demonstration differs from the processes within real volcanoes, because the gases that cause explosive eruptions do not result from sudden chemical reactions. In the soda water, and baking soda and vinegar experiments, carbon dioxide acts as the main gas driving the explosion. In most volcanic eruptions, water is the principal gas driving an explosive eruption and not carbon dioxide.

Sidebar 2 Why Volcanoes Stink

Two of the principal gases released from volcanoes, water and carbon dioxide, are odorless. Volcanoes also release sulfur dioxide and hydrogen sulfide into the atmosphere in lesser amounts. These gases have strong smells. Sulfur dioxide has an odor similar to struck matches. Hydrogen sulfide smells like rotten eggs or sewer gas and can be sensed even in low concentrations.

Procedure

Human Molecules—Studying the Role of Gas Bubbles in an Explosive Eruption

Explore how gas molecules respond to pressure using an illustration and classroom demonstration.

1. Demonstrate how gas reacts in different pressure conditions. Divide the class into two groups. One group will act as "rock walls" and the other group will act as "gas molecules." The gas molecules should always be in random motion.

2. Instruct the "rock walls" to form a tight circle around five of the "gas molecules." Further instruct students (walls) not to change size of circle once formed.

3. Ask the five students (gas molecules) in the center of the circle to move randomly from one side of the "rock walls" to the other. They should have a difficult time doing this in such a tight space.

4. Add one student at a time from the "gas molecules" group to the inside of the circle until there are no more students (gas molecules) left. Students should have a hard time squeezing into the circle if the "rock walls" circle has not changed its size.

5. Tell everyone to "Freeze."

6. Explain to the students that they have just demonstrated what happens in a magma chamber. Gases rise out of the magma and accumulate at the top of the chamber. As more gases accumulate, the pressure increases. Eventually the pressure of the gas exceeds the pressure of surrounding rock, so the gases must escape up the magma conduit.

7. Instruct the "rock walls" to enlarge the circle while the "gas molecules" remain in place.

8. Tell the "gas molecules" to mingle so that they move throughout the entire space. This is what happens when pressure is decreased; gases expand to fill up space.

9. Instruct two people in the "rock wall" to open a hole in the circle. This allows the "gas molecules" to escape rapidly, as in a volcanic eruption.

10. Show students the "***The Role of Gas Bubbles in an Eruption***" graphic. Use the "***What Starts an Eruption?***" narrative to discuss the graphic.

Making Your Own Volcanic Eruption

Examine the role of gas in explosive volcanic eruptions by using either ***Option 1*** (soda water) or ***Option 2*** (a baking soda and vinegar mixture in a bottle). This activity can be done as a demonstration or in small student groups.

Option 1: Soda Water Eruption

1. Divide students into groups of three or four.

2. Provide each group with an unshaken bottle of soda water with the label removed.

3. Instruct students to examine the bottle and discuss their observations. They should pay close attention to the number and size of bubbles in the soda water and also to the firmness of the sides of the bottle.

4. Have students shake the bottle vigorously for about 30 seconds.

5. Instruct students to examine the appearance of the bottle's contents. How did the change in size and location within the bottle? Where are they smaller? Where are they larger? If froth forms at the top of the bottle, explain that small bubbles in the soda water expanded after shaking to form this froth.

6. Ask students to look at the bulging cap on the bottle and feel the firmness of the sides of the bottle. Why has this happened?

7. Instruct students to predict what would happen if the bottle is shaken and uncapped immediately afterward.

8. Tell students to imagine the bottle is a volcano, with the opening as the volcanic vent.

9. Ask students to shake the bottle rapidly and open it with the top directed AWAY from viewers.

10. Discuss the similarities between gases in the soda bottle and those in a magma chamber beneath an erupting volcano.

11. On the empty soda bottle, draw a volcano with magma conduit (throat), magma chamber, and surrounding rocks. Use the "***Soda Bottle Volcano***" graphic as a model. Draw circles to indicate how bubble size changes with reduction of pressure.

12. Refer to the graphic and ask students to point out which features they played during the human molecule exercise earlier in this activity.

"Making your Own Volcanic Eruption" can be messy, so do the experiment outside or in an easy-to-clean area.

Option 2: Vinegar and Baking Soda Eruption

1. Explain to students that they will be making baking soda and vinegar volcanoes. The baking soda reacts with vinegar to form carbon dioxide gas. Carbon dioxide, sulfur dioxide, and water vapor are common volcanic gases. Gases building up in the magma chamber provide the main trigger for volcanic eruptions.

2. Divide the class into groups of three or four.

3. Give each group an empty eight or nine-ounce soda bottle (no caps required). Using the "***Soda Bottle Volcano***" graphic as a model, have students draw a volcano on the empty soda bottle showing the magma conduit (throat), magma chamber, and surrounding rocks. Draw circles to illustrate bubbles that enlarge as they rise because of reduction of pressure. Note that if you use larger bottles, you need to raise the volumes of ingredients proportionally.

4. Preferably in an outdoor setting, instruct students to prepare their makeshift volcano by pouring vinegar into the bottle, so that the bottle is at least one-third full.

5. On single sheets of tissue, each group should **pour one heaping teaspoon of baking soda so that the tissue can be rolled up and squeezed through the bottle neck quickly.** Students SHOULD NOT push the baking soda bundle into the bottle until instructed to do so.

6. Before students activate the chemical reaction, inform them to make some observation during the experiment. Each group should look, listen, and feel for an increase in pressure within the bottle. They should watch the gas bubbles and note any increase or decrease in size. Additionally, they should keep an eye on the volume of gas bubbles produced during the remainder of the experiment.

7. Keeping the bottle pointed AWAY from viewers, students push the baking soda bundle into the bottle of vinegar. They should immediately place a hand over the top of the bottle and try not to let any gas escape. They should feel the pressure build and hear the escaping gases make hissing sounds similar to what you would hear near a real volcanic vent.

8. Instruct students to shake the bottle for 10 to 20 seconds with their hand firmly over the opening of the bottle. The gases inside the bottle will dramatically expand, force their hand away, and propel a foamy froth into the air and down the sides of the bottle.

9. How did the students' results compare to that of a real volcanic eruption? Did the pressure increase? How do they know? How was covering the top of the soda bottle similar to a closed magma conduit? What happened to the size and quantity of the gas bubbles after the eruption?

Adaptations

- Ask students to use different shaped containers that represent the magma chamber and conduit of a volcano. How does shape affect the eruption results?

- For younger students, direct them to draw lines on a piece of paper that divide it into six sections. Ask students to draw a before, during, and after experiment picture in squares 1, 2, and 3. Instruct students to draw pictures in squares 4, 5, and 6, of what a volcano would look like if it behaved like the experiment represented in squares 1, 2, and 3 respectively.

Extensions

- Instruct students to make a four-page book that illustrates gas bubbles increasing in size as the magma rises in the Earth and ends with a volcano erupting.

- Search for the link between volcanic gases and acid lakes. Ask students to use the Internet to research this topic. Some examples of lakes containing volcanic gases include Lake Nyos, Cameroon, Kawa Ijen, Indonesia, and Santa Ana, El Salvador.

- Direct students to explore Internet-based computer programs that simulate volcanic eruptions. Note the list of selected computer programs in Internet Resources.

Assessment

Look for evidence of students' understanding of the following concepts: that magma contains gases under great pressure; that gases provide the energy for volcanic eruptions; that gases influence the texture and appearance of volcanic rocks. Look for students' recognition of the differences between the baking soda and vinegar eruption, which is based on chemical reactions, and an actual volcanic eruption, which is based solely upon pressure release.

References

Decker, R., and Decker, B., 1998, Volcanoes: New York, N.Y., W.H. Freeman and Company, 321 p.

Francis, P., and Oppenheimer, C., 2003, Volcanoes: New York, N.Y., Oxford University Press, 536 p.

VanCleve, J., 1994, Volcanoes—Mind-boggling experiments you can turn into science fair projects: New York, N.Y., John Wiley and Sons, 89 p.

Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

Teacher Page

What Starts an Eruption?

Narrative

Gases, such as water vapor, CO_2, SO_2, and other rarer gases, are the driving forces that power explosive volcanic eruptions. However, gases are not the only players in a volcanic eruption. The size and explosiveness of an eruption are also controlled by the amount of magma in the magma chamber, the magma's chemical composition, and the pressure change in the narrow conduit that leads to Earth's surface.

Magma

Deep below the surface of the earth, the subducting plate's temperature increases. Water rises out of the sinking slab, migrates into the surrounding hotter mantle rock, and initiates melting. The molten rock is called magma.

Pressure

Within the Earth, the weight of rock causes pressure to increase with depth (imagine the weight, or pressure, on your body if a million rocks were sitting on top of you!). The greater the depth, the greater the pressure. Pressure can cause gases such as water vapor and carbon dioxide to dissolve in magma at great depth, and then to come out of the magma to form bubbles, like those in a carbonated drink, as the magma rises and pressure decreases.

Magma Chamber

The magma chamber is a zone of molten and partially molten rock that exists beneath a volcano. The top of the magma chamber at Mount Rainier is about 8 kilometers (5 miles) below the Earth's surface and is only a few kilometers wide. As gas bubbles accumulate, the upward pressure increases, forcing cracks in the rocks to widen, often in the direction of Earth's surface. For magma to erupt from a volcano, this upward pressure must exceed the downward pressure that is exerted by the 8-kilometer (5-mile) thick load of rock overhead.

Magma Conduit

With the accumulation and rise of bubbles through the magma chamber, the pressure increases and will eventually become great enough to break through overlying roof rocks, creating a conduit to the surface. Magma escapes through the "super highway" of the volcano, known as the magma conduit or throat. This long, narrow opening leads from the top of the magma chamber to the Earth's surface. Near the surface, the throat of Mount Rainier is only 10 to 15 meters (33 to 50 feet) wide and is currently filled with solid rock.

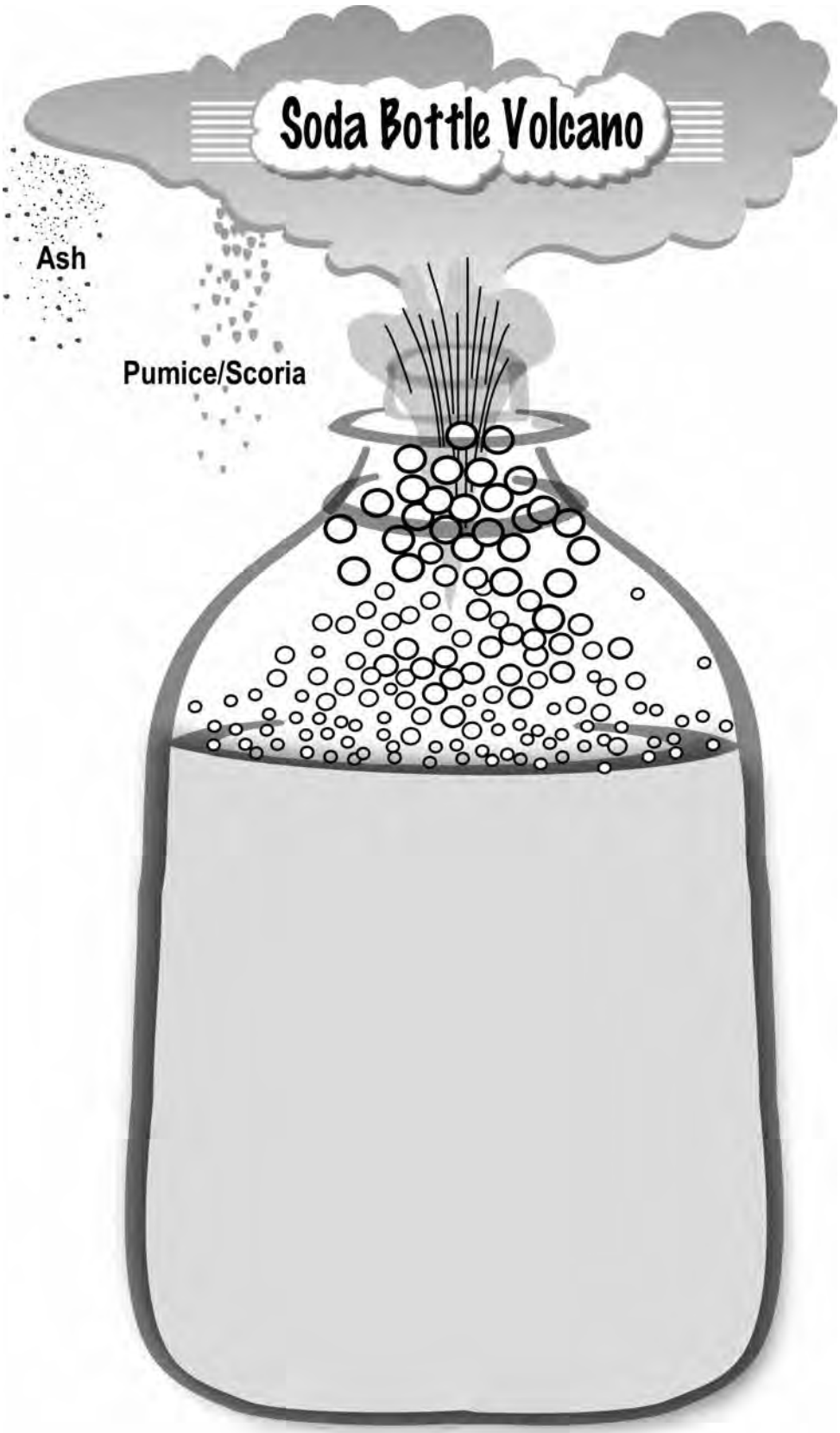
What Starts an Eruption?

Narrative-continued . . .

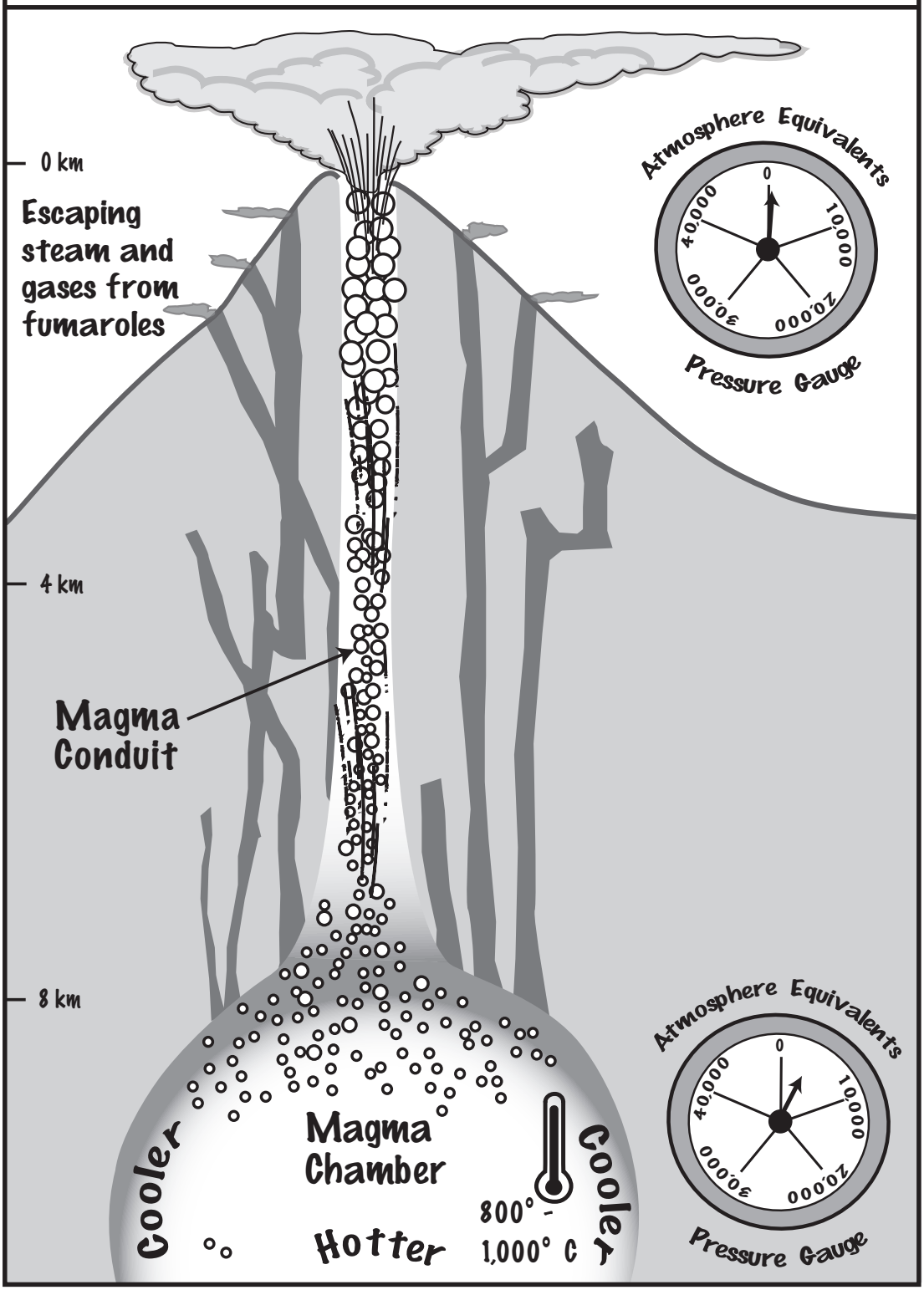
As gas bubbles rush up the magma conduit, the pressure declines, causing the bubbles to expand rapidly. They can expand to thousands of times their original size! The rapid expansion of gas bubbles propels the magma and gas up the conduit. Within minutes, the volcano erupts, explosively spewing hot lava and tephra into the air. Lava can be jetted thousands of feet into the air. Eventually, if the magma is "runny enough," the gas bubbles escape easily; and instead of exploding, magma pours down the flanks of volcano as a lava flow.

Vents and Fumaroles

Vents and fumaroles in the rock surrounding the conduit can also allow gases to escape from the magma through vents and fumaroles. If enough gas escapes, the character of the eruption will be changed from explosive to nonexplosive.


Soda Bottle Volcano
Ash
Pumice/Scoria

The Role of Gas Bubbles in an Eruption



Living with a volcano in your backyard—An educator's guide with emphasis on Mount Rainier
Coordinated by Carolyn Driedger, Anne Doherty, Cheryl Dixon, and Lisa Faust
U.S. Geological Survey General Information Product 19
http://pubs.usgs.gov/gip/19/

Chapter 2. Today's Discoveries Unlock the Past

Volcanic processes are the principal focus of Chapter 2 and are the natural progression from the Chapter 1 overview of how volcanoes work. Activities grouped under the theme "Lava, Rock Rubble, and Mud, Oh My!" invite inquiry about volcanic processes at Cascade volcanoes, and activities grouped under the theme "Interpreting Volcanic History" invite inquiry about how researchers conduct their research:

Overview

Lava, Rock Rubble, and Mud, Oh My!

- **Understanding Volcanic Hazards Video/DVD**—Introduces students to the vocabulary and character of volcanic processes and how volcano hazards impact people living near and far from a volcano. This video/DVD is intended for older students only.
- **Volcanic Processes**—This activity is an alternative to the Understanding Volcanic Hazards video. Students view graphics of volcanic processes, then answer questions on a worksheet. As an optional activity, they can prepare a booklet or computer presentation about each process with an emphasis on the interaction of these processes during a volcanic eruption.
- **Tephra Popcorn**—Students study physical characteristics of tephra using samples and make mass and volume measurements of popcorn to understand the role gases play in tephra formation.
- **Lava Building Blocks of Mount Rainier**—Students explore the nature and motion of lava flows and learn their importance as the building blocks of Mount Rainier. Students learn how the composition and texture of lava differs between volcanoes and affects the ultimate shape of a volcano.
- **Rock Stars**—Using photos and rock samples, students identify the characteristics that tell a story about where and how each rock was formed.
- **Fire and Ice**—Students conduct or observe an experiment simulating glacier/lava flow interactions, then answer questions about how glacier and lava interactions shaped specific features on Mount Rainier.
- **Lahar in a Jar**—Using experimental and scientific methods, explore how loose rock is mobilized by small amounts of water to form lahars.
- **Rock Rubble Review**—This is a physically active game that tests the students' knowledge of volcano terminology, processes, and impacts on communities.

Interpreting Volcanic History

- **Earth Blocks**—Learn about the "Law of Superposition" and how to interpret rock and sediment layers by reading a short story and arranging "Earth Blocks."
- **Volcano Fan Club**—Students learn that tephra layers at Mount Rainier originated from several volcanoes by looking at tephra dispersal patterns and thickness contours on maps.
- **Tephra Explorer**—Students view distributions of tephra layers found around Mount Rainier and discover the source.
- **Shoebox Geologist**—Make a model of layers emplaced by processes of deposition and erosion in a volcanically active landscape. Students interpret geologic events from layers in a classmate's model using stratigraphic columns and the Law of Superposition.
- **Perilous Beauty Video**—The "Perilous Beauty" video introduces students to the types of hazards common to Mount Rainier, specifically mudflows and the types of mechanisms that produce them.

This page left intentionally blank

Today's Discoveries Unlock the Past
Overview—Chapter 2

Chapter 2 introduces external volcanic processes at Cascade volcanoes, such as lava flows, pyroclastic flows, volcanic ash, and the formation of volcanic mudflows (lahars). Students discover methods for investigation of past volcanic activity and learn how scientists identify hazardous areas. Chapter 2 activities strengthen students' mental connections among volcanic processes, hazards, and their own community.

Throughout Chapter 2, encourage students' recognition of lahars as the principal hazard to communities located on valley floors at the base of Cascade volcanoes. Identify volcanic ash as abrasive but nontoxic fragments of volcanic rock that cool to air temperature and are transported by winds, often to great distances from their source volcano. Activities in Chapter 2 dispel any notion of direct risk to communities near Mount Rainier by lava flows, pyroclastic flows, and volcanic gases.

Start this chapter by viewing the **Understanding Volcanic Hazards Video/DVD** and instructing students to complete the worksheet. Use **Volcanic Processes** with younger students or if the video is unavailable. Both activities provide descriptions of volcanic processes and their potential effects on communities. The **Perilous Beauty Video** activity describes volcanic hazards at Mount Rainier.

Offer students more in-depth investigations into the mechanics of each process in **Tephra Popcorn**, **Rock Stars**, **Lava Building Blocks**, **Fire and Ice**, and **Lahar in a Jar**. In **Volcano Fan Club**, **Tephra Explorer**, and **Earth Blocks**, students learn about the Law of Superposition and other principles of geological investigation. Students become the scientists as they construct and reveal rocky layers in **Shoebox Geologist**. They test their knowledge of volcanic processes in **Rock Rubble Review**. The information learned in Chapter 2 will help students appreciate the geology observed during school field trips to the south side of Mount Rainier (see **Journey Back in Time** fieldtrip in the appendixes). This knowledge of volcanic processes can motivate your students to participate in the family and community preparedness actions presented in Chapter 3.

Make your message clear:

Volcanic events have changed the landscape of the Pacific Northwest noticeably through time. The volcanic landscapes that we view today differ from the vistas enjoyed by our ancestors and the scenes to be observed by our descendents.

Understanding Volcanic Hazards Video/DVD

Living with a VOLCANO in Your Backyard
MOUNT RAINIER

Grade Level: 6–12+

Learner Objectives:

Students will:

- Explain the origin and character of common volcanic hazards
- Understand how each volcanic hazard can affect humans

Setting: Classroom

Timeframe: 45 minutes (video is 25 minutes)

Materials:

- *"Understanding Volcanic Hazards"* Video/DVD
- DVD or VHS player
- Television monitor
- Copies of *"Understanding Volcanic Hazards Questions"* student page

Vocabulary: Lava flows, ash falls, volcanic ash, hot ash flows (pyroclastic flows), mudflows (lahars), volcanic landslides, tsunamis, volcanic gases

USGS science for a changing world

NATIONAL PARK SERVICE

Living with a Volcano in Your Backyard-An Educator's Guide with Emphasis on Mount Rainier

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

The video "***Understanding Volcanic Hazards***" introduces students to the vocabulary and character of hazardous volcanic processes and how they impact people both near and far from a volcano.

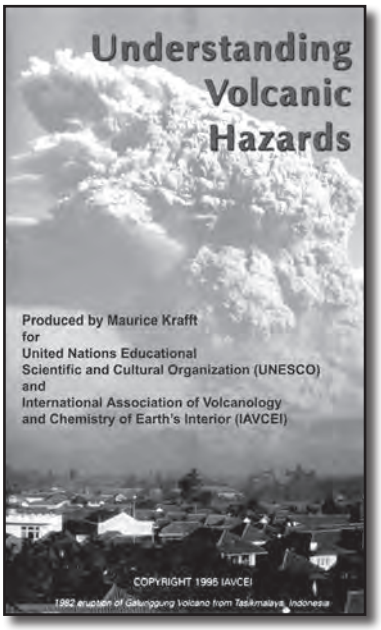
Skills: application, interpretation, listening

Benchmarks:

See benchmarks in Introduction.

Activity last modified: November 21, 2014

Teacher Background



This twenty-five minute videotape features stunning images of erupting volcanoes and graphic depictions of how volcanic activity can affect people, their property, and the land on which they live. The program is neatly divided into segments that focus on seven common volcanic hazards: ***ash falls***, ***hot ash flows (pyroclastic flows)***, ***mudflows (lahars)***, ***volcanic landslides***, ***tsunamis***, ***lava flows***, ***and volcanic gases.***

What to do Before Class Begins:

- Watch the video and determine if it is appropriate for your students.
- Decide whether to watch the video in full or in segments aligned with each volcanic process in Chapter 2.
- Use activities in Chapter 3 from **Living with a Volcano in your Backyard** to learn more about how to prepare for these types of volcanic processes.

What to do Before Class Begins:

- Obtain the video "***Understanding Volcanic Hazards***," from your school or community library, or through the Northwest Interpretive Association. When ordering this video, you may wish to order copies of the two other videos used in this guide: "***Reducing Volcanic Risk"*** and "***Perilous Beauty—The Hidden Dangers of Mount Rainier***."

Volcano Video Productions
PO BOX 5151, Hilo, HI 96720
lava@volcanovideo.com
fax (808) 959-3885
TOLL FREE at 1-888-458-7538

Discover Your Northwest
164 Jackson St.
Seattle, WA 98104
Order online at:
http://www.discovernw.org/

A summary of this product is available in the products section on the following Web site http://volcanoes.usgs.gov/

The authors advise teachers to preview this video and make a judgment about whether it is appropriate for their students. This video shows photographs of volcanic processes; in several situations, the video shows people and animals injured or killed by the volcanic events. There is potential for students to be overwhelmed by the graphic depictions. Teachers may opt to show the video in segments, or in full with warnings to students. The activity Volcano Processes may be used in lieu of the video, where similar material is presented in a less graphic manner.

A NOTE ON TERMINOLOGY: The general term "mudflow" used in the video describes both lahars and debris flows. At Mount Rainier, scientists and public officials have defined the terms more specifically to reduce confusion between major and minor events. They define lahars as large, far-traveling slurries of rock, mud and water caused by landslides or eruptions, which threaten distant communities. They use the term debris flow for small events initiated by excess rain or glacial meltwater, which seldom move beyond park boundaries. Debris flows are common in river valleys at Cascade Volcanoes and happen almost annually at Mount Rainier.

Sidebar 1

Volcanic Processes at Mount Rainier

Volcanic Ash

Mount Rainier has produced more than 40 layers of volcanic ash since the end of the last ice age, around 10,000 years ago. The thickest and most complete sequence of ash layers exists on the volcano's eastern flank. During these eruptions, Mount Rainier has produced more lava than volcanic ash. In the future, eruptions of ash, commonly will precede or accompany lava flows. While airborne ash will affect aviation regionally, winds generally blow from west to east, and thus, volcanic ash most likely will fall in sparsely populated areas east of Mount Rainier National Park. On at least ten occasions during the past 4,000 years, Mount Rainier's slopes were covered with volcanic ash from eruptions at Mount St. Helens. See also **Tephra Explorer**, **Volcano Fan Club**, **Tephra Popcorn**, **Volcanic Processes** and Chapter 3 activities for maps of hazard potential and safety.

Hot Ash Flows (Pyroclastic Flows)

At Mount Rainier, hot ash flows (pyroclastic flows) form occasionally during explosive eruptions but most of the time by the disintegration of lava flows on the mountain's steep slopes. Scientists expect that future pyroclastic flows will flow only as far as the lower slopes of the volcano. The snow and ice melted by pyroclastic flows are a principal source of mudflows. See also in this chapter, **Lava—Building Blocks**, **Rock Stars**, **Fire and Ice**, **Earth Blocks**, **Volcanic Processes** and Chapter 3 activities about hazard potential and safety.

Volcanic Mudflows (Lahars and Debris Flows)

An abundance of loose rock and surface water makes Mount Rainier an ideal environment for the formation of lahars and debris flows (see Teacher Tip above regarding terminology). Since the end of the last ice age approximately 10,000 years ago, mudflows repeatedly inundated the floors of the White, Puyallup and Nisqually River valleys at Mount Rainier to distances of up to 100 kilometers (60 miles) from the volcano. The melting of snow and ice by ash flows (pyroclastic flows) during eruptions forms the great majority of lahars; landslides have been the origin of others. Debris flows happen almost annually along some river drainages at Mount Rainier. Debris flows move sediment and raise the elevation of streambeds.

Mudflows (lahars) are the most serious volcanic threat to people near Mount Rainier. People can best avoid lahars and debris flows by becoming aware of conditions that generate lahars and moving from the valley floors to higher ground when necessary. See also in **Lahar in a Jar**, and Chapter 3 maps of hazard potential and safety information.

Sidebar 1 Volcanic Processes at Mount Rainier -continued

Volcanic Landslides at Mount Rainier

Volcanic landslides are more likely to occur during eruptive times and less likely during noneruptive times. Water contained in the landslide and water from melting snow and streams mixes with landslide rocks to produce lahars that travel tens of kilometers from the volcano. Lahars formed by landslides most commonly derive from rocks that have been hydrothermally altered and are now water saturated. Landslide-driven lahars most often occur during periods of volcanism, though they can form at other times, too. See **Lahar in a Jar** activity and Chapter 3 activities for information about safety around volcanic landslides.

Tsunami

While lahars may enter reservoirs and cause a rise of water levels, there is little threat of lahars causing tsunamis in major water bodies in the vicinity of Mount Rainier.

Lava Flows at Mount Rainier

Hundreds of thin overlapping lava flows form the volcanic cone of Mount Rainier. Some lava flows traveled along the cold margins of ice age glaciers for tens of kilometers (tens of miles) and formed long ridges. Today, the large ice age glaciers are gone, but a radiating pattern of lava flow ridges spread outward from the volcano like spokes on a wheel. Few lava flows have traveled beyond current park boundaries. Scientists expect that future lava flows will not travel farther than those of the past. See the **Lava—Building Blocks**, **Fire and Ice**, and **A Journey Back in Time** activities, and Chapter 3 activities for maps of hazard potential and for safety tips.

Volcanic Gases

Water vapor, carbon dioxide and sulfur gases are the principal volcanic gases present during eruptive activity. These gases mix readily with the atmosphere and are not a health concern for visitors and communities near Mount Rainier.

Procedure

Learning about Volcano Processes

1. Discuss with students their present knowledge about volcanic processes.
2. Distribute the "***Understanding Volcano Hazards—Questions***" student page.
3. ***View the video in full or in segments.***
4. Instruct students to answer questions on the student page.
5. Initiate a discussion of the answers.

Extensions

- Students draw a picture of one or more of the hazards and label each process.
- Students research and write a report about each of the volcanic processes discussed in the video.

Volcanic Processes *is an excellent follow-up assessment activity to this video.*

Assessment

Use the video questions to assess students' current knowledge of Mount Rainier volcanic processes and hazards. You may wish to use the same questions at the end of your study of volcanoes as a postassessment activity.

References

Myers, B., Brantley, S.R., Stauffer, P.H., and Hendley J.W., II, 1997, What are volcano hazards? (revised July, 2004): U.S. Geological Survey Fact Sheet 002–97, 2 p.

Myers, B., and Driedger, C., 2008, Geologic hazards at volcanoes: U.S. Geological Survey General Information Product 64, poster.

Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

Student Page

Name _____

Understanding Volcanic Hazards—Questions

Instructions: *View the video and answer the questions.*

1. List several reasons why people choose to live near volcanoes in spite of potential dangers.

ASH FALLS

2. An erupting volcano throws rock debris tens of thousands of feet into the air. Which answer best describes how far fine, dust-size fragments, called volcanic ash, can travel? Circle your answer.

a. The slopes of the volcano.
b. Volcanic ash can travel up to one kilometer from the volcano.
c. Volcanic ash can be carried by winds around the Earth.

3. Describe at least three effects that ash falls can have on people and property.

4. Falling ash generally is not as life-threatening as some other volcanic hazards, but it can disrupt lives for long periods of time. Is this true or false?

Student Page

Name _____

Understanding Volcanic Hazards—Questions -continued

HOT ASHFLOWS (also called Pyroclastic Flows)

5. A hot ashflow: (circle all that are true)

a. Moves very slowly.
b. Moves at high speed down the slopes of a volcano.
c. Is an avalanche of hot ash, rock and gas.
d. Is rarely dangerous to people at a distance from the volcano.
e. Burns, asphyxiates, and flattens everything in its path.

6. What volcano in Washington displayed the powerful force of an ashflow during the 1980s?

7. A human can outrun an ashflow. Is this true or false?

MUDFLOWS (also called lahars—an Indonesian word for volcanic mudflow)

8. A volcanic mudflow: (circle all that are true)

a. Is a fast-moving flood (mixture) of water, mud, sand, rocks, and trees.
b. Behaves like flowing wet concrete.
c. Travels not more than 5 kilometers (3 miles) from the volcano.
d. Destroys and buries all that lies in its path.

Student Page

Name _____

Understanding Volcanic Hazards—Questions -continued

9. How could villagers in Colombia have protected themselves from the deadly mudflows at volcano Nevado del Ruiz?

VOLCANIC LANDSLIDES

10. Which of the factors below makes many volcanoes susceptible to rock fall and landslides? (Circle the best answer below.)

a. Volcanoes are made of many layers of lava and volcanic ash.
b. Some rocks are weak and unstable.
c. Volcanic slopes are steep.
d. Rising magma can force collapse of part of the volcano
f. All of the above

11. What processes caused the northern slope of Mount St. Helens to bulge outward and collapse in 1980?

12. Where did the missing part (top and northern slope) of Mount St. Helens end up?

Student Page

Name _____

Understanding Volcanic Hazards—Questions -continued

VOLCANIC TSUNAMI

13. Describe what causes a tsunami.

14. Describe the effects of a tsunami.

15. What actions can people take to protect themselves in the event of a tsunami?

LAVA FLOWS

16. Describe a lava flow and how it can affect people and property.

17. Most lava flows move slowly enough for people to outrun. What actions can people take to protect themselves when they are near a lava flow?

Student Page

Name _____

Understanding Volcanic Hazards—Questions -continued

VOLCANIC GASES

18. Every active volcano releases gases. (True or False)

19. Water vapor (steam) is the most common gas released from an erupting volcano, followed by carbon dioxide and sulfur dioxide. (True or False)

20. Volcanic gases: (circle all that are true)

- **a.** Are released from cracks or vents in a volcano or from crater lakes.
- **b.** Are generally invisible and some are odorless.
- **c.** Generally become diluted before they reach populated areas and become only an irritation.
- **d.** In high concentrations, can suffocate animals and humans.
- **e.** Can corrode metal.
- **f.** All of the above are true.

CONCLUSION

21. Describe why it is important to understand the dangers associated with volcanoes.

Teacher Page

Understanding Volcanic Hazards—Answers

Instructions: *View the video and answer the questions.*

1. List several reasons why people choose to live near volcanoes in spite of these dangers.

ANSWER: ***Student responses could be any one of the following: Volcanoes are quiet most of the time, so people forget that they are capable of erupting. Volcanoes provide rich soils for crops. People are attracted to volcanoes because they are prominent features on the landscape and are symbolic of beauty, power and life.***

ASH FALLS

2. An erupting volcano throws rock debris tens of thousands of feet into the air. Which answer best describes how far fine, dust-size fragments, called volcanic ash, can travel? Circle your answer.

a. The slopes of the volcano.
b. Volcanic ash can travel up to one kilometer from the volcano.
c. Volcanic ash can be carried by winds around the Earth.

ANSWER: ***c***

3. Describe at least three effects that ash falls can have on people and property.

ANSWER: ***Possible answers could be any of the following: breathing may become difficult and vision affected; forests, orchards and field crops can be destroyed; pastures can be rendered useless for livestock; water may be unsuitable for drinking, communication and electrical systems can be damaged; buildings may be destroyed by the weight of ash; driving may become dangerous from the haze creating poor visibility; roads can be buried under ash; ash is destructive to aircraft.***

4. Falling ash generally is not as life-threatening as some other volcanic hazards, but it can disrupt our lives for long periods of time. Is this true or false?

ANSWER: ***True***

Teacher Page

Understanding Volcanic Hazards—Answers -continued

HOT ASH FLOWS (also called Pyroclastic Flows)

5. A hot ashflow: (circle all that are true)

a. Moves very slowly.
b. Moves at high speed down the slopes of a volcano.
c. Is an avalanche of hot ash, rock and gas.
d. Is rarely dangerous to people at a distance from the volcano.
e. Burns, asphyxiates, and flattens everything in its path.

ANSWER: ***b, c, d & e***

6. What volcano in Washington displayed the powerful force of an ashflow during the 1980s?

ANSWER: ***Mount St. Helens***

7. A human can outrun an ashflow. Is this true or false?

ANSWER: ***False***

MUDFLOWS (also called a lahar, an Indonesian word for volcanic mudflow)

8. A volcanic mudflow: (Circle all that are true)

a. Is a fast-moving flood (mixture) of water, mud, sand, rocks, and trees.
b. Behaves like flowing wet concrete.
c. Travels not more than 3 miles from the volcano.
d. Destroys and buries all that lies in its path

ANSWER: ***a, b, d***

9. How could villagers in Colombia have protected themselves from the deadly mudflows at volcano Nevado del Ruiz?

ANSWER: ***They could have headed for higher ground.***

Teacher Page

Understanding Volcanic Hazards—Answers -continued

VOLCANIC LANDSLIDES

10. Which of the factors below makes many volcanoes susceptible to rock fall and landslides? (Circle the best answer below).

a. Volcanoes are made of many layers of lava and volcanic ash.
b. Some rocks are weak and unstable.
c. Volcanic slopes are steep.
d. Rising magma can force collapse of part of the volcano
e. All of the above.

ANSWER: ***e***

11. What processes caused the northern slope of Mount St. Helens to bulge outward and collapse in 1980?

ANSWER: ***Molten rock (magma) forced its way into the volcano and the north flank was pushed outward; this eventually resulted in collapse.***

12. Where did the missing part (top and northern slope) of Mount St. Helens end up?

ANSWER: ***At the bottom of a river valley.***

VOLCANIC TSUNAMI

13. Describe what causes a tsunami.

ANSWER: ***They are caused by the displacement of water during volcanic eruptions, initiated by volcanic earthquakes, submarine landslides or entry of volcanic flows into a body of water.***

14. Describe the effects of a tsunami.

ANSWER: ***Buildings and other structures in the community can be destroyed. As tsunami waves retreat they sweep people and debris out to sea, As they come ashore they carry people and debris inland.***

Understanding Volcanic Hazards—Answers -continued

15. What actions can people take to protect themselves in the event of a tsunami?

ANSWER: ***People should head for higher ground and leave coastal areas when a tsunami approaches.***

LAVA FLOWS

16. Describe a lava flow and how it can affect people and property.

ANSWER: ***A flow of molten rock that pours rapidly or slowly from a volcanic vent. Everything that lava encounters is burned, buried or otherwise destroyed.***

17. Most lava flows move slowly enough for people to outrun. What actions can people take to protect themselves when they are near a lava flow?

ANSWER: ***Keep a safe distance from the leading edge of moving lava flows.***

VOLCANIC GASES

18. Every active volcano releases gases. (True or False)

ANSWER: ***True***

19. Water vapor (steam) is the most common gas released from an erupting volcano, followed by carbon dioxide and sulfur dioxide. (True or False)

ANSWER: ***True***

20. Volcanic gases: (circle all that are true)

- **a.** Are released from cracks or vents in a volcano or from crater lakes.
- **b.** Are generally invisible and some are odorless.
- **c.** Generally become diluted before they reach populated areas and become only an irritation.
- **d.** In high concentrations, can suffocate animals and humans.
- **e.** Can corrode metal.
- **f.** All of the above are true.

ANSWER: ***f***

Understanding Volcanic Hazards—Answers -continued

CONCLUSION

21. Describe why it is important to understand the dangers associated with volcanoes.

ANSWER: ***Sooner or later, people living near a volcano will experience the dangers of an erupting volcano. Studying past volcanic disasters can prevent future disasters and tragedies.***

Volcanic Processes

Grade Level: 3–6

Learner Objectives:

Students will:

- Recognize the scope of geologic processes that occur at Cascade volcanoes
- Identify volcanic processes seen in photographs
- Understand that, during an eruption, volcanic processes often occur simultaneously or sequentially.

Setting: Classroom

Timeframe: 40 minutes

Materials:

- Copies of *"Volcanic Processes"* student page
- Nine graphics illustrating *"Common Volcanic Processes at Cascade Volcanoes"* (computer projection, transparencies, or paper copies to students)
- Library or Internet access

USGS
science for a changing world

Living with a Volcano in Your Backyard–An Educator's Guide with Emphasis on Mount Rainier

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

Students learn about volcanic processes at Cascade volcanoes as they view the graphics provided, research processes further and write results on a student page. As an optional activity, students prepare a booklet or computer presentation about each process with an emphasis on process interaction. This activity is offered as an alternative to the **Understanding Volcanic Hazards** video that may be unavailable or inappropriate for your students.

Vocabulary: Blocks, bombs, crater, debris flow, earthquake, eruption, eruption cloud, explosive eruption, fractures, fumarole, hydrothermal alteration, lahar, landslide, lava, lava dome, lava flow, magma, pyroclastic flow, tephra, volcano, volcanic ash, volcanic gas

Skills: application, interpretation, inference

Benchmarks:

See benchmarks in Introduction.

Activity last modified: November 21, 2014

Teacher Background

Background information about volcanic processes can be found in the teacher pages that follow.

Procedure

Volcanic Processes

The term volcanic processes refers to eruptive and noneruptive activities that take place on volcanoes. Students viewing photos individually may get the faulty impression that volcanic events occur in isolation. During an eruption, volcanic processes often occur simultaneously or sequentially, as explained in the descriptions below. Keep in mind that one of the objectives for this activity is this recognition of volcanic processes occuring in a sequence rather than in isolation.

1. Display the individual graphics, one through nine and for end review, repeat graphic one. Convey the written information to students by paraphrasing, reading, or providing the pages to the students. Alternatively, make copies of each graphic and distribute it to groups, or at stations around the classroom.

2. Distribute the "***Volcano Processes***" student page. Students should work in small groups to research processes further and write definitions and descriptions beside each graphic.

3. Discuss the information learned in student research. Emphasize the wide range of geologic processes that occur on Cascade volcanoes; identification of volcanic processes seen in photographs; and knowledge that, during an eruption, volcanic processes often occur simultaneously or sequentially.

Adaptations

- Older students can perform an Internet or library search for information about these processes. Students then create a volcano book, collage, or computer presentation with text, definitions, and additional graphics.

Extensions

- Students conduct Internet research to discover where these processes are observed at volcanic eruptions today. Instruct students to write a report about the progression of volcanic processes noted by observers over the course of an eruption. For a list of eruptions in progress, visit the Web site for Smithsonian Global Volcanism. The address is found at **Internet Resources**.

Assessment

Use the "***Volcanic Processes***" student page as a learning tool, and your discussion as an assessment of students' knowledge about important volcanic processes. After completing this activity, students should be able to recognize the scope of geologic processes that occur on Cascade volcanoes; identify volcanic processes seen in photographs; and understand that during an eruption, volcanic processes often occur simultaneously or sequentally.

References

Harris, S.L., 2005, Fire mountains of the west—the Cascade and Mono Lake volcanoes: Missoula, Mont., Mountain Press Publishing Company, 454 p.

Kennedi, C.A., Brantley, S.R., Hendley J.W., II, and Stauffer, P.H., 2000, Volcanic ash fall—a "hard rain" of abrasive particles: U.S. Geological Survey Fact Sheet 027–00 (revised April 2002), 2 p.

Myers, B., Brantley, S.R., Stauffer, P.H., and Hendley J.W., II, 1998, What are volcano hazards? (revised July 2004): U.S. Geological Survey Fact Sheet 002–97, 2 p.

Myers, B., and Driedger, C., 2008, Geologic hazards at volcanoes: U.S. Geological Survey General Information Product 64, poster.

Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

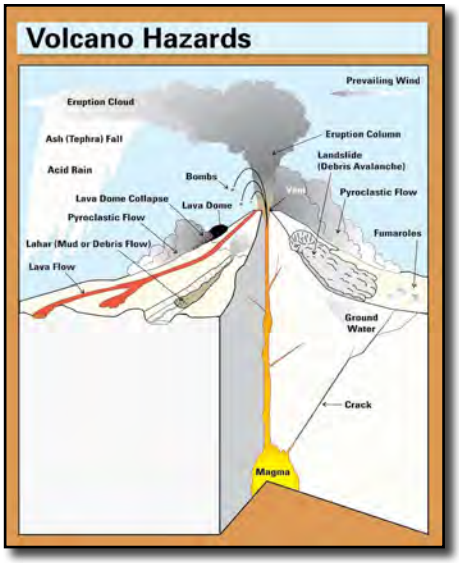
Photo Credits

Graphic 1. USGS, after Myers, B., and Driedger C., 2008, Geologic Hazards at Volcanoes, General Information Product 64, poster.
Graphic 2. Photo by Jack Whitnall, May 18, 1980.
Graphic 3. Photo by Christina Heliker, USGS, January 26, 1988.
Graphic 4. Photo by Hugo Moreno, Servecío National de Geologiá y Mineriá, Chile.
Graphic 5. Photo by Willie Scott, USGS, 1995.
Graphic 6. Photo by Richard Janda, USGS,1985.
Graphic 7. Photo by Toni Venzin.
Graphic 8. Photo by Kevin Scott, USGS, March 25, 1999.
Graphic 9. Photo by Steve Brantley, USGS.

Teacher Page

Common Volcanic Processes at Cascade Volcanoes

Graphic 1—Overview



Common sequences of events at stratovolcanoes:

Before an ***eruption*** begins, rising ***magma*** opens cracks ***(fractures)*** in rocks beneath the ***volcano***, commonly causing ***earthquakes***, deformation of the land surface and gas release. During the onset of an ***explosive eruption***, ***volcanic gases*** in the magma expand and break magma into tiny pieces called ***tephra***. After many of the gases have dispersed in the atmosphere, a more fluid ***lava*** pool within the crater rises and flows over the ***crater*** lip as a ***lava flow***. The ensuing lava flows sometimes break apart on steep volcanic terrain as avalanches of hot rock and gases. These ***pyroclastic flows*** (sometimes called hot ash flows), melt snow and ice, providing the water for ***debris flows*** and ***lahars*** (large debris flows). Pyroclastic flows also originate from the collapse of eruption columns-the dark column of ash, steam, and other gases that rises above an explosively erupting volcano. Rocks that have been weakened by hot acidic groundwater ***(hydrothermal alteration)*** become more susceptible to collapse as a ***landslide***. Volcanoes can also erupt nonexplosively, without tephra. Where lava is too viscous to flow, it forms a dome-shaped feature commonly called a ***lava dome***.

Graphic 2—Tephra—Volcanic ash fall from Mount St. Helens darkens Yakima, Washington, at noon on May 18, 1980

Explosive eruptions blast fragments of rock high into the air. Large fragments fall to the ground near to the volcano, while small fragments create large ***eruption clouds*** capable of traveling thousands of kilometers (miles) from the volcano. ***Volcanic ash*** clouds are usually nontoxic but have the capability to disrupt peoples' lives for long periods. Heavy ash fall can collapse buildings, and even minor ash fall reduces visibility and can damage crops, electronics, and machinery. Aircraft that fly into a volcanic ash cloud are at great risk of engine failure.

Teacher Page

Common Volcanic Processes at Cascade Volcanoes-continued

Graphic 3—Tephra—Volcanic blocks and bombs at Kilauea Volcano, Hawaii

A volcanic ***block*** is a solid rock fragment greater than 64 millimeters (2.5 inches) in diameter that was ejected from a volcano during an explosive eruption. Blocks commonly consist of solidified pieces of old lava flows that were part of a volcano's cone.

By comparison, semi-solid rock can be aerodynamically shaped into a variety of forms called volcanic ***bombs***.

Graphic 4—Lava flow on Villarica Volcano in Chile

Lava is molten rock that pours or oozes onto the planet surface. Lava flows cool and harden faster on the outside (within minutes), than on the inside, where cooling continues for days to years.

Graphic 5—Pyroclastic flow on Montserrat Volcano in the Caribbean

Pyroclastic flows are avalanches of hot lava fragments and volcanic gases formed by the collapse of ash clouds and lava domes and flows. These flows rush down the mountain at speeds up to a few hundred kilometers (miles) per hour. They destroy everything in their path by impact, incineration, asphyxiation, or burial. Nothing will survive in the path of a pyroclastic flow.

Teacher Page

Common Volcanic Processes at Cascade Volcanoes-continued

Graphic 6—Lahar at Armero, Colombia

The word lahar is an Indonesian term that describes a mixture of rock, mud, and water that rushes down the slopes of a volcano and its river valleys for many miles away from the volcano and at speeds of up to 60 kilometers per hour (40 miles per hour). Lahars and their scaled-down versions, known as debris flows, once witnessed, are never forgotten. The ground shakes and rumbles in a way similar to that of an approaching train. Dust plumes rise into the air above the flow front and small pebbles splash skyward. These flows look and behave like a river of wet flowing concrete and are tan to gray in color.

During volcanic eruptions on snow or glacier-clad volcanoes, hot rocks melt the snow and ice to produce large amounts of meltwater that can entrain loose rock and make a lahar. The enormous snow and ice packs on the slopes of Cascade volcanoes are a particular threat. Approximately 4.4 cubic kilometers (1cubic mile) of ice and perennial snow (snow that remains from year to year) cover the slopes of Mount Rainier. That is as much as on all the other Cascade volcanoes combined! Catastrophic landslides also can trigger lahars.

The above photo of Armero, Colombia, illustrates the devastation caused by lahars triggered by the November 13, 1985, eruption of the snow and ice-capped Nevado del Ruiz volcano in Colombia. This lahar traveled at an average velocity of more than 30 kilometers (20 miles) per hour, so the people in the nearby city of Armero had more than two hours to climb to the safety of higher ground on nearby valley walls. However, they had not been advised on evacuation procedures or warned of the lahar's approach. More than 20,000 people perished as they slept, while lahars swept through and buried much of the city.

Teacher Page

Common Volcanic Processes at Cascade Volcanoes-continued

Graphic 7—Debris flow in Tren, Canton of Grissons, Switzerland

At Mount Rainier, small flows of water, mud and rock debris that stay within park boundaries are know locally as debris flows. Flows that travel beyond park boundaries are classified as lahars. Debris flows commonly occur during noneruptive times, especially during periods of intense rainfall or snowmelt, as opposed to lahars, which are generally caused by eruption or landslide activity.

Graphic 8—Landslide at Casita Volcano in Nicaragua

A landslide, or debris avalanche, is a rapid downhill movement of rock and overlying material. Volcano landslides can be small movements of loose debris on the surface of a volcano or massive collapses of the entire summit or sides of a volcano. Steep-sided volcanoes can be especially vulnerable to landslides, since they are built partially of layers of loose volcanic rock fragments, which break free and move downhill. Landslides on volcano slopes are triggered when eruptions, heavy rainfall, or large earthquakes occur.

Graphic 9—Hydrothermal Alteration Weakens Lava Rock at Mount Rainier, Washington

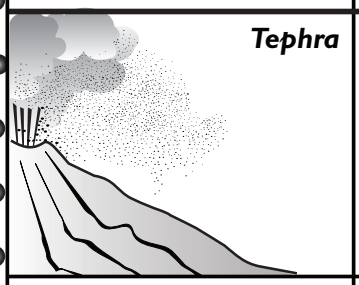
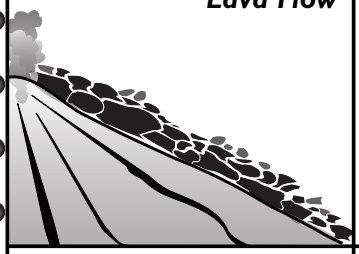
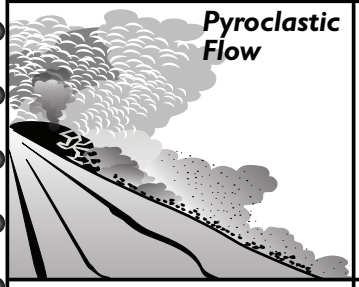
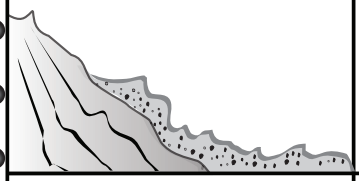
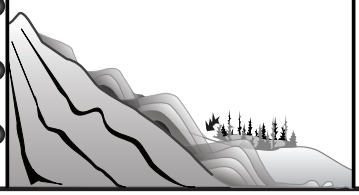
Some rocks on volcanoes have been altered to soft, slippery clay minerals because of exposure to circulating hot, acidic ground water, a process called hydrothermal alteration. Entire portions of a volcano can be left susceptible to collapse through landslides. Altered rock is often visible in the vicinity of ***fumaroles,*** or steam vents on the volcano's surface.

Student Page

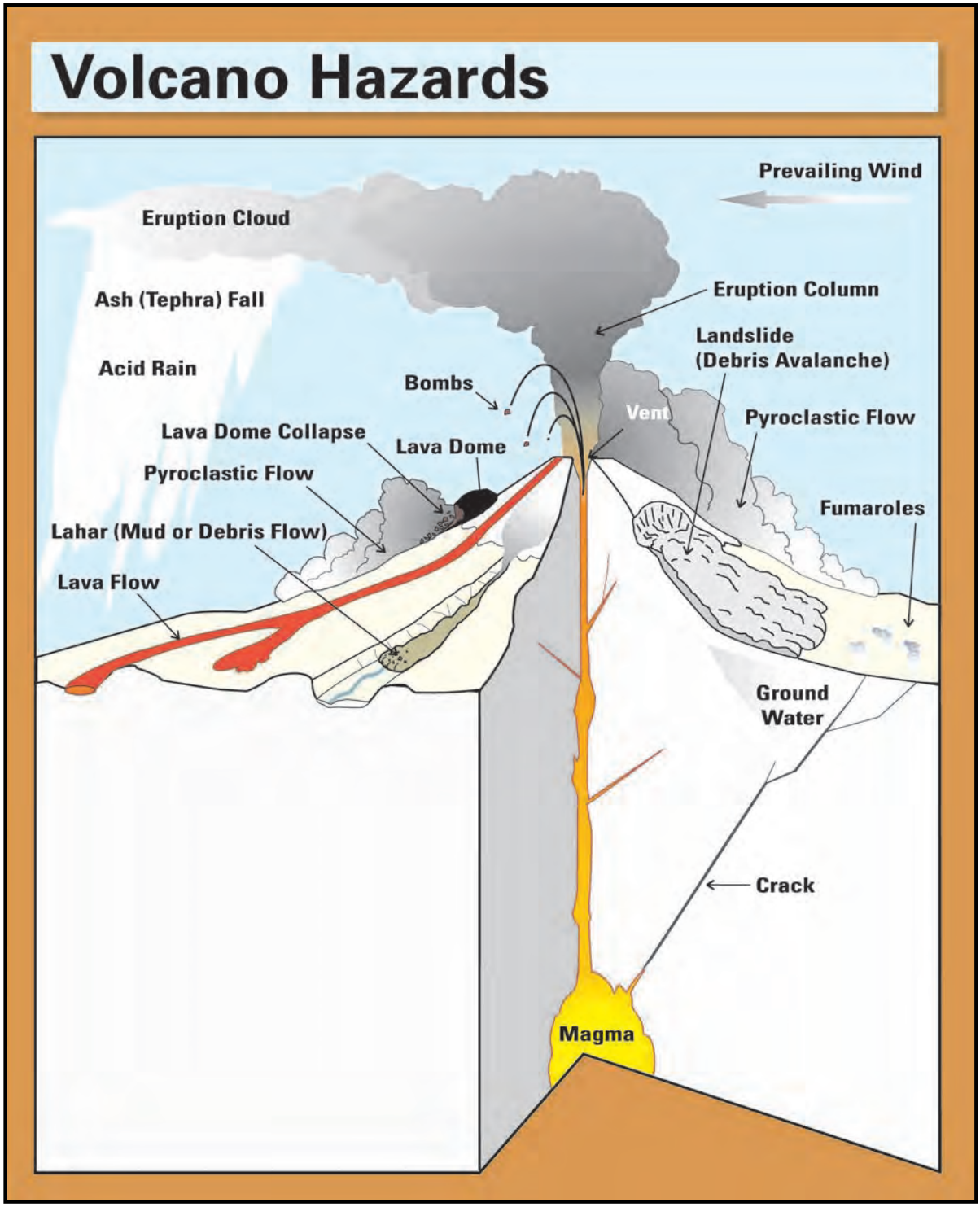
Name _____

Volcanic Processes

Instructions: *Learn more about each of the volcanic processes listed below. Write definitions and descriptions beside each graphic.*

Volcanic Processes	Definitions and Descriptions
Tephra 	
Lava Flow 	
Pyroclastic Flow 	
Lahar or debris flow 	
Landslide 	

Volcanic Processes—Graphic 1



Volcanic Processes—Graphic 2—Tephra—Volcanic ash fall from Mount St. Helens darkens Yakima, Washington, at noon on May 18, 1980

Photo by Jack Whitnall

Graphic Page

Volcanic Processes—Graphic 3—Tephra—Volcanic blocks and bombs at Kilauea Volcano, Hawaii

Photo by Christina Heliker, USGS

Volcanic Processes—Graphic 4—Lava flow on Villarica Volcano in Chile

Photo by Hugo Moreno, Servecio National de Geologia y Mineria, Chile

Volcanic Processes—Graphic 5—Pyroclastic flow on Montserrat Volcano in the Caribbean

Photo by Willie Scott, USGS

Volcanic Processes—Graphic 6—Lahar at Armero, Colombia

Photo by Richard Janda in 1985, USGS

Volcanic Processes—Graphic 7—Debris flow in Tren, Canton of Grissons, Switzerland

Photo by Toni Venzin

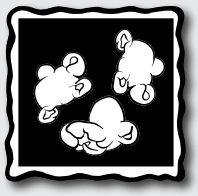
Volcanic Processes—Graphic 8—Landslide at Casita Volcano in Nicaragua

Photo by Kevin Scott, USGS

Volcanic Processes—Graphic 9—Hydrothermal Alteration Weakens Lava Rock at Mount Rainier, Washington

Photo by Steve Brantley, USGS

Tephra Popcorn



Grade Level: 6–9

Learner Objectives:

Students will:

- Understand meaning of the term "tephra"
- Observe that volcanic ash consists of rock fragments and not a burned substance
- Recognize that expanding gas bubbles can inflate and fragment magma explosively
- Understand that the volume of erupted bubble-filled tephra is greater than the original volume of magma because of the expansion of gas bubbles
- Recognize volcanic ash (grain size equal to or less than 2 millimeters, or 1/10 inch) as a common form of tephra
- Identify energy transformations that occur in popping corn and a tephra eruption
- Volcanic gases are an important driving force of volcanic eruptions

Setting: Classroom

USGS science for a changing world

Living with a Volcano in Your Backyard-An Educator's Guide with Emphasis on Mount Rainier

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

Students measure the volume and mass of popcorn before and after popping in an exploration of how expanding gas bubbles inflate and fragment magma during a volcanic eruption. They study the physical characteristics of tephra using samples or photographs.

Timeframe: 50 minutes

Comparing Tephra to Popcorn—30 minutes

Analyzing the Characteristics of Volcanic Ash—20 minutes

Materials:

Comparing Tephra to Popcorn

- Graphic *"Images of Popcorn—Up Close"*
- Graphic *"Soda Bottle Volcano"*
- Graphic *"Tephra Types"*
- Student pages *"Tephra Popcorn"*

One for each student group:

- Hot air popper or stove and pot for corn popping
- 2 1/2 cups unpopped kernels
- Graduated cylinder, beaker, or metric kitchen measuring cups (one liter or larger)
- Empty containers for popped kernels
- Scale or balance

continued.....

Activity last modified: November 21, 2014

Analyzing the Characteristics of Volcanic Ash

- Graphic *"Samples Collected by a Geologist"*
- Copies of student page *"Samples Collected by a Geologist"*

Vocabulary: Blocks, bread-crust bombs, conduit, eruption, eruption cloud, explosion, lava, lithic, magma, magma chamber, obsidian, Pele's Hair, pumice, scoria, spindle-shaped bombs, tephra, vent, vesicles, volcano, volcanic ash, volcanic gas, viscous

Skills: Comparison, describing, measurement, observation, prediction

Benchmarks:

See benchmarks in Introduction.

Teacher Background

Tephra—General term for fragments blasted into the air by a volcano

Tephra is a general term used for fragments of volcanic rock, regardless of size, that a ***volcano*** blasts into the air by an ***explosion*** or ***eruption***. Tephra is not a product of combustion like ash produced by burning wood or paper. Some tephra originates as local rock while other tephra consists of fresh ***magma*** that retains gases and is bubbly in appearance. The heat and expansion of ***volcanic gas*** can force tephra and steam to rise to high altitudes as part of a billowing ***eruption cloud*** that resembles a giant puff of smoke.

Tephra ranges in size from enormous blocks the size of small houses to ***volcanic ash*** (particles < 2 mm (1/10 inch) in diameter). Tephra comes in a variety of shapes and textures, such as masses of solid ***blocks,*** bubbly ***pumice***, ***bread-crust*** and ***spindle-shaped bombs***, fine dust, and at some volcanoes, of glass fibers called ***Pele's Hair***.

Gases are an important driving force of volcanic eruptions

The expansion and release of volcanic gases (principally water vapor) provide the energy for eruptions. Gas bubbles expand dramatically within the magma as they rise from a deep, high-pressure to a shallow, low-pressure environment. As they rise up the ***conduit***, the gas expands to the breaking point and explodes, causing the magma to break into fragments. Evidence of gas bubbles in magma is preserved as holes ***(vesicles)*** in tephra and lava rocks. See the **Soda Bottle Volcano** activity for further detail.

The expansion of magma during a volcanic eruption

During the journey from the ***magma chamber*** to the ***vent*** of a volcano, gas bubbles expand to a thousand times or so of their original size, which increases the volume of magma by three to four times. An inexact analogy can be made with the effect that baker's yeast has as it feeds on bread dough. The yeast produces carbon dioxide bubbles that expand and force the dough to rise in the bowl. The result is a highly porous loaf of bread.

By these volcanic processes described above, gases are added to the atmosphere and oceans. The activity below, "***Comparing Tephra to Popcorn***," addresses the evolution of bubble-filled tephra.

Sidebar 1

The Texture of Tephra Particles Provides Clues to Their Origin

After a volcano erupts tephra into the air, large particles fall back onto the volcano's slopes, while finer particles are carried away from the volcano by the wind. The appearance of tephra tells us a lot about its origin and cooling history. Find a comprehensive list of tephra appearances on the **Internet Resources Page**.

Bubble-filled (Vesicular) Tephra and Pumice

Pumice is similar to the liquid foam produced during the opening of a bottle of pressurized soda. The gases can remain entrapped or can escape and leave behind foam that solidifies within a few seconds, locking in gas bubbles. We call these bubbly, light-colored rocks pumice. ***Scoria*** rock is bubbly, though usually darker and heavier than pumice.

Tephra with no Bubbles—(Lithic Tephra)

Some tephra contains few or no bubbles, either because it originated in gas-poor magma, or because the gases already escaped. Other bubble-poor tephra, called ***lithic*** tephra, consists of rock from the vent walls that was blasted into small pieces by eruptive forces.

Volcanic Glass

Some ***viscous lavas*** do not allow growth of minerals, and instead form glass. ***Obsidian*** is one example of volcanic glass.

Mineral-Rich Tephra

Magma that cools slowly underground (days to centuries) can grow large minerals that give pumice and scoria a speckled appearance.

Bread-Crust Bombs

Fragments cool faster on the outside and more slowly inside. When the interior vesicles expand, the surface cracks. The result is a rock with a crusty surface like baked bread.

Tephra with a Streamlined Appearance such as Spindle Bombs

Molten lava is twisted and smoothed as it falls through the air to the volcano slopes below.

Sidebar 2 Tephra as a Hazard

Tephra can be a hazard, a nuisance, or a harmless substance, depending on its size and distribution. While large blocks of tephra can crush structures, it usually falls back to the ground within 1.2 kilometers (2 miles) of the crater where human populations are generally sparse. Volcanic ash is fine-grained and its movement is influenced by wind direction and speed. Volcanic ash can disrupt daily life for people hundreds of miles from a volcano for long periods of time.

Envision a cloud of fine particles that covers the sky over a town and deposits a layer of dust everywhere. Fine particles of volcanic ash can be easily breathed into lungs and cause respiratory problems for people and animals, in addition to irritating eyes and skin. The ash itself is not toxic, but high amounts of fluorine and chlorine on ash surfaces from a few volcanoes in the world have caused livestock deaths and contaminated human water supplies. Volcanic ashfall can strip leaves from crops and trees and disrupt pollination of flowers.

Volcanic ash can severely impact transportation systems. Ash reduces driver visibility. It can disrupt vehicle operation and impede traffic flow. Volcanic ash clouds can pose a serious hazard to aviation. Engines of jet aircraft have failed after flying through clouds of ash. Roads, highways, and airport runways can be treacherous or impassable because ash is slippery. Wind and vehicle movement often resuspends ash for months after an eruption. Billowing ash can reduce driver and pilot visibility to near zero.

Ash can collapse building roofs when they are burdened by 10 centimeters (approximately 4 inches) or more of wet ash. When people use high volumes of water, they can dramatically reduce the community's water supply. Volcanic ash clogs drains; it damages sewer systems, which can require expensive repair. Use **Internet Resources** as a guide to current information about how to plan and respond before, during, and after an ashfall.

Teacher Tips

Use of the term "Mass and Weight on Earth"

Students often have difficulty understanding the difference between mass and weight because in everyday use, people use weight as a synonym for mass. You might want to remind students that we define mass as the amount of matter in an object. The weight of an object is defined as the force of gravity upon that object, and is calculated as the mass times the acceleration of gravity, w = mg. The difference between mass and weight would become more apparent if students spent time on multiple planets where gravitation attractions are different. This activity uses "mass." For younger students, teachers can substitute "weight on earth" for "mass" if it helps students conduct the activity with greater understanding.

Teacher Tips

Optionally, conduct the Soda Bottle Volcano activity in Chapter 1 prior to this activity.

Procedure

What to do Before Class Begins:

Comparing Tephra to Popcorn

- A few days before conducting this activity, ask students to bring in hot air poppers from home or arrange to use local stove facilities where kernels can be popped in an ungreased pot.
- Assemble graphics "***Soda Bottle Volcano***," "***Types of Tephra***" and "***Images of Popcorn—Up Close***."
- If using real samples, assemble one each of fireplace ash, volcanic ash, and small stones for each group.
- If using real samples, set up the microscope and (or) hand lens for students.

Comparing Tephra to Popcorn

For this activity you and (or) the students will pop popcorn kernels in an air popper or in an ungreased pot on the stove. Students examine changes in the volume and mass of unpopped and popped kernels and hypothesize how these results apply to actual tephra deposits. Look for evidence of gas bubbles using microscopes or microscope images of popcorn and relate this to characteristics of real tephra. Use this activity in small student groups or as a teacher demonstration.

1. Use the graphic "***Soda Bottle Volcano***" to review the role of gases in production of a volcanic eruption. See information in the teacher background.

2. Define the word tephra and show the graphic "***Tephra Types***" to provide examples of a variety of tephra types. Emphasize that tephra can be big or small and can greatly vary in texture.

3. Provide each student with a "***Tephra Popcorn***" student page.

4. Divide the class into groups of 4 or 5 students.

5. Give each group a hot air popper, container for popped kernels, graduated cylinder, metric measuring cup or beaker, 100 milliliters of unpopped kernels.

6. Point out the location of the scale or balance in the classroom, and note whether your scales allow students to "zero" automatically.

7. Instruct students to follow directions on their student pages. Students will develop a method to obtain the percent change in mass and the expansion factor for volume.

$$\% \text{ Change in Mass} = \frac{\text{Mass of popped corn} - \text{Mass of unpopped corn}}{\text{Mass of unpopped corn}} \times 100$$

Expansion factor = (Final volume/Initial volume)

8. After students conduct the experiment, lead a class discussion. Ask students what they observed in their experiments. Ask students why the volume of popcorn increased while the mass might have decreased. Ask what factors might lead to a decrease of mass (as with magma, loss of water from the popcorn by heating will cause some decrease in mass). Discuss how expanding gases provide the energy for an eruption. Note that volcanic gases disperse in Earth's atmosphere. Ask how the popcorn expansion is similar to, or different from, processes at an actual volcano. The volume of actual erupted tephra is commonly 3 to 4 times the volume of the original magma. ***The popcorn generally increases to 10 to 20 times or more of its original volume.*** As you discuss the popcorn images, project the graphics "***Images of Popcorn—Up Close***" and "***Types of Tephra***" (optional).

Instruct students to list potential sources of error such as inaccurate measurements of popped and unpopped corn and some unpopped kernels.

9. Finish your discussion with a dialogue about energy transformation. Students should comprehend that the unpopped kernel gains thermal energy during heating, which changes water to steam. Steam expands and increases pressure in the kernel until the kernel pops, and the expanding steam converts thermal energy to kinetic energy.

Analyzing the Characteristics of Volcanic Ash

Discover the difference between volcanic ash and fireplace ash by analyzing the characteristics of several samples. This is done most effectively when actual samples are used.

1. Give each student "***Samples Collected by a Geologist***" student page.

2. Divide the class into 6 to 8 groups.

3. Display the graphic "***Samples Collected by a Geologist***" or distribute samples of volcanic ash, river sediment, and fireplace ash to each group.

4. Without divulging the sample origins, direct students to answer questions on their student pages and identify the volcanic ash sample.

5. Lead a class discussion. Ask the class how they reached their conclusions.

Adaptations

- ***The Foil-Wrapped Popcorn Experiment***

  Use foil pan-wrapped popcorn (available at most grocery stores) to demonstrate how volume changes when kernels pop. Hold the popcorn over a stove burner to pop the kernels. Point out how kernels pop and release steam. Discuss how this is similar to expulsion of gases in a volcanic eruption.

- ***Analyzing the Characteristics of Volcanic Ash***

  As an alternative to providing all the samples, ask students to collect ash from a fireplace at home, and sediment from a streambed. Instruct students to devise classification categories for the samples or photos.

Extensions

- ***Expansion of Magma***

  Direct students to use library and Internet resources to collect additional estimates of tephra volume for observed volcanic deposits. Some tephra volumes they can use are as follows: for a 2,200 year old tephra fall at Mount Rainier the volume was 0.2 cubic kilometers; for the May 18, 1980 Mount St. Helens the volume was 1 cubic kilometer; 1883 Krakatau tephra fall deposit has a volume of 10 cubic kilometers; the 1812 Tambora deposit had a volume of 100 cubic kilometers. Students divide the volume of the deposit by four to obtain the volume of the preeruptive magma. Students can create innovative ways to depict this expansion graphically, on paper or with use of a computer-based graphics program. Another follow-up activity is for students to depict the relative sizes of eruptions graphically.

- ***Pumice Demonstration***

  Demonstrate to students that pumice contains holes and ask students how the holes formed. Ask students to predict what will happen when the samples are placed into a water-filled bucket. When the samples are placed into the bucket, most pumice floats. Ask students to hypothesize about why pumice floats. Encourage discussion about how pumice floats because the air-filled holes are isolated from one another. Some other bubbly rocks such as scoria are denser than water, or have holes that are interconnected so that water travels through these spaces and replaces the air, making them heavy and sinkable.

- ***Tephra Poster and (or) Computer Research***

  Assign students one of the following types of tephra to research using a computer: volcanic block, volcanic bomb, lapilli, pyroclastic rock deposits, volcanic ash, pumice, or scoria. Instruct students to find a definition for their type of tephra. Make a poster with the definition on it. Students can print images from the computer to use on their poster.

Assessment

For assessment, instruct students to show results of calculations and other answers on the student pages. Use the questions in "Analysis and Conclusions" (question 8) and "For Further Thought" (question 9) to assess students' understanding of the comparisons of popcorn and tephra. Students should demonstrate ability to follow instructions on the student page, record results and make calculations. Look for evidence that students understand the following concepts: tephra consists of rock fragments and not burned material; that expanding gas bubbles can inflate and fragment magma; that the volume of erupted tephra is greater that the original volume of magma because of the expansion of gas bubbles; that volcanic gases are an important driving force for volcanic eruptions. Assess application to real-world situations by assigning one or more of the extension activities.

References

Frances, P., Oppenheimer, C., 2004, Volcanoes: New York, N.Y., Oxford University Press, 521 p.

Kenedi, C.A., Brantley, S.R., Hendley, J.W., II, and Stauffer, P.H., 2000, Volcanic ash fall—A hard rain of abrasive particles: U.S. Geological Survey Fact Sheet 027–00, 2 p.

Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

Photo Credits

Images of Popcorn—Up close and Microscope images of popcorn. (U.S. Geological Survey photography by Robert Oscarson)

A. Tephra in eruption column at Mount St. Helens on May 18, 1980, Photo by Austin Post, USGS.

B. Hand sample of tephra erupted by Mount St. Helens on May 18, 1980, Photo by David Wieprecht, USGS.

C. Microphotograph of tephra erupted by Mount St. Helens on May 18, 1980, Scanning Electron Microscope (SEM) image provided by Andre M. Sarna-Wojcicki, USGS.

D. Block was ejected into the air by an explosion at Kilauea Volcano, Hawai`i on January 26, 1988, Photo by Christina Heliker, USGS.

E. Spindle-shaped bombs erupted by Mauna Kea Volcano, Hawai`i, on July 10, 1992, Photo by Jack Lockwood, USGS.

F. Gas-rich pumice fragments erupted by Mount Pinatubo, Philippines on June 15, 1991, Photo by Willie Scott, USGS.

G. Bread-crust bomb erupted from the lava dome at Mount St. Helens, Washington, in March, 1997, Photo by David Wieprecht, USGS.

Student Page

Name _____

Tephra Popcorn

Instructions: *Follow the procedure and answer the questions.*

1. ***Before Popping the Popcorn:*** Measure the mass of the container, then add 100 ml of popcorn kernels. Subtract the values to obtain mass of the kernels. Note that some scales allow you to "zero" automatically.

   Measured Volume of Popcorn:

   Initial Measured volume of unpopped kernels _____

2. ***Initial Measured Mass of Popcorn:***

Measured mass of unpopped kernels + container	_____	-	Measured mass of container	_____	=	Initial measured mass of unpopped kernels	_____

3. ***Your Prediction***:
   Write down your hypothesis about potential changes in mass and volume of the popcorn. Will they increase, decrease or remain the same? Then predict the mass and volume of the popped kernels.

   Predicted mass of popped kernels: _____

   Predicted volume of popped kernels: _____

Student Page

Name _____

Tephra Popcorn-continued

4. ***Pop the Popcorn:***
Plug in the air popper and turn it on. Set a container in front of the popper to catch the popped kernels. Add the unpopped kernels to the popper and watch the corn pop. Or, pop the popcorn in a pot on a stove **without the oil**.

5. ***After Popping the Popcorn:***
Measure the volume, then measure the mass of the popped kernels using a scale or balance. Obtain the volume using a measuring cup or graduated cylinder. Calculate the percent change in mass and the expansion factor in volume.

Final Measured Volume of Popped Popcorn:

Measured volume of popped kernels _____

Final Measured Mass of Popped Popcorn:

Measured mass of popped kernels + container _____ - Measured mass of container _____ = Measured mass of popped kernels _____

Calculations:

Change in Volume:

Change in volume = (Final volume/Initial volume) = _____

Change in Mass:

Change in mass = [(Final mass - Initial mass) / Initial mass] x 100 _____

Name _____

Tephra Popcorn-continued

6. ***Read the information about why popcorn pops.***

Why Does Popcorn Pop?

Inside the hard, outer shell of a kernel of corn is a starchy middle that contains water. As the kernel warms, the water within it changes into steam, which is the gaseous form of water. The steam expands. Eventually, the pressure inside the kernel exceeds the strength of the hard, outer shell and the kernel explodes with a pop!

7. ***Examine popcorn under a microscope below.***
These microscope images show popped kernels at different magnifications. Compare the size and shape of the popped kernels to unpopped kernels. List some characteristic features of the popped kernels.

Popcorn magnified 10 times, 70 times and 250 times

10 mm — 1.5 mm — 0.05 mm

Student Page

Name _____

Tephra Popcorn-continued

8. ***Analysis and Conclusions:*** *Answer the following questions.*

a. Explain the origin of holes in the popcorn.
(Review the box on **"Why Does Popcorn Pop?"**)

b. How did the mass and volume change during popping?

c. Imagine that the unpopped kernels represent magma inside a volcano and that the popped kernels are tephra erupted from a volcano. Do you think the preeruptive magma and erupted volumes of tephra are the same? Explain your answer.

d. Based on your observations of popcorn microscope images, what common features might be shared by both popcorn and tephra?

e. Explain the origin of holes in real tephra.

Student Page

Name _____

Tephra Popcorn-continued

9. ***For Further Thought:***

a. Describe how the expansion of gases in magma contributes to the energy of the volcanic eruption.

b. Describe the energy transformations that take place in popping kernels, and in erupting magma.

c. The volume expansion factor for erupted tephra is commonly three to four times the volume of the original magma. Is this magma expansion factor greater or less than that for popcorn? Explain how Earth's landscape would appear different if magma showed the same expansion factor as popcorn.

d. Popping kernels may lose mass due to water loss. The same can be said of rising magma. Explain what happens to excess water expelled from rising magma.

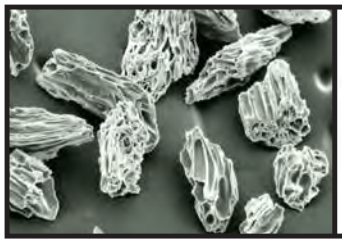
e. Describe how the presence of bubble-filled tephra on Earth's surface can affect the ecology of a landscape.

Student Page

Name _____

Samples Collected by a Geologist

Instructions: *These samples are similar to those a geologist would collect while working in the field. One sample is volcanic ash, one is ash from a fireplace, and the other is river sediment. Determine which sample is volcanic ash by answering the following questions.*

Sample A	Sample B	Sample C
		
0.6mm	100mm	200mm

1. Predict which sample you think is volcanic ash, fireplace ash, or river sediment.

Volcanic Ash _____ Fireplace Ash _____ River Sediment _____

2. List three adjectives that describe each sample.

Sample A	1		1		1	
Sample B	2		2		2	
Sample C	3		3		3	

3. Which sample contains bubbles? _____

4. Hypothesize about the origin of these holes.

5. Based on your descriptions of the three samples, which sample is volcanic ash? How did you reach this conclusion?

6. Which sample is most likely the fireplace ash? Describe how it differs from volcanic ash.

Teacher Page

Tephra Popcorn—Answers

Instructions: *Follow the procedure and answer the questions.*

1. ***Before Popping the Popcorn:*** Measure the mass of the container, then add 100 ml of popcorn kernels. Subtract the values to obtain mass of the kernels. Note that some scales allow you to "zero" automatically. *Note to teacher: Values listed are examples. Your values and answer will vary, and depend in part upon use of fresh or stale popcorn.*

   Measured Volume of Popcorn:

   Initial Measured volume of unpopped kernels ***100 ml***

2. ***Initial Measured Mass of Popcorn:***

   Measured mass of unpopped kernels + container ***133 grams*** − Measured mass of container ***41 grams*** = Initial measured mass of unpopped kernels ***92 grams***

3. ***Your Prediction***:
   Write down your hypothesis about potential changes in mass and volume of the popcorn. Will they increase, decrease or remain the same? Then predict the mass and volume of the popped kernels.

   ANSWER: Students might predict that the mass remains unchanged. A correct hypothesis is that the mass of the popcorn decreases because the popping process releases water, in a similar way that magma releases water during a volcanic eruption. Volume of popcorn increases.

   Predicted mass of popped kernels:

   ANSWER: <120 grams

   Predicted volume of popped kernels:

   ANSWER: 1,000 ml

Teacher Page

Tephra Popcorn—Answers -continued

4. ***Pop the Popcorn:***
Plug in the air popper and turn it on. Set a container in front of the popper to catch the popped kernels. Add the unpopped kernels to the popper and watch the corn pop. Or, pop the popcorn in a pot on a stove **without the oil**.

5. ***After Popping the Popcorn:***
Measure the volume, then measure the mass of the popped kernels using a scale or balance. Obtain the volume using a measuring cup or graduated cylinder. Calculate the percent change in mass and the expansion factor in volume.

Final Measured Volume of Popped Popcorn:

Measured volume of popped kernels *2300 ml*

Final Measured Mass of Popped Popcorn:

Measured mass of popped kernels + container *336 grams* - Measured mass of container *255 grams* = Measured mass of popped kernels *81 grams*

Calculations:

Change in Volume:

Change in volume = (Final volume/Initial volume) = *23 times initial volume*

Change in Mass:

Change in mass = [(Final mass - Initial mass) / Initial mass] x 100 *11%*

Teacher Page

Tephra Popcorn—Answers -continued

6. ***Read the information about why popcorn pops.***

Why Does Popcorn Pop?

Inside the hard, outer shell of a kernel of corn is a starchy middle that contains water. As the kernel warms, the water within it changes into steam, which is the gaseous form of water. The steam expands. Eventually, the pressure inside the kernel exceeds the strength of the hard, outer shell and the kernel explodes with a pop!

7. ***Examine popcorn under a microscope*** or the "***Images of Popcorn—Up Close***" below. These microscope images show popped kernels at different magnifications. Compare the size and shape of the popped kernels to unpopped kernels. List some characteristic features of the popped kernels.

ANSWER: On the 10 mm image, students might note that the popped kernel is rounded and appears pitted, foamy, puffed up, inflated, bubbly or frothy. These same descriptions also might be used in the 1.5 mm image, with the addition of the words fragile, delicate, shiny, or sparkling. The 0.05mm image shows a clear honeycomb structure within the popcorn. Students might use that term in addition to hollow, fragile, flimsy, or note that the popped kernel is of low density

Teacher Page

Tephra Popcorn—Answers -continued

Popcorn magnified 10 times, 70 times and 250 times

10 mm — 1.5 mm — 0.05 mm

8. ***Analysis and Conclusions:*** *Answer the following questions.*

a. Explain the origin of holes in the popcorn. (review the box on "**Why Does Popcorn Pop?**")

ANSWER: As the kernel is heated, water changes to steam, which is a gas. The steam expands. Eventually, pressure inside the kernel is so great that the gas escapes in a small explosion that "pops" the kernel.

b. How did the mass and volume change during popping?

ANSWER: Mass decreased and volume increased

c. Imagine that the unpopped kernels represent magma inside a volcano and that the popped kernels are tephra erupted from a volcano. Do you think the pre-eruptive magma and erupted volumes of tephra are the same? Explain your answer.

ANSWER: No, magma expands as it rises from the volcano. Water within the kernels expands when heated, expands the corn, and pops the outer shell.

d. Based on your observations of popcorn microscope images, what common features might be shared by both popcorn and tephra?

ANSWER: bubbles, gases, water contained within the magma

e. Explain the origin of holes in real tephra.

ANSWER: Bubbles enlarged as steam expanded

Teacher Page

Tephra Popcorn—Answers -continued

9. ***For Further Thought:***

a. Describe how the expansion of gases in magma contributes to the energy of the volcanic eruption.

ANSWER: During an eruption, gases (principally water vapor) within the magma expand and escape, and force magma to the surface. Gases are an important driving force of volcanic eruptions.

b. Describe the energy transformations that take place in popping kernels, and in erupting magma.

ANSWER: The unpopped kernel gains thermal energy during heating, and the water inside changes to steam. Pressure in the kernel increases until the kernel pops. Expanding steam converts thermal energy to kinetic energy. In a volcanic system, magma and the water molecules within it gain thermal energy while confined within the earth. The magma and water within it expand and the pressure within increases. During a volcanic eruption, magma rushes up the conduit and explodes into the atmosphere. Thermal energy converts to kinetic energy.

c. The volume expansion factor for erupted tephra is commonly three to four times the volume of the original magma. Is this magma expansion factor greater or less than that for popcorn? Explain how Earth's landscape would appear different if magma showed the same expansion factor as popcorn.

ANSWER: Popcorn generally increases to 10 to 30 times its original volume. If magma had the same expansion rate as popcorn, Earth's surface would be covered with thicker (and less dense) accumulations of tephra.

d. Popping kernels may lose mass due to water loss. The same can be said of rising magma. Explain what happens to excess water expelled from rising magma.

ANSWER: Steam from rising magma adds water vapor to Earth's atmosphere.

e. Describe how the presence of bubble-filled tephra on Earth's surface can affect the ecology of a landscape.

ANSWER: Bubble spaces allow for movement of air and groundwater. Tephra layers are unconsolidated and easily penetrated by plant roots and burrowing animals.

Teacher Page

Samples Collected by a Geologist

Instructions: *These samples are similar to those a geologist would collect while working in the field. One sample is volcanic ash, one is ash from a fireplace, and the other is river sediment. Determine which sample is volcanic ash by answering the following questions.*

Sample A | Sample B | Sample C

0.6mm — 100mm — 200mm

1. Predict which sample you think is volcanic ash, fireplace ash, or river sediment.

Volcanic Ash ***A*** Fireplace Ash ***B*** River Sediment ***C***

2. List three adjectives that describe each sample.

Sample A	1	***Bubbly***	1	***Fluted***	1	***Oblong***
Sample B	2	***Irregular***	2	***Flat***	2	***Fragile***
Sample C	3	***Smooth***	3	***Rounded***	3	***Solid***

3. Which sample contains bubbles?

ANSWER: Sample A

4. Hypothesize about the origin of these holes.

ANSWER: Expanding gases form bubbles.

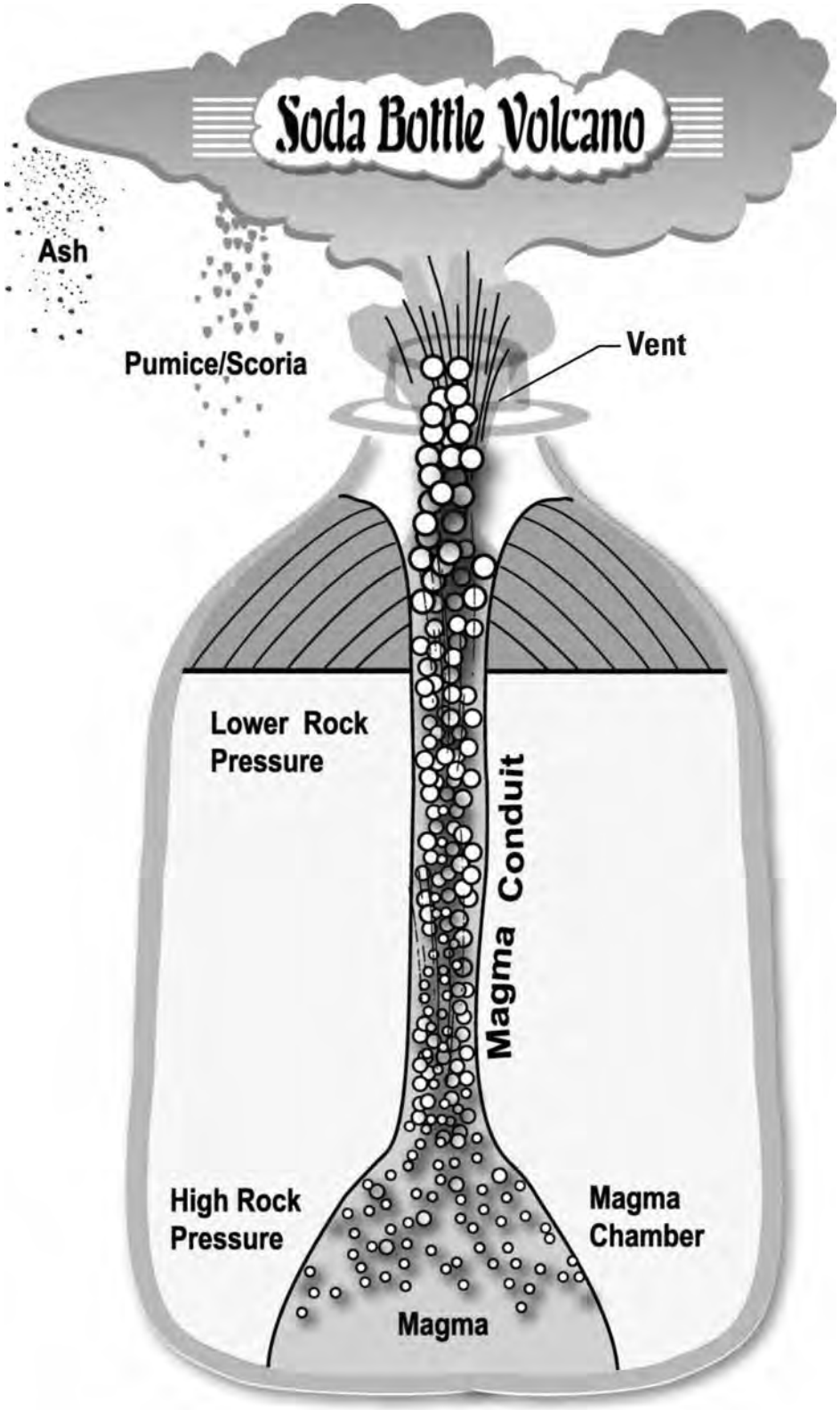
5. Based on your descriptions of the three samples, which sample is volcanic ash? How did you reach this conclusion?

ANSWER: A

6. Which sample is most likely the fireplace ash? Describe how it differs from volcanic ash.

ANSWER: Fireplace ash is not bubbly. It is fragile and platy, and the skeleton of wood fiber is visible in some pieces. Volcanic ash is bubbly, fluted, and often sharp-edged.

Graphic Page

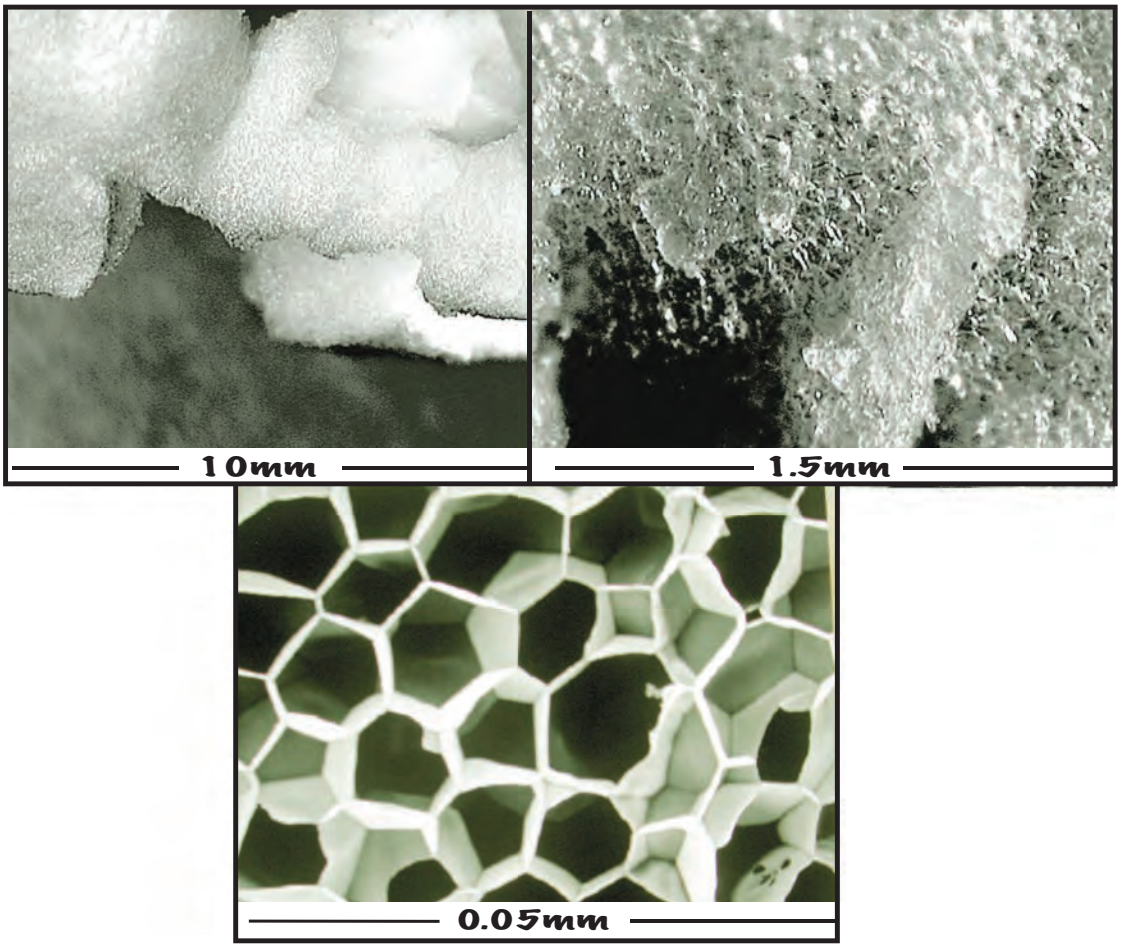


Graphic Page

Images of Popcorn—Up Close

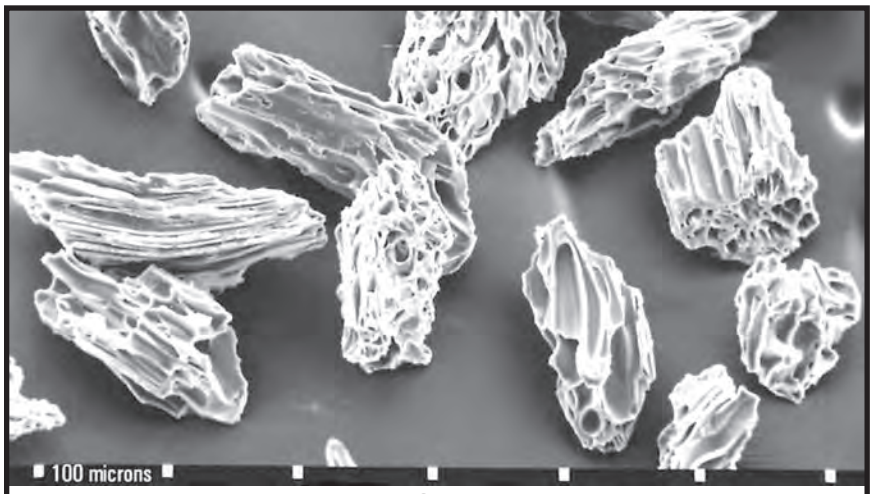
90mm 30mm

Microscope Images of Popcorn Kernels



Graphic Page

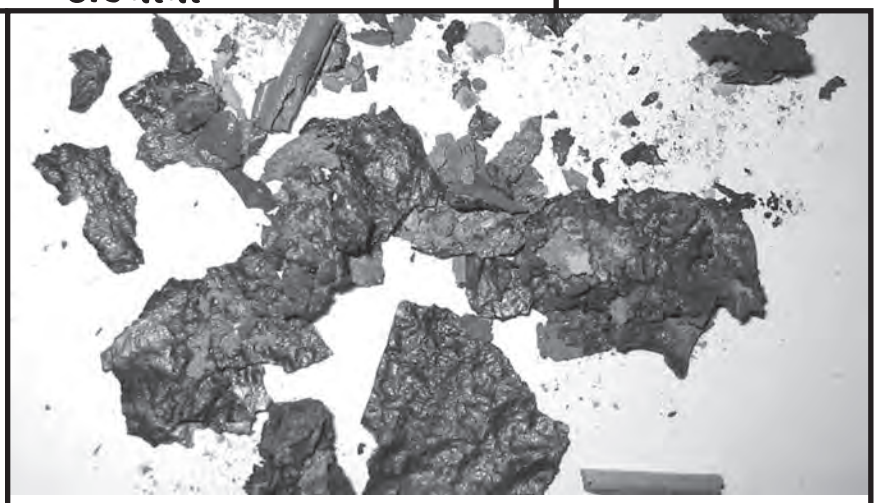
Samples Collected by a Geologist



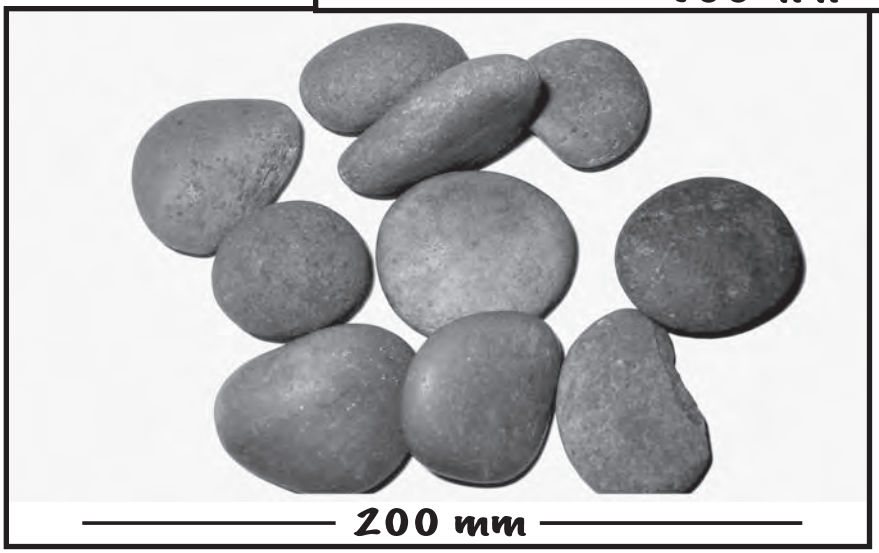
0.6mm

Sample A

Sample B



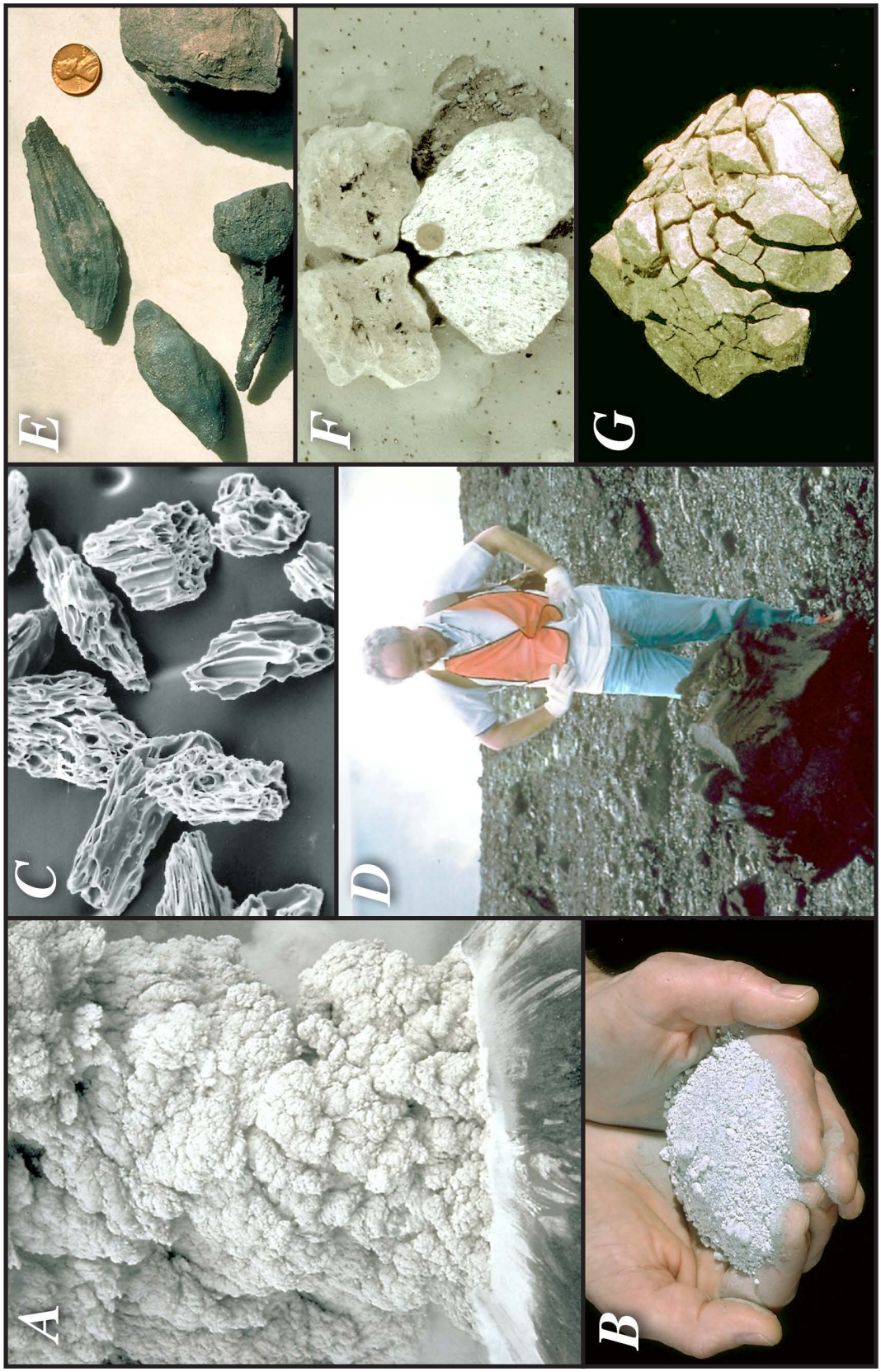
100 mm



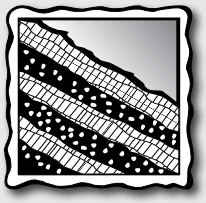
200 mm

Sample C

Tephra Types



Lava Building Blocks



Grade Level: 5–10

Learner Objectives:

Students will:

- Recognize the importance of lava flows in the construction of Mount Rainier.
- Recognize that at Mount Rainier lava flows are visible as thick ridges that radiate from the volcano and as thin ledges within the volcanic cone.
- Relate the general viscosity of lava flows to a type of volcano: shield, cinder cone, or stratovolcano.
- Make some generalized comparisons of lava flow behavior at Mount Rainier, Mount St. Helens, and Kilauea Volcano

Setting: Classroom

Timeframe: 40 minutes

Lava on the Run—40 minutes

Materials:

Lava on the Run

- *"Lava on the Run"* student page
- Graphic *"Three Types of Volcanic Cones"*

USGS science for a changing world

Living with a Volcano in Your Backyard–An Educator's Guide with Emphasis on Mount Rainier

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

Students investigate the influence of magma viscosity on the shape of a volcanic cone. Then, they explore the nature and motions of lava flows and learn about the importance of lava flows as the building blocks of Mount Rainier.

- Graphic *"Photographs of Lava Flows at Mount Rainier"*
- Graphic *"Volcanic Rocks of Modern Mount Rainier"*

For each student group:

- Newspaper
- Cardboard 1 x 1 meter (3 x 3 foot)
- One sample (small half-filled paper cup) each of three household products (e.g., chocolate syrup, corn syrup, shampoo, oatmeal, jelly, ketchup, rubber cement, and a tube of tooth paste)
- Specimens of lava rocks (optional)
- Paper cups
- Pencil
- Ruler
- Stopwatch
- Measuring spoon

Vocabulary: Andesite, basaltic andesite, composite volcano, cinder cone, cone, crater, dacite, eruption, eruption column, glacier, lahar, landslides, lava, lava dome, lava flow, magma, magma chamber, pyroclastic flow, rockfall, rock rubble, shield volcano, silica, stratovolcano, vent, viscosity, volcano, volcanic gases

Activity last modified: November 21, 2014

Skills: Predicting, data collecting, recording, measuring, graphing

Benchmarks:

See benchmarks in Introduction.

Teacher Background

Lava flows—Building blocks of Mount Rainier

Mount Rainier consists of hundreds of overlapping ***lava flow*** layers. Sandwiched between the lava flows are layers of loose rock rubble. These lava flows formed during hundreds of individual ***eruptions*** over the last 500,000 years. While the ***volcano*** has erupted frequently during this time, most ***lava*** was erupted between 500,000 to 420,000 years ago and 280,000 to 180,000 years ago. Today, chilled and hardened lava flows extend up to 22 kilometers (14 miles) from the volcano's summit. Future lava flows are more likely to be smaller and travel no more distant than 10 kilometers (6 miles) from the summit. The most recent lava flows at Mount Rainier were erupted around 1,100 to 2,200 years ago, and some of these young lava flows can be seen as raised rock ridges that bisect Emmons Glacier, and as raised areas beneath the ice. Mount Rainier lava flows consist of ***andesite*** and some low-silica ***dacites***, with some minor lava flows containing ***basaltic andesite***. For additional information about the building of Mount Rainier, visit **A Journey Back in Time**.

The volume of lava on Mount Rainier is approximately 150 cubic kilometers (36 cubic miles), an amount sufficient to fill Seattle's Safeco Stadium 100,000 times! Lava flows from each new eruption accumulate on top of older flows, building the ***cone*** taller and broader. Lava flows on the upper cone are relatively thin, commonly 30 meters (100 feet) or less in thickness. However, lava flows that pooled along the base of the cone formed layers hundreds of meters in thickness. When the eruption ends, many processes begin to destroy the cone, including ***glacier*** erosion, flowing water, ***rockfall***, and ***landslides***. A volcano will grow in size if the volume of lava erupted exceeds the amount lost to erosion.

How do lava flows form on steep-sided volcanoes?

Volcanic eruptions often begin with the release of steam and other ***volcanic gases*** that have been trapped within the ***magma*** during its long ascent from the ***magma chamber***. The real mountain building begins after most volcanic gases have escaped. Inside the ***vent***, molten lava rises and subsides repeatedly. The lava within the vent eventually rises high enough to spill over the ***crater*** rim as a glowing lava flow, often with temperatures that range between 900 to 1,100 degrees Celsius (1,650 to 2,000 degrees Farenheit). The outside of the lava flow cools and hardens into a rubbly crust within minutes, while the interior of the flow remains hot and gooey and continues to spill downhill. But, that is not the end of the story.

Pyroclastic flows, avalanches of hot rock and gas

Many lava flows that issue from steep-sided volcanoes break up into blocks and rubble that avalanche down valley accompanied by a billowing cloud of rock dust and steam. ***Pyroclastic flows*** can also form from the collapse of ***eruption columns***. The swift melting of snow and ice by pyroclastic flows has the potential to create ***lahars*** that travel great distances beyond the slope of the mountain and threaten nearby communities. Geologists speculate that, at steep-sided Cascade volcanoes, some of the ***rock rubble*** found sandwiched between lava flows originated as pyroclastic flows. Learn more about lava flows, pyroclastic flows and associated hazards in the **Rock Stars**, **Volcanic Processes,** and **Understanding Volcano Hazard Video** activity.

Where are the lava flows at Mount Rainier?

Lava flows are visible in two general arrangements at Mount Rainier—as thin rock ledges that protrude from the cone of the volcano, and as the immense ridges that radiate from the volcano in every direction. The rock ledge lava flows, commonly 30 meters (100 feet) in thickness, are all that remain of longer flows that during the eruptions disintegrated into pyroclastic flows, or after the eruption were eroded away by glacial action. The great lava flow ridges, exemplified as Paradise Ridge, Ricksecker Point, Mazama Ridge, and Rampart Ridge, rise hundreds of meters (hundreds of feet) above the valley floors. Their rock-rubble tops can be difficult to observe because of dense meadow and forest vegetation. Almost every step taken on these ridges is made upon hardened lava flows. From valley bottoms, the educated observer can view multiple lava flows that have built the ridge. The lava rocks usually appear gray, and in some places form columns. See examples of thin and thick lava flow types in the graphic "***Photographs of Lava Flows at Mount Rainier***."

Silica influences lava viscosity and overall shape of the volcano

Silica content is the principal control upon the ***viscosity*** of magma. Silica molecules form a strong bond that permits entrapment of volcanic gases and promotes explosive volcanic eruptions. Low-silica magmas allow rapid escape of gases and low-explosivity eruptions. Other factors that control magma viscosity include the magma's temperature, gas and water content, and the amount of crystals in the magma. The massive ***shield volcanoes*** of Kilauea and Mauna Loa, in Hawai'i, contains 50 percent silica in its magma, whereas the ***stratovolcano*** of Mount Rainier has silica content of nearly 60 percent. Mount St. Helens has the highest average silica content at 64 percent. For more information about magma, visit the **Magma Mash** activity and the **Internet Resources Page**.

Sidebar 1

Get A Sense About Lava Flows

Color

Color and texture of lava vary considerably depending on cooling conditions. Lava rocks at high temperatures appear red to orange in color but cool quickly to shades of red (due to oxidation) and gray.

Sound

Witnesses of slow-moving, partially cooled lava flows report sounds similar to breaking of glass and pottery, caused by the splintering of the cooled outer skin of the lava flow. In contrast, the passing of a pyroclastic flow is eerily quiet. Some people say this is because its sound energy is absorbed within the billowing ash cloud.

Smell

Observers of lava flows report a slight sulfur smell in the air and the odor of burning vegetation.

Texture

Lava at Mount Rainier is not as fluid as lava at the volcanoes on Hawai'i, where lava flows sometimes resemble hot molasses, nor is it as viscous as lava at Mount St. Helens.

Not all volcanoes are created equal

While there are many ways to classify volcano types, one very simplistic and common classification system separates all volcanoes into three types based upon overall shape—shield volcanoes, ***cinder cones***, and stratovolcanoes, sometimes known as ***composite volcanoes***. The overall shape of a volcano provides clues about the texture and chemical content of the lava that formed it. Magma erupted from shield volcanoes produces fluid lava that spreads quickly and thinly for great distances across the surface. This produces a gentle slope, similar in shape to the round shields used by Roman soldiers. Shield volcanoes have large foundations that cover massive areas. A stratovolcano consists of accumulations of viscous lava flows and rock rubble. Their slopes are much steeper than slopes of shield volcanoes. The type of magma that creates a cinder cone is similar to that producing shield volcanoes. During an eruption, expanding gases inflate small pieces of rock called cinders, which accumulate into a pile forming a rubbly cone. Many cinder cones also contain small lava flows. The graphic "***Three Types of Volcanic Cones***" depicts examples of these volcanic cones.

Mount Rainier and Mount St. Helens—Some comparisons

Mount Rainier and Mount St. Helens have very different ages (oldest rocks 500,000 years ago and 40,000 years ago, respectively) and eruption styles, which explains their difference in shape and size. Mount Rainier's tendency to erupt more lava than tephra is one reason why it has been able to grow to such a great height. On the other hand, Mount St. Helens produces a tremendous amount of tephra that is blown away from the volcano and does not contribute to the volcano's cone. Lava at Mount St. Helens can be so viscous that it appears to squeeze out of the ground like toothpaste from a tube. This creates a muffin-shaped feature called a ***lava dome*** that grows over the vent. Later explosive eruptions will destroy earlier lava domes and prevent the volcano from growing to great heights.

Sidebar 1 Viscosity

This is the resistance of a material (usually a fluid) to flow. Examples higher and lower viscosity would be the higher resistance to flow of cake batter compared to water.

Procedure

What to do Before Class Begins:

- Choose three products to represent lava samples. Products should have different compositions and textures and viscosities (chocolate syrup, corn syrup, shampoo, oatmeal, jelly, ketchup, rubber cement, etc.). Place each of these materials in small containers to give to each lab group. Use paper cups or other containers.

Introducing Viscosity

1. Briefly review the different types of volcanoes. Use the "***Three Types of Volcanoes***" graphic to compare the shapes and sizes of shield, cinder cones, and stratovolcanoes.

2. Introduce the term viscosity and describe how the viscosity of lava will determine eruptive style and the type of volcano produced. Note that other factors, such as the amount of gases in magma can influence eruptive style.

Lava On The Run

Students test the viscosity of three "lava samples" and draw conclusions about the type of volcano that might result.

Provide each student with a "***Lava on the Run***" student page.

1. Divide the class into groups of three or four persons. Each team member should have at least one role in the experiment, such as recorder, timekeeper, marker and measurer, and sample pourer.

2. Students spread newspaper or plastic sheeting over activity areas to ensure easy cleanup.

3. Students use a marker to draw a start line at the top of the cardboard and then prop the cardboard against an object at a steep angle.

4. Provide the lava flow samples to each group.

5. Instruct students to examine the lava samples.

6. On the student page, students write their prediction about which sample is the most viscous (slowest flowing) and least viscous (fastest flowing).

7. Instruct students to measure one tablespoon of sample and hold it above the start line ready to pour when the *timekeeper* says go. Pour the sample onto the cardboard. After ten seconds, the timekeeper will say stop, and the *marker* will draw a line where the "lava" was at that time. The *measurer* will determine the distance traveled during that time. The *recorder* writes the distance on the student page.

8. Students repeat the process with all samples. Average the results of each "lava" sample for all groups.

9. Instruct each group to graph the results showing which sample is more viscous or resistant to flow in the experiment.

Concluding the Experiment

1. Discuss results with the class. Address similarities and differences among group results. Did each group mark the same specimen as most or least viscous? Instruct students to explain their answers. Which specimen might represent each type of volcano? How did slope play a role in the results? How would shape or slope of a volcano and changes in silica content affect the volcano? Discuss how each consecutive lava flow adds height to the volcano.

2. Display the graphics "***Three Types of Volcanic Cones***," "***Photographs of Lava Flows at Mount Rainier***," and "***Volcanic Rocks of Modern Mount Rainier***." Ask students to identify the samples that would build a shield and stratovolcano. Note the presence of thin flows on Success Cleaver, and thick flows in the Ricksecker Point Lava Flow. Explain how thin lava flows form high on the volcano while lava pools along the base of the volcano, forming thick flows and ridges that radiate from the volcano.

Adaptations

- Conduct "***Lava on the Run***" as a classroom demonstration.

- ***Illustrating volcano types using simple foods***—Display to the class a chocolate chip, a chocolate kiss, and a wafer cookie. The chocolate kiss represents a steeply sloped stratovolcano, or composite volcano; the chocolate chip represents a cinder cone; the wafer illustrates the broad slope of a shield volcano. Ask students which type of volcano each of the foods represents.*Used courtesy of Dr. Robert Lillie, Oregon State University*

Extensions

- For older students, assign Internet or library research concerning volcano growth rates. Instruct students to examine the life histories of other Cascade volcanoes.

Assessment

For assessment, instruct students to show results on the student page and on the graph. Students should demonstrate ability to follow instructions on the student page, record results and graph their data. Look for evidence that students understand the following concepts: that the type of lava material erupted from a volcano influences the volcano's shape; that Mount Rainier is a stratovolcano; that lava flows are the principal building blocks of Mount Rainier; that lava flows are visible as thick ridges that radiate from the volcano and as thin ledges within the volcanic cone. Assess application to real-world situations by assigning further class interpretation of photographs of volcanoes on the graphics pages and of photographs in books and websites. Ask questions about how viscosity of magma affects the shape of volcanoes near your community.

References

Sisson, T.W., Vallance, J.W., and Pringle, P.T., 2001, Progress made in understanding Mount Rainier's hazards: EOS (American Geophysical Union Transactions), v. 82, no. 9, p. 113, 118–120.

Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

Photo Credits

Photographs of Lava flows at Mount Rainier

1. Thin lava flow layers on the flanks of Mount Rainier stratovolcano in February, 2003, Photo by Carolyn Driedger, USGS.
2. Thick lava layers that accumulated as Paradise Ridge in September, 2006, Photo by Carolyn Driedger, USGS.

Three Types of Volcanic Cones

3. Shield volcano view of the northwest flank of Mauna Loa Volcano from the south side of Mauna Kea Volcano, Photo by D. Little, USGS.
4. Cinder cone Lava Butte, Oregon, taken from Highway 97, Photo by National Park Service.
5. Stratovolcano (composite Cone) Mount Rainier on July l, 2004, Photo by Carolyn Driedger, USGS.

Student Page

Team Names _____

_____

Lava on the Run

During this activity, you will test the viscosity of three lava-like products and draw conclusions about the type of volcano they might form.

1. Choose roles for each team member—recorder, timekeeper, marker and measurer, and sample pourer.

2. Spread newspaper or plastic sheeting over activity areas for easier cleanup.

3. Use a marker to draw a start line at the top of the cardboard and, then prop the cardboard against an object at a steep angle.

4. Examine the three samples provided to your group (chocolate syrup, corn syrup, shampoo, oatmeal, jelly, ketchup, rubber cement, etc...)

5. On the student page, write your prediction about which sample is more viscous and will flow downhill the slowest, and which sample is least viscous and will flow fastest.

6. Measure 1 tablespoon of sample and hold it above the start line ready to pour when the *timekeeper* says go. Pour the sample onto the cardboard. After 10 seconds, the timekeeper will say stop, and the *marker* will draw a line where the "lava" was at that time. The *measurer* will determine the distance traveled during that time. The *recorder* writes the distance on the student page.

7. Perform each lava run twice. Average the results of each sample and record it.

8. On the back of this page, draw a graph of your results. Write on your graph which lava-like samples are more viscous (resistant to flow).

Student Page

Team Names _____

_____

Lava on the Run-continued

Predictions:

Which sample will travel the greatest distance in 10 seconds? _____

Which sample will travel the shortest distance in 10 seconds? _____

Sample #	Distance (mm) 1st time	Distance (mm) 2nd time	Average

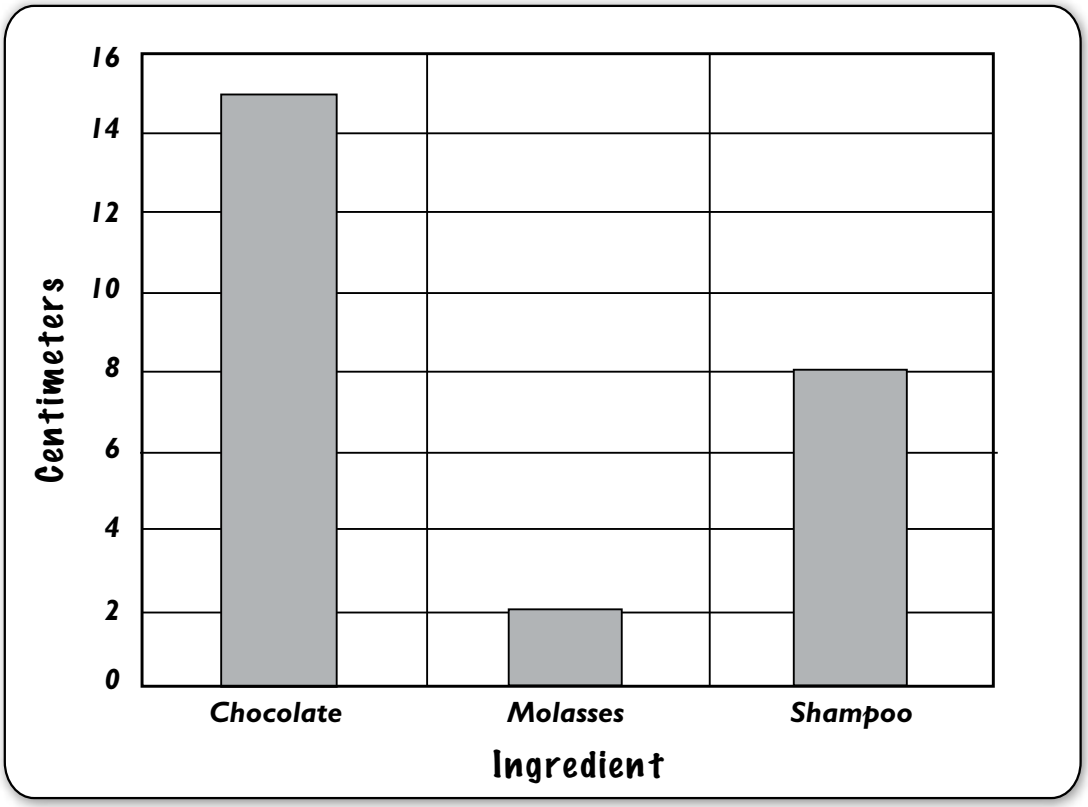
1. List factor(s) which control distances traveled by your lava-like flows.

2. List which products most closely resemble the behavior of lava flows on a shield volcano and a stratovolcano.

Teacher Page

Lava on the Run—Sample Graph

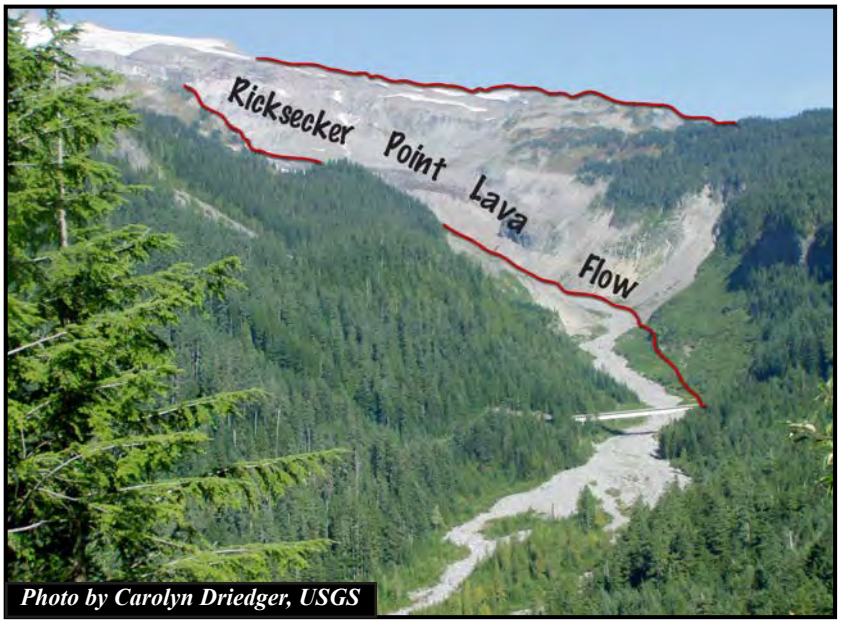
Lava on the Run



Graphic Page

Photographs of Lava Flows at Mount Rainier

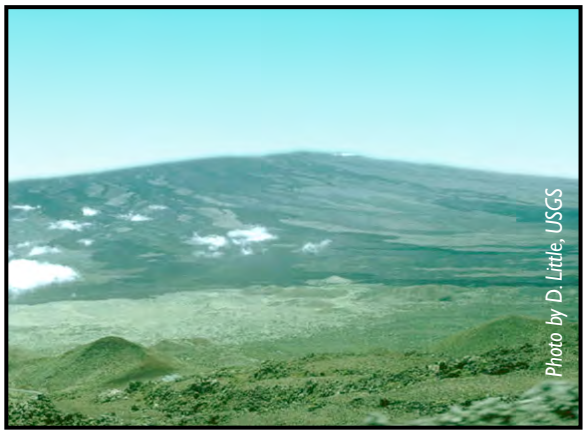
Layers of thin lava flows, each about 30 meters (100 feet) thick on Success Cleaver.



Thick lava flows (300 meters or 1,000 feet thick). Ricksecker Point lava flow.

Graphic Page

Three Types of Volcanic Cones



Shield Volcano

View of the northwest flank of Mauna Loa Volcano from the south side of Mauna Kea Volcano, Hawaii.

Cinder Cone

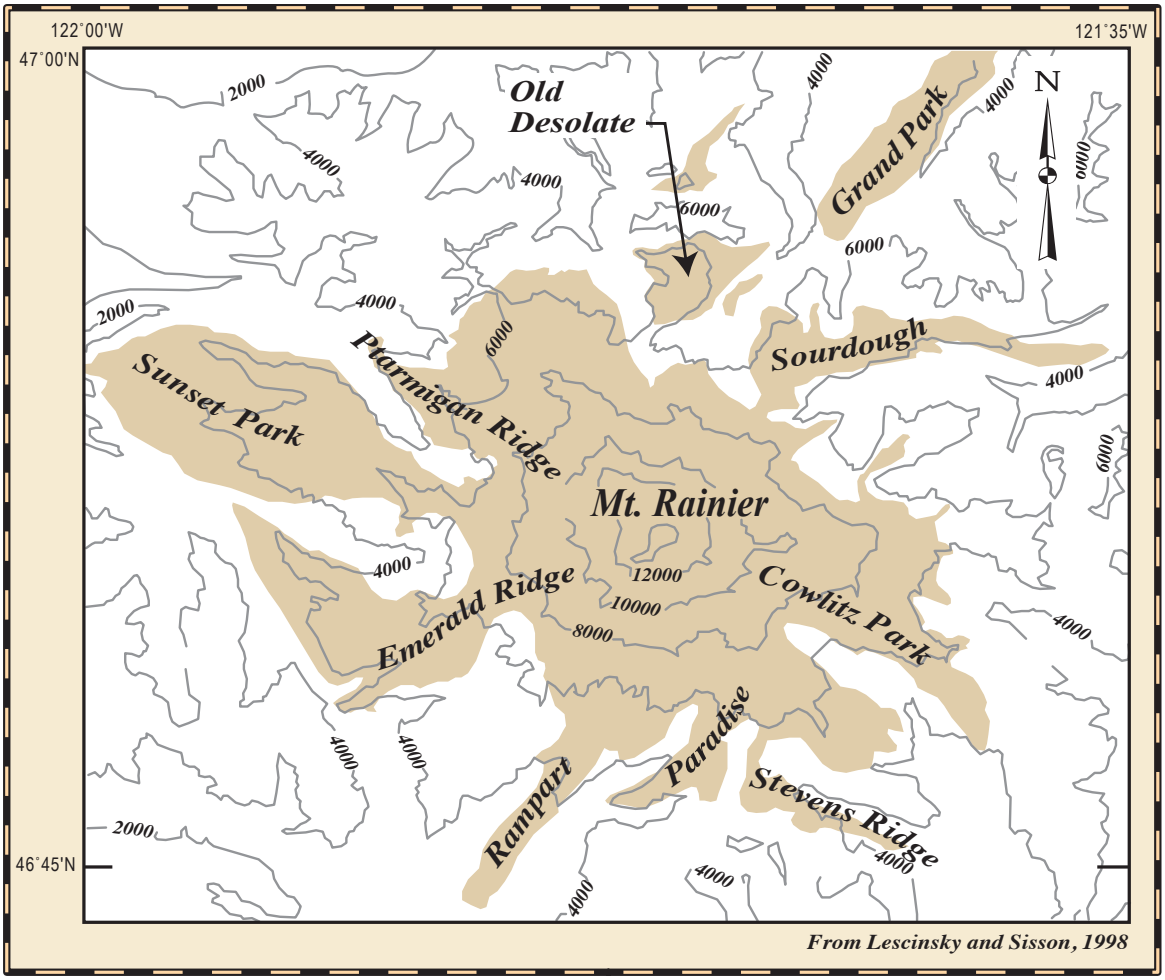
Lava Butte Cinder Cone, Oregon, from Highway 97.

Stratovolcano (Composite Cone)

South side of Mount Rainier from Paradise Ridge.

Graphic Page

Volcanic Rocks of Modern Mount Rainier



0 5 10 Kilometers

0 5 10 Miles

Rock Stars

Grade Level: 6–10

Learner Objectives:

Students will:

- Identify and understand the processes responsible for different appearances of lava rocks
- Recognize rock samples from various parts of a lava flow

Setting: Classroom

Timeframe: 40 minutes

Materials:

- Graphic *"Lava Flow Features"*
- Graphics *"Rock Star Photo Examples"*
- Copies of *"Interview a Rock Star"* student page
- Rock samples (optional) see *"Adaptations"* on page 7
- Station numbers
- Pencils
- Hand lenses

USGS
science for a changing world

Living with a Volcano in Your Backyard–An Educator's Guide with Emphasis on Mount Rainier

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

Students identify the characteristics of rocks in samples or photos and then tell a story about where and how each formed.

Teacher Background

Understanding a gray rocky landscape

A stroll across the slopes of a volcano is akin to walking the halls of a great natural museum, though the rocks of the volcano are on display in their natural setting. From a distance, Mount Rainier's volcanic landscape appears uniformly gray in color. Upon closer examination, however, subtle and significant differences in rock texture, color, and crystal size become apparent. For the most part, lava rocks on the slopes of Mount Rainier came from a common magma source and have similar chemical composition. Why then do their appearances differ? The conditions under which molten lava rocks cool and solidify have the greatest influence on a rock's appearance. Knowledge of a rock's cooling conditions helps geologists determine whether the rock cooled inside the earth (***intrusive***) or outside the volcano, on Earth's surface (***extrusive***). Intrusive rocks are uniformly coarse grained. Extrusive rocks are fine-grained or have mixed grain sizes.

Rocks from the same lava flow can appear different, depending on where they cooled and solidified.

With practice, students can identify the origin of any lava rock as being from a lava flow's exterior or interior. Lava flows have a dense interior and a rubbly flow top.

Activity last modified: November 21, 2014

Vocabulary: Andesite, breccia, extrusive, granodiorite, hydrothermal alteration, intrusive, lava flow, sandstone

Skills: Compare, describe, identify, visualize, observe

Benchmarks:

See benchmarks in Introduction.

Lava flow exteriors

The tops of lava flows are rubbly and consist of ***breccia*** because the cooled exterior rocks break apart when pulled along by the still moving interior of the flow. Rocks at the exterior of the flow can be rich in gas bubbles. Some exterior rocks that cool instantly, with no time for crystal formation, have a glassy texture and appearance.

Lava flow interiors

The massive interior of a lava flow cools slowly, and requires days to years for complete cooling. Gases are less common in the flow's interior, so rocks contain fewer gas bubbles. The margins of lava flow interiors contract and crack as they cool and can form long columns oriented perpendicular to the cooling surface—the top, sides, base or the toe of the flow. View these features on the graphic "***Lava Flow Features***."

Rusty and hardboiled lavas

The iron in rocks that cool in the presence of steam oxidizes to rust, giving the rocks a red or mauve color. Inside the mountain, hot gases mix with heated ground water to produce a weakly acidic solution that stains rocks yellow, orange, and red or chemically alters the entire rock mass, leaving it weakened and crumbly. This process is called ***hydrothermal alteration***.

With this knowledge at hand, geologists can visit previously unexplored volcanic landscapes and recognize the conditions that existed when the lava flows cooled and solidified. Observations of crystal size, color, and texture of rocks provide valuable clues about a rock's former position within a lava flow and the conditions in which the rocks cooled. Below are some photo examples of rocks that formed within the boundaries of Mount Rainier National Park.

Rock star photo examples

1. ***Gray Andesite***

   Andesite commonly appears dark gray to black in color, has a consistent look and texture throughout, and contains no gas bubbles. The rock cooled relatively quickly, within days to years, so mineral crystals are generally fine grained. Typically, crystals (small white and dark spots) are visible that grew in the magma chamber before the eruption.

2. ***Red andesite***

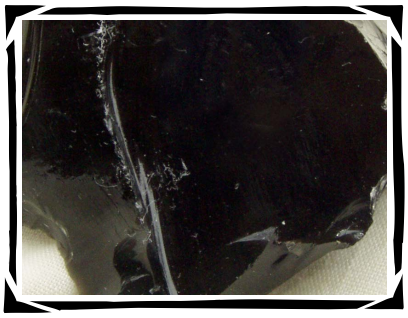
   Escaping steam caused iron in these rocks to rust and produce the red color. Rocks are sometimes red on one side and gray on the other, which indicates the lava cooled adjacent to cracks in the lava flow.

3. ***Bubbly rock***

   Holes form when volcanic gas bubbles are trapped during the cooling process.

4. ***Black glassy andesite***

This rock cooled in just seconds. Mineral grains had no time to grow; thus it appears black with a glassy texture.



5. ***Hydrothermally altered andesite***

Prolonged exposure to hot acidic water changed this rock from gray to a yellow/orange color. This is a process called hydrothermal alteration. The rock is now crumbly and weak.

6. ***Tatoosh Granodiorite***

It took thousands of years for this magma to cool, plenty of time for the mineral grains to grow. Individual crystals of feldspar and hornblende are apparent to the unaided eye in this ***granodiorite***, an intrusive rock.

7. ***Rounded andesite***

Steam action broke off the sharp edges of this lava rock leaving it rounded and polished.

8. ***Open book slabs***

As this lava flow slowed and cooled, fractures developed that later caused the rock to split open into slabs.

9. ***Columnar andesite***

As lava cools, it contracts and forms long cracks perpendicular to the cooling surface. This creates a colonnade appearance. The cooling surface can be on the top, base, the sides, or at the toe of the lava flow.

10. ***Blocky rock rubble/breccia***

Lava exteriors cool faster than interiors because of their exposure to cool air. The hotter, still molten interior continues to flow and eventually the solidified top layer breaks into pieces. This process is akin to the lava flow top being placed on a conveyer belt. The rock is constantly being pulled apart and jumbled as the lava flow creeps down slope. This uneven motion continues until the entire lava flow has cooled and solidified as breccia.

11. ***Sandstone (non-igneous rock)***

This sandstone consists of tiny sand grains. The edges of each grain are well rounded because of the collisions of grains during transport by wind and water.

Procedure

What to do Before Class Begins:

1. Choose one of these teaching options:

- Project images of rocks to the entire class.
- Print color graphics and place at work stations.
- Display actual rock samples (see sample list in "***Adaptations***" on page 8).
- Display combination of actual rock samples and projected images.

2. If you provide actual samples, place one rock sample and a hand lens at each station.

3. Provide each student with a copy of the two student pages "***Interview a Rock Star***."

For purposes of general class discussion, you might review the terms "***intrusive***" and "***extrusive***" with students prior to conducting the activity.

Interview a Rock Star

Students learn to identify the origin of lava-rock samples by observing texture, grain size, shape and color.

1. Prepare the students for their interview by reviewing the visual characteristics of rocks, such as grain size, texture, shape, and color. Ask what characteristics are different in intrusive and extrusive rocks. Use the "***Lava Flow Features***" graphic to discuss how cooling and position within the lava flow can affect the appearance of a rock.

2. Instruct students to either view images projected or to visit each station, study each sample, and answer the guiding questions on the "***Interview a Rock Star***" student page.

3. Review the results after all samples have been viewed. Point out positions of rock origin on the "***Lava Flow Features***" graphic.

4. With the graphic on display, begin a discussion. Discuss how characteristics of the lava rocks can help a geologist learn about the conditions that existed where the rocks formed. What questions might be answered by close observation?

ANSWER: Geologists might learn whether the lava was gas rich; whether it cooled quickly or more slowly; whether it formed on the interior or exterior of the lava flow; whether it cooled in the presence of steam or adjacent to a glacier.

Adaptations

- Use rock samples instead of the photographs provided.
  - ***Gray andesite***
  - ***Red andesite***
  - ***Bubbly rock***
  - ***Black glassy andesite or obsidian***
  - ***Hydrothermally altered andesite***
  - ***Granodiorite***
  - ***Rounded volcanic rock***
  - ***Plate-like pieces of lava rock***
  - ***Columnar andesite***
  - ***Breccia***
  - ***Sandstone (or other non-igneous rock that contains visible grains)***
- Adapt a broader study of rocks with the addition of information presented in this activity.

Extensions

- Students conduct an Internet or library search for more information about other igneous rocks not addressed in this activity.

Assessment

Use **Interview a Rock Star** student page as an assessment tool. Look for students' understanding of the following concepts: rocks of the same or similar chemical composition can be very different in appearance; cooling conditions determine much of the appearance of igneous rocks; rocks within the lava flow interior cool faster than rocks on the lava flow exterior; steam, gas volume, crystal size, lava flow motion are influences on the color, texture and form of igneous rocks.

References

Francis, P., and Oppenheimer, C., 2003, Volcanoes: New York, N.Y., Oxford University Press, 536 p.

Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

Photo Credits

1. Station 1 Gray andesite, Photo by Carolyn Driedger, USGS.
2. Station 2 Red andesite, Photo by Carolyn Driedger, USGS.
3. Station 3 Bubbly rock, Photo by Willie Scott, USGS.
4. Station 4 Black glassy andesite, Photo by Carolyn Driedger, USGS.
5. Station 5 Hydrothermally altered andesite, Photo by Steve Brantley, USGS.
6. Station 6 Tatoosh Granodiorite, Photo by Carolyn Driedger, USGS.
7. Station 7 Rounded andesite, Photo by Carolyn Driedger, USGS.
8. Station 8 Open book slabs, Photo by Carolyn Driedger, USGS Station.
9. Station 9 Columnar andesite, Photo by Carolyn Driedger, USGS.
10. Station 10 Bubbly rock rubble/breccia, Photo by Carolyn Driedger, USGS.
11. Station 11 Sandstone, Photo by Carolyn Driedger, USGS.

Student Page

Name _____

Interview a Rock Star

Station	Guiding Questions	Cooling Conditions for this Rock
1	Explain evidence that suggests this rock cooled quickly.	
2	Explain how the presence of steam influenced the color of this rock.	
3	What formed the holes in this rock?	
4	Why is this rock black and glassy with no visible crystals?	
5	What combined with the sulfur in this rock to change the color from gray to yellow/orange/red? Name the chemical process that transformed this rock from a solid piece to one that crumbles easily.	
6	Describe any evidence that suggests whether this rock cooled instantly or over a long period of years.	

Student Page

Name _____

Interview a Rock Star-continued

Station	Guiding Questions	Cooling Conditions for this Rock
7	Explain why the corners of this rock are rounded.	
8	What lava flow motion caused the platy, "open-book" appearance of these lava rocks?	
9	In a cooling lava flow, lava rock contracts and forms long cracks that point towards the closest cool ground or air. This creates the appearance of lava columns. Draw an arrow in the box that indicates the direction to that nearest cool surface.	
10	In what general part of a lava flow would you expect to find this loose rock rubble? Explain its origin.	
11	Is this an igneous rock? Explain your answer.	

Teacher Page

Interview a Rock Star—Answers

Station	Guiding Questions	Cooling Conditions for this Rock
1	Explain evidence that suggests this rock cooled quickly.	***Crystals are not visible. They did not have sufficient time to grow.***
2	Explain how the presence of steam influenced the color of this rock.	***Steam oxidized (rusted) iron within the rock and gave it a red-mauve color.***
3	What formed the holes in this rock?	***Expanding gases enlarged the holes (vesicles), and then escaped into Earth's atmosphere.***
4	Why is this rock black and glassy with no visible crystals?	***This rock cooled and hardened instantly and had no time for crystal formation. Black color is caused by light absorption.***
5	What combined with the sulfur in this rock to change the color from gray to yellow/orange/red? Name the chemical process that transformed this rock from a solid piece to one that crumbles easily.	***Water*** ***Hydrothermal alteration***
6	Describe any evidence that suggests whether this rock cooled instantly or over a long period of years.	***Crystals are visible, and thus had time to grow over a period of years.***

Teacher Page

Interview a Rock Star—Answers -continued

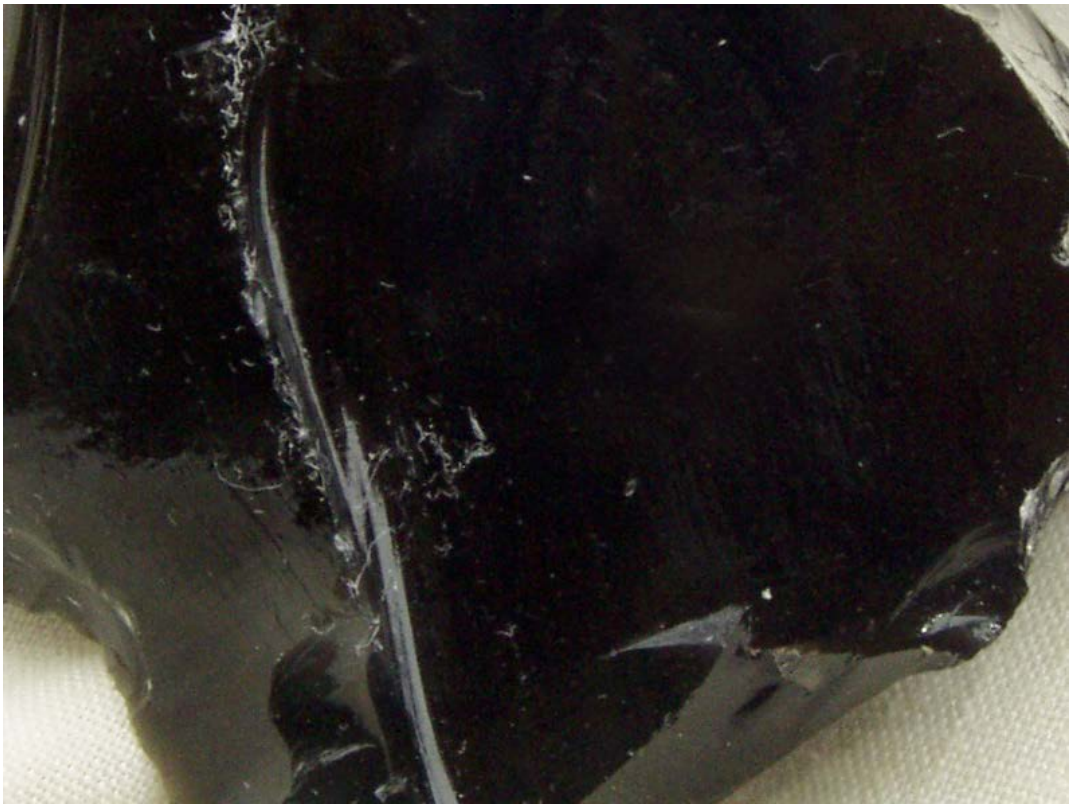
Station	Guiding Questions	Cooling Conditions for this Rock
7	Explain why the corners of this rock are rounded.	***Repeated collisions during river transport rounded off the corners of those boulders.***
8	What lava flow motion caused the platy, "open-book" appearance of these lava rocks?	***As the lava slowed and cooled, fractures developed which later split the rock into slabs.***
9	In a cooling lava flow, lava rock contracts and forms long cracks that point towards the closest cool ground or air. This creates the appearance of lava columns. Draw an arrow in the box that indicates the direction to that nearest cool surface.	***Students should draw an arrow that points towards the upper left.***
10	In what general part of a lava flow would you expect to find this loose rock rubble? Explain its origin.	***Exterior***
11	Is this an igneous rock? Explain your answer.	***No, this is not an igneous rock. It contains round-edged sand particles produced by erosion.***

Gray Andesite—Station 1

Red Andesite—Station 2

Bubbly Rock—Station 3

Black Glassy Andesite—Station 4



Hydrothermally Altered Andesite—Station 5

Tatoosh Granodiorite—Station 6

Rounded Andesite—Station 7

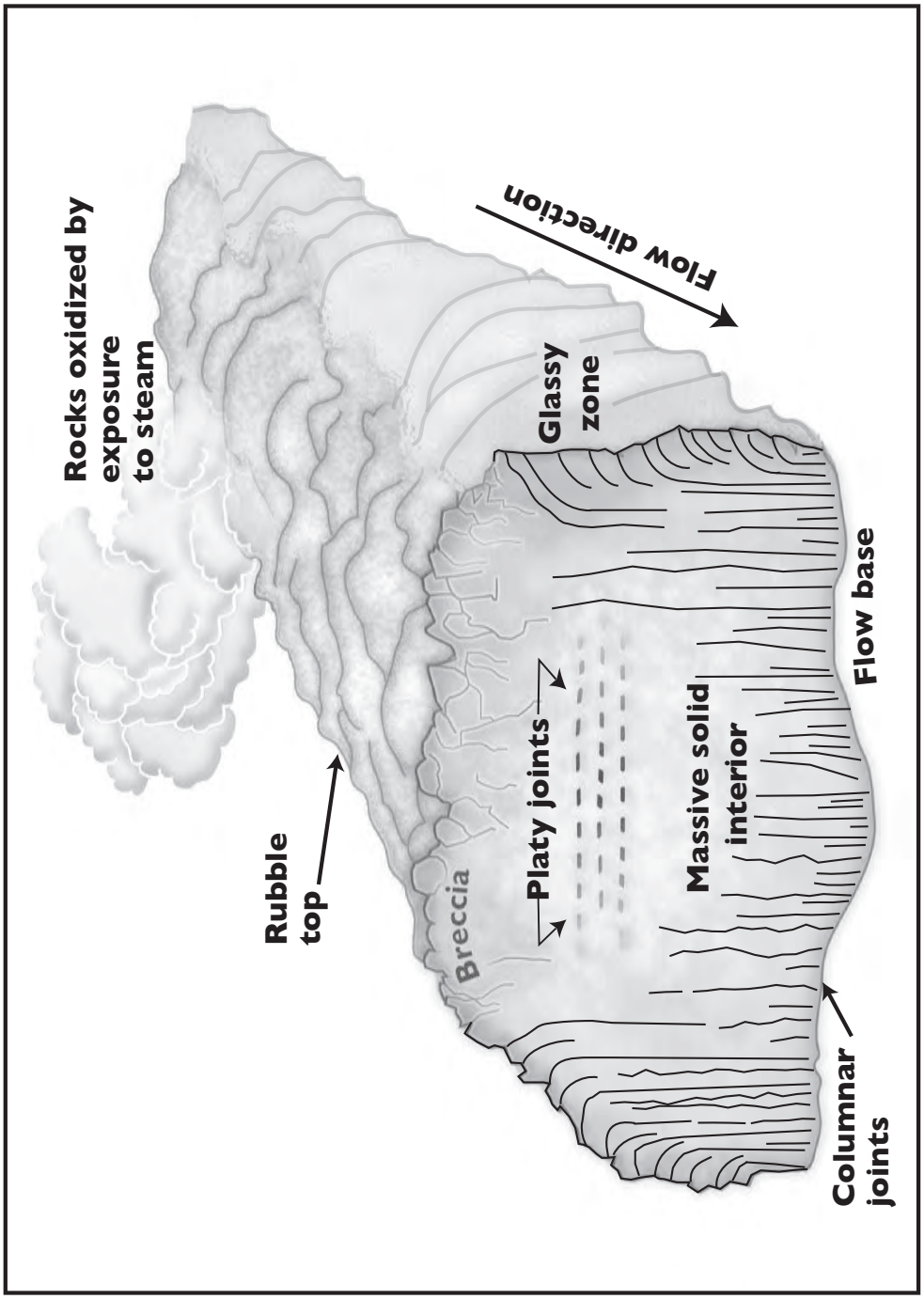
Open Book Slabs—Station 8

Columnar Andesite—Station 9

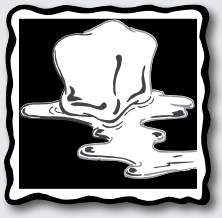
Bubbly Rock Rubble/Breccia—Station 10

Sandstone—Station 11

Lava Flow Features



Fire and Ice



Grade Level: 6–10

Learner Objectives:

Students will:

- Recognize that the volcano and its glaciers co-exist as a dynamic system
- Identify the types of interactions and energy transformations, that occur between glaciers and hot volcanic rocks
- Identify some types of geologic features at Mount Rainier that are a product of glacier-volcano interactions

Setting: classroom

Timeframe: 50 minutes for demonstration and discussion. For student groups, add 20–30 minutes for next day observations and discussions

Materials:

- Graphic *"Glaciers on Mount Rainier"*
- Graphic *"Columbia Crest Summit"*
- Graphic *"Glacier-Volcano Interactions"*
- Graphic *"Maximum Extent of Glaciers on Mount Rainier During the Ice Ages"*
- Graphic *"How Lava Ridges are Made"*

USGS science for a changing world

Living with a Volcano in Your Backyard-An Educator's Guide with Emphasis on Mount Rainier

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

Students use ice cream glaciers and hot wax lava flows to simulate the interaction of glaciers and lava flows.

- Graphic *"Glacier Scratches (Striations) on Lava Rock at Mount Rainier"*
- Graphic *"Volcanic Rocks of Modern Mount Rainier"*
- Graphic *"Lava flows—Experimental and Real World Comparisons"*
- Stove or other heat source
- Candy thermometer
- Double-boiler pot
- Disposable stirrer (pencil, paint stirrer, stick
- Camera (optional)

Ingredients required for each model:

- metal cookie tray with sides (1/2 inch high minimum)
- cereal bowl
- wax paper
- masking tape
- modeling clay (8 oz per model group; black illustrates solidified lava well)
- ice cream (1 quart; vanilla illustrates glacier ice well)
- ice cream scoop
- household wax (one pound; used for canning, candle making; also called "Home Canning Wax," or "Paraffin")
- crayons (four different colors (quality crayons work best; do not use water soluble crayons)
- scissors to cut clay strips—for use with soft clay only (optional)

Activity last modified: September 5, 2014

Vocabulary: Erosion, glacier, ice ages, lahar, lava, lava flows, pyroclastic flow, striations, vent, volcano, volcanic eruptions

Skills: Interpret, infer, demonstrate, explain, predict, visualize

Benchmarks:

See benchmarks in Introduction.

Teacher Background

Glaciers and Mount Rainier co-exist as a dynamic system

Mount Rainier distinguishes itself among other Cascade ***volcanoes*** because of its widespread high-altitude slopes and extensive snow and ice cover. About 88 square kilometers (34 square miles) of snow and ice cover the mountain at summer's end. ***Glaciers*** have covered Mount Rainier over much of the volcano's 500,000-year lifespan, creating a dynamic system. The volcano provides high-elevation slopes that are conducive to glacier formation and glacial ***erosion***. ***Volcanic eruptions*** can melt snow and ice, even while glaciers influence the movement of ***lava flows***. A general list of mechanisms of influence between glaciers and volcanoes is shown in the sidebar. This information is depicted in graphics "***Glaciers on Mount Rainier,*** *"* ***"Columbia Crest Summit,"*** and *"**Glacier-Volcano Interactions**."*

Sidebar 1 Mechanisms of Influence—Glaciers and Volcanoes

A Volcano's Influences upon its Glaciers	*A Glacier's Influence upon its Volcano*
Mount Rainier is an obstacle to moisture-laden air from the Pacific Ocean. The air is forced to rise, cool, and drop its moisture.	Rock debris embedded in ice at the bottom and margins of a glacier mechanically erodes surrounding rocks.
Frequent cold temperatures on high-altitude slopes provide an ideal environment for snow retention and transformation to glacier ice.	Glacial meltwater streams remove and transport loose rock from the mountain.
Extensive slopes of rugged volcanic terrain trap blowing snow and contribute to snow retention and glacier formation.	Glaciers can influence the distribution of lava flows.
Volcanic eruptions melt snow and ice.	Glaciers provide meltwater for formation of debris flows and lahars, which alter the volcano's landscape.

Ice-age glaciers envelop Mount Rainier

To understand the extent to which hot volcanic rocks have interacted with surrounding glaciers, we need to put on our "glacier glasses" and envision landscapes largely buried by ice. During ***ice ages*** that occurred repeatedly between approximately 1.8 million and 11,000 years ago, large ice sheets covered northern Europe and much of Canada and the northern United States, including the Puget Sound area. Mountain ranges in the western United States, including the Cascades were mantled by extensive glaciers. Some of the glaciers on Mount Rainier were hundreds of meters (1,000 feet or more) thick on the flanks of the volcano and almost 1,000 meters (3,000 feet) thick in valleys at the base of the cone. Mountain glaciers coalesced and flowed for 100 kilometers (60 miles). Glacier ice covered the locations of the present day communities of Ashford, Alder, Greenwater, and Carbonado. Around 15,000 years ago, these enormous glaciers began to thin and recede into existing valleys. Their descendents cover much of Mount Rainier today. View the extents of glaciers then and now in the graphic *"**Maximum Extent of Glaciers on Mount Rainier During the Ice Ages**."*

Mount Rainier erupted repeatedly while buried by ice-age glaciers

Mount Rainier erupted repeatedly during past ice ages. The co-existence of volcanic and glacial processes led to a variety of interactions that shaped the mountain in a unique way. The origins of these features can be understood only when the interactions of the glaciers and volcanic forces are recognized.

When lava meets ice

During times of extensive glaciation, ***lava*** poured repeatedly from the summit ***vent*** of Mount Rainier and encountered glaciers. In the contest between lava flows, rock, and ice, glaciers at first appear to be less durable. In theory, a lava flow can melt about ten times its volume of ice, though it rarely does so. We commonly think of lava flows as bullish, relentless, and unstoppable. However, observations at ice-clad volcanoes around the world prove that glaciers can survive the onslaught of heat from lava flows. In some situations, glaciers can exert some control over the movement of lava flows, and as such are the architects of Mount Rainier. Consider these mechanisms.

- ***Lava flows tumble and disintegrate on steep slopes*:** Lava that flows over steep slopes often breaks apart and plunges onto the glacier, where it cools as rock debris. Sometimes the fragmenting lava flow forms a turbulent avalanche of scorching hot rock and gas called a ***pyroclastic flow***, which can sweep across the snow and ice. Incorporation of snow and ice into the pyroclastic flow can cause the flow to transform into a volcanic mudflow ***(lahar)***. Lahar layers are found in river valleys that extend from Mount Rainier.

- ***Ice-age glaciers act as physical and thermal barriers to lava flows*:** An advancing lava flow melts downward through thick ice until it contacts bedrock, where it chills and hardens, confined within the glacier. After the eruption, glacier ice often flows across the hardened lava flow. By this mechanism, Mount Rainier gains volume, and retains its glacier cover. Some of these lava flows, now partially eroded, are visible as ledges on the flanks of Mount Rainier.

- ***Thin ice and ice-free regions allow lava flows to travel far*:** Lava encounters less resistance in the thin ice and ice-free ridges between thick valley glaciers. The lava flow's outer skin cools and hardens, while the interior of the flow remains fluid and travels many kilometers (miles) from the base of the volcano. Over time, successive stacks of elongated lava flows have built ridges—from the bottom up—in a pattern that radiates from the cone of Mount Rainier. Paradise Ridge, Mazama Ridge, Rampart Ridge, and Emerald Ridge are some examples of this phenomenon. This interaction is depicted in the graphic *"**How Lava Ridges are Made.**"* The phenomenon can happen only when glaciers envelop Mount Rainier, such as during an ice age.

More about glaciers

A glacier is a large mass of flowing ice formed by the compaction and recrystallization of snow that has accumulated over a period of years. When snow crystals land atop one another their fragile edges snap and break. Pressure from overlying snowpack settles the crystals, squeezes out adjacent air pockets, forces them to liquify and then recrystallize as ice. By these processes, delicate snow crystals transform into a strong lattice of ice crystals that has sufficient strength to transform the landscape.

Glaciers as sculptors

Glaciers are well known as sculptors of the landscape, but the true artist is rock debris encased within the ice. Landslides and rock fall produce rock debris that drops onto the glacier surface. Winter snow falls bury the rock debris. Snow surrounding this rock debris transforms to ice. Eventually some of the entrapped rocks touch the valley floor and walls where they scrape and polish, as with grit in a gem polishing machine. Millennia of erosion by glaciers are responsible in part for the characteristic U-shaped valleys. See glacial scratches (***striations***) depicted in the graphic *"**Glacial Scratches (Striations) on Lava Rock at Mount Rainier**."*

Present-day glaciers at Mount Rainier

While Ice-Age glaciers have thinned and receded dramatically over the last 15,000 years, Mount Rainier still hosts one of North America's largest single peak glacier systems. The present glaciers consist of approximately 4.4 cubic kilometers (1 cubic mile). For scale, imagine an ice cream scoop the size of Seattle's Safeco Field sports stadium. Removing all the perennial (long-lasting) snow and glacier ice from Mount Rainier would require 2,600 stadium-sized scoops! Envision this also as an ice cube one mile on a side. The volume of perennial snow and glacier ice on Mount Rainier is equivalent to the amount of ice on all the other Cascade volcanoes combined.

Procedure

Fire and Ice

Students use ice cream glaciers and hot wax to simulate the interaction of ice-age glaciers and lava flows. They observe results and relate this to actual processes and features at Mount Rainier.

What to do Before Class Begins:

1. Decide whether you will conduct this activity as a demonstration or with student groups. Student groups will require multiple amounts of items listed in *"**Materials,**"* and additional time for setup. Students build their model, and then make repeated trips to the source of the molten wax on a stove top or hot plate.

2. A demonstration can be accomplished in less time, but will require you to assemble the wax papered tray and volcano model, and to break crayons and melt the wax prior to the beginning of class. If conducting the demonstration with several classes, consider constructing ice age glaciers with the first class and adding one or more layers of wax "lava" with each successive class, followed by examination of the model the next day.

3. Decide whether to assign students with homework that investigates glaciers, ice ages, and glacier-ice interactions (Procedure Part I number 2) prior to performing the activity.

4. As you prepare for post-activity discussion, keep in mind that no two completed volcanoes models will be alike. On these models, both ice cream glaciers and the older clay lava flows can influence the route of young wax lava flows. Students might observe that successive pourings of wax cause "stacking" of lava flows, as produced at Mount Rainier during the ice ages. Remind students that they should make general observations about melting of ice cream glaciers, the size, shape and overlapping nature of lava flow layers, and any interactions of wax lava flows with the tray rim. Be prepared for a variety of results.

Fire and Ice

Part I: Preparing Students for the Activity

1. Display the graphic *"**Glaciers on Mount Rainier**"* and point out that the glaciers are large; they show crevasses and are visible in white. Small discontinuous white areas are snow or ice patches. These do not flow and are not considered glaciers.

2. Instruct students to hypothesize about ways that the volcano and the glaciers influence one another. (You might wish to assign this as homework on the day previous to the volcano model.) Diagram their answers on the classroom whiteboard. Refer to the *"**Teacher Background**,"* and to the graphics *"**Columbia Crest Summit**," "**Glacier-Volcano Interaction**,"* and *"**Glacier Scratches (Striations) on Lava Rock at Mount Rainier**."*

3. Display the graphic ***"Maximum Extent of Glaciers on Mount Rainier During the Ice Ages"*** which illustrates the maximum extent of glaciation during the ice ages and today. Tell students that the volcano model in the activity represents glaciation during the last ice age; some older ice ages had even more extensive glaciers.

Part II: Setup of the Volcano and Glacier Model

1. **Begin preparation of the volcano model by covering a tray and cereal bowl with wax paper.**

Use masking tape to hold paper in place. Less surface area exposed to hot wax means reduced time spent on messy cleanup.

2. **Turn bowl upside down on the tray as a volcano model.**

The inverted bowl will represent the existing volcano that formed previously by the accumulation of volcanic rocks. Newer lava flows made of wax will be poured over the top of it.

3. **Make clay strips that represent previous accumulations of lava rock as ridges that radiate from the volcano.**

   Remove clay from its container and shape into strips 1.5 centimeters (0.5 inch thick) and approximately 13 to 17 cm (5 to 8 inches) in length. Drape clay strips over the volcano model in a variety of configurations. Some strips should be longer than others; some should diverge and others converge at their toes. Cover the top of the bowl completely with a thin layer of clay. Optionally, obtain additional clay in other colors, and stack multiple lava layers on top of each other. Remind students that each strip represents accumulations of volcanic rock from previous lava flows.

4. **Cover volcano model with vanilla ice cream to represent enormous ice-age glaciers.**

   Scoop the ice cream onto the volcano model. Press it tightly against the clay and the waxed paper to reduce leakage. Stuff the ice cream into the deeper spaces between the clay strips to represent thick glaciers. Cover the clay strips (existing lava flows) with a thin layer approximately 1 centimeter, (approximately 1/3 inch) of ice cream. Alternatively, leave some of the clay strips exposed so that the students observe how existing ridges can influence lava flow speed and direction.

5. **Melt the wax.**

   Obtain a stove top heat source and double-boiler system. Place 454 grams (1 pound) of wax into the double-boiler carefully and melt it, following all product safety instructions. Monitor temperature with a candy thermometer. Temperature should never exceed 90 degrees Celsius (200 degrees Farenheit). Wax takes about 15 minutes to melt, but remains fluid for about 45 minutes after removal from heat. Cooler wax makes thicker, more obvious wax lava flows.

6. <u>Color the wax lava with crayons.</u>

Remove the paper wrappers from 5 or 6 different colored non-water soluble crayons and break each crayon into fingernail-sized pieces. Melt one colored crayon for each pouring of a wax lava flow, starting with the crayon lightest in color, and progressing to darker colors with each new lava flow (example: clear, orange, red, purple, black). With this method, you need melt only one pot of wax to obtain multiple colors of lava flows. There is no need to subdivide the melted wax into separate containers.

<u>Part III: Fire And Ice Simulation</u>

1. <u>To be sure that students understand the volcano model, ask them the following questions:</u>

a. What does the bowl represent?
b. What do the clay strips represent?
c. What do the areas of ice cream represent?
d. What does the wax represent?
e. Describe the appearance of the landscape beneath the glaciers.

2. Ask students to hypothesize about what happens when hot lava and glacier ice interact. What will happen to the glaciers? To the lava flows?

3. <u>Add half of a colored crayon to the melting wax.</u>

Point out to students that each colored wax batch represent a new series of lava flows. Slowly pour approximately one-fifth of the melted colored wax over the summit area and upper slopes of the volcano model. Allow the wax to cool and solidify for a number of minutes. In the meantime, add the next color crayon to the wax in the pot and allow several minutes for melting. This also provides valuable time for student observations and discussion of glacier-lava flow interactions.

4. **Instruct student to observe where the lava travels faster.**

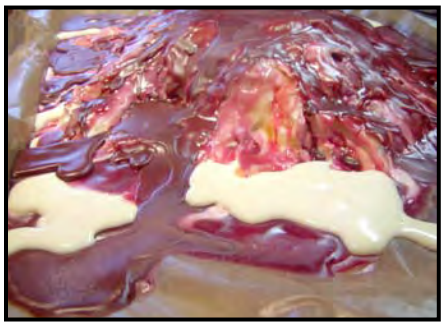
   Where does the wax lava travel the farthest? Where does the wax lava pool? Do students observe melting of the ice cream glaciers? How does the lava interact with the walls of the tray?

5. **Repeat the pouring of wax lava flows and student observations until all wax has been poured.**

   Use cooling times for discussion of energy transformation that occur when hot lava meets glacier ice.

6. **Instruct students to make additional observations and to relate them to an actual volcano.**

   For example, students might note that melting of the ice cream represents melting of glaciers; wax lava flows travel fastest on steep slopes and they form pools and solidify at the base of the volcano; wax lava solidifies against tray walls as real lava flows would pool against valley walls. Students might note that wax lava flows that travel off the volcanic cone, and over glaciers are thin and breakable.



Part IV: Explore Lava Flows at Mount Rainier

1. Review the graphic *"**How Lava Ridges are Made**"* with the students. Was this process of ridge formation one of the processes noted in the *"**Fire and Ice**"* demonstration?

2. Look at the *"**Volcanic Rocks of Modern Mount Rainier**"* graphic with students and locate the more than a dozen lava flow ridges at Mount Rainier such as Rampart, Paradise, and Mazama Ridge. Optionally, instruct students to find these ridges on a topographic map of Mount Rainier. What type of features are located adjacent to ridges? ***(answer is glacial valleys)***. These ridges were formed during successive ice ages 500,000–11,000 years ago.

3. Further examine the graphic "***Volcanic Rocks of Modern Mount Rainier***." Look at the general "spoked-wheel" pattern of the lava flows. Ask students if they observed a similar process in the *"**Fire and Ice**"* simulation. Ask students why there are gaps in the spokes of some of the wheels. Refer back to the *"**Fire and Ice**"* volcano model for clues. Ask students how weathering and erosion could have changed the ridges over the course of the last 10,000 years.

4. Make the process relevant to the situation today. In the absence of glaciers that envelop the entire volcano, and recent lava flows, are the current valleys at Mount Rainier being built or carved by glaciers? ***Glaciers are eroding the valleys. Students should also recognize that today's glaciers are small and constrained within valley walls, and are incapable of routing the course of lava flows as in the days of the ice ages***.

Adaptations

- Use modeling clay on a relief map to simulate large glaciers from the ice age. Lift the modeling clay and examine the shapes on the underside. Students note that the clay glaciers are thicker in valleys between the ridges.

- Take time-lapse photographs of your experiment.

Extensions

- Instruct students to conduct research projects about glacier-volcano interactions. Students can visit Web sites listed on the **Internet Resources List** to identify landscape features that are products of glacier-volcano interactions at Cascade volcanoes, Iceland, and elsewhere.

- Engage the class in a discussion of energy transformations using these concepts: As the blocks of lava begin to avalanche down the mountainside, the lava begins to accelerate. If you've ever tried to carry a large block up a mountain, you know that it takes a lot of energy! Once you drop that block down the mountain side and it begins to roll, the energy that it took to lift it up the mountain is converted into kinetic energy—the energy of motion.

- Engage the class in a discussion of heat transfer between lava and glacier ice along the following concepts: Many lava flows that issue from steep-sided volcanoes break up into blocks and rubble that avalanche down the slope and mix with snow and ice. The melting of snow and ice by this process has the potential to create lahars that travel great distances beyond the slope of the mountain and threaten nearby communities.

Assessment

Use the questions in the *"**Fire and Ice Simulation**"* to assess students' thinking as it progresses through recognition that glaciers influence the landscape on a volcano. Note how students' understanding develops from general observations of the volcano model to recognition of the processes that shape an actual ice-covered volcano. As the activity progresses, students should recognize that the volcano and glaciers co-exist as a dynamic system and that many geologic and hydrologic features on the volcano are the results of glacier-volcano interactions. Students should begin to think more globally, and recognize that glaciers can influence the shape of glacier-clad volcanoes worldwide. To further assess their understanding, instruct students to write a summary paragraph about glacier-volcano interactions.

References

Crandell, D.R., and Miller, R.D., 1974, Quaternary stratigraphy and extent of glaciation in the Mount Rainier region, Washington: U.S. Geological Survey Professional Paper 847, 59 p.

Driedger, C.L., 1986, A visitors guide to Mount Rainier glaciers: Pacific Northwest National Parks and Forests Association, 80 p.

Driedger, C.L., and Kennard, P.M., 1986, Ice volumes on the Cascade volcanoes: Mount Rainier, Mount Hood, Three Sisters, and Mount Shasta: U.S. Geological Survey Professional Paper 1365, 28 p.

Driedger, C.L., 1993, Glaciers on Mount Rainier, U.S. Geological Survey Fact Sheet, Open-File Report 92–474, 2 p.

Lescinsky, D.T., and Sisson, T.W., 1998, Ridge-forming, ice-bounded lava flows at Mount Rainier, Washington: Geology, v. 26, pp. 351–354.

Lescinsky, D.T., and Fink, J.H., 2000, Lava and ice interaction at stratovolcanoes: use of characteristic features to determine past glacial extents and future volcanic hazards: Journal of Geophysical Research, v.105, 23, pp. 711–23,726.

Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

Photo Credits

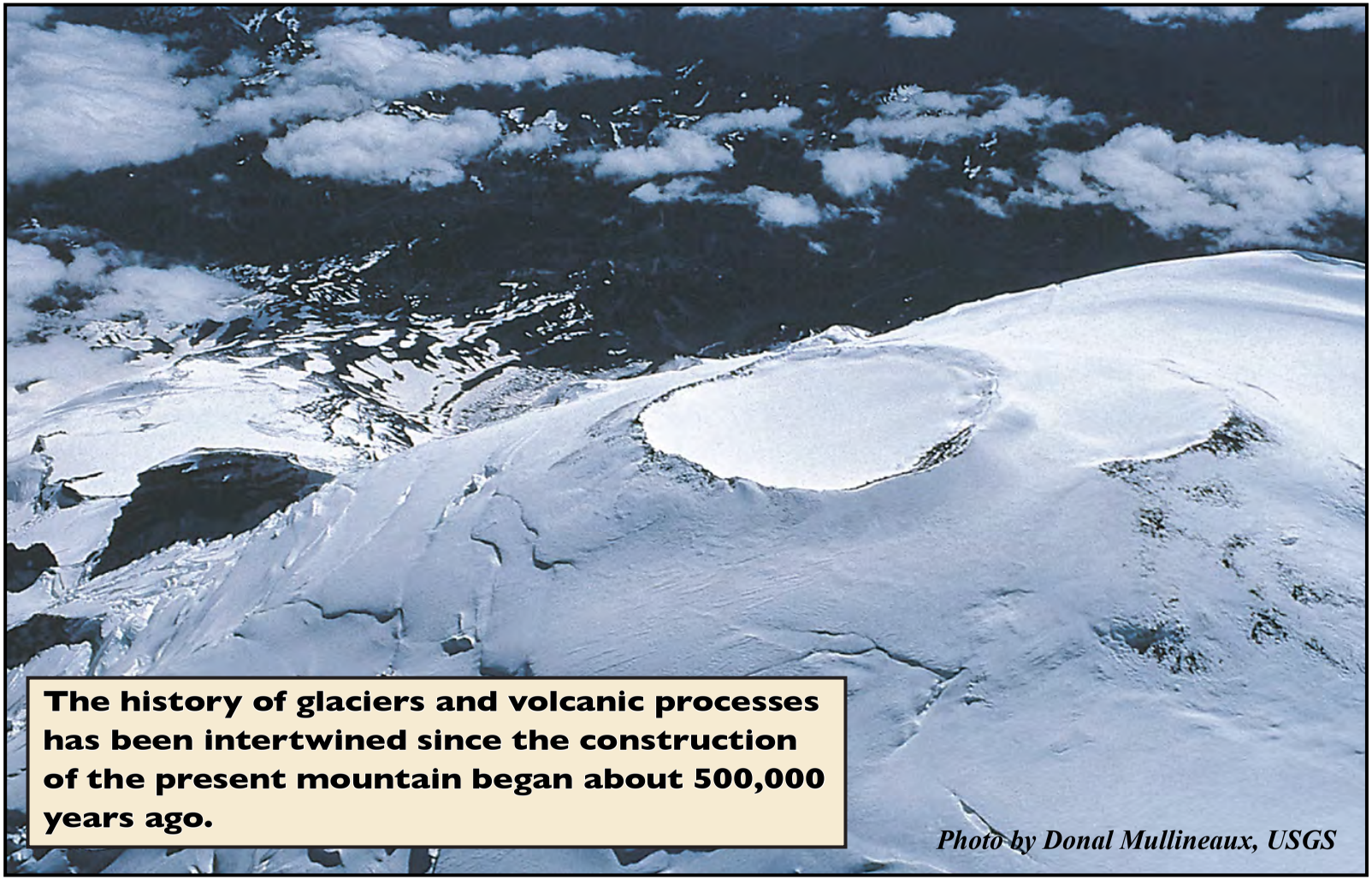
1. Glaciers on Mount Rainier, Photo by Carolyn Driedger, USGS.
2. Columbia Crest summit, Photo by Donal Mullineaux, USGS.
3. Glacier-volcano interactions, Photo by Carolyn Driedger, USGS.
4. Glacier scratches (striations) on lava rock at Mount Rainier, Photo by Carolyn Driedger, USGS.
5. Lava Flows—Experimental and real world comparisons, Photo by Carolyn Driedger, USGS.

Graphic Page

Glaciers on Mount Rainier

Photo by Carolyn Driedger, USGS

Columbia Crest Summit



The history of glaciers and volcanic processes has been intertwined since the construction of the present mountain began about 500,000 years ago.

Photo by Donal Mullineaux, USGS

Graphic Page

Glacier Volcano Interactions

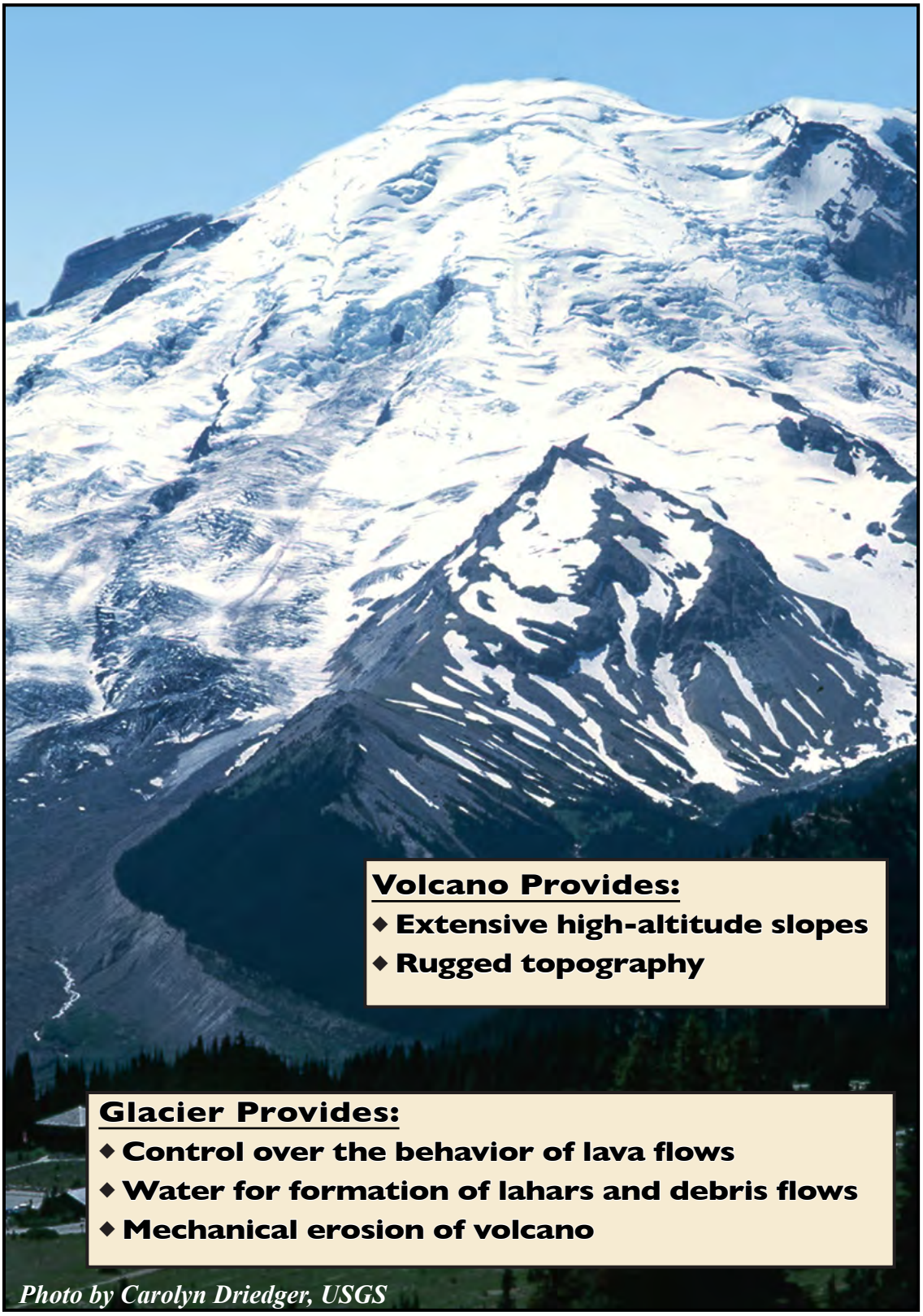
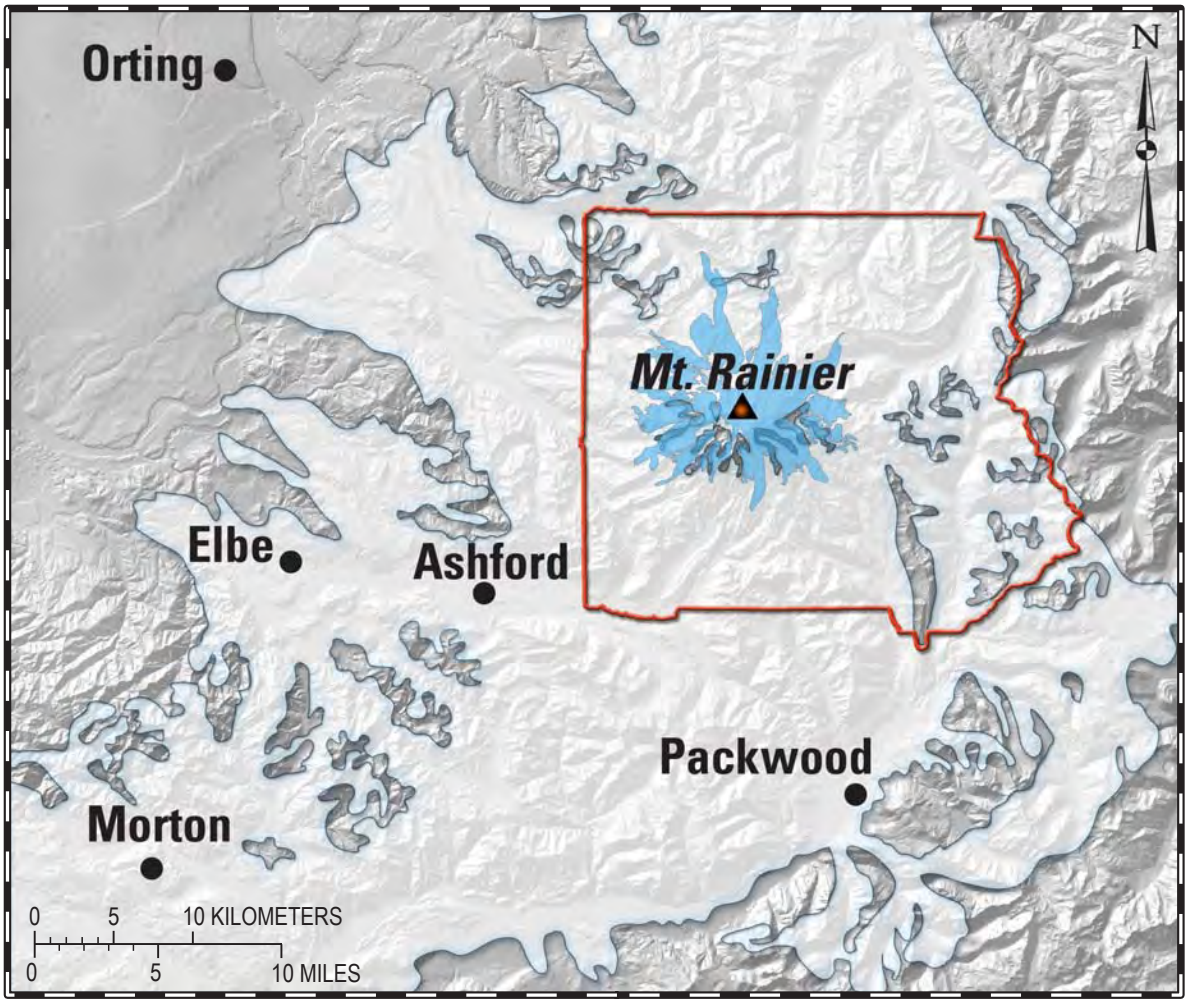


Photo by Carolyn Driedger, USGS

Graphic Page

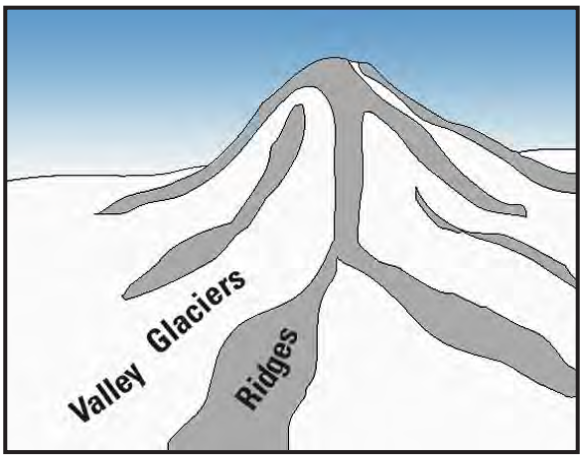
Maximum Extent of Glaciers on Mount Rainier During the Ice Ages



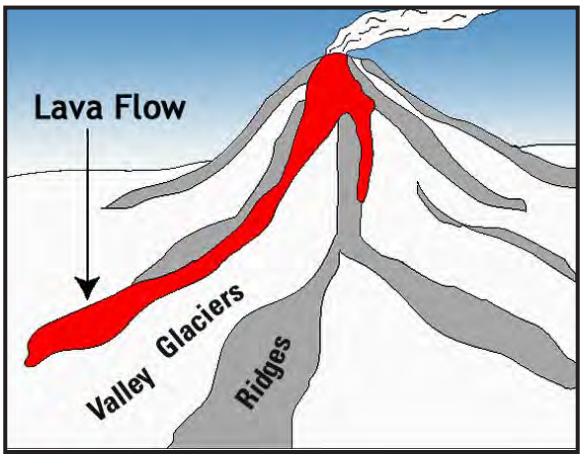
Modified from Crandall and Miller, 1974.

Graphic Page

How Lava Ridges are Made

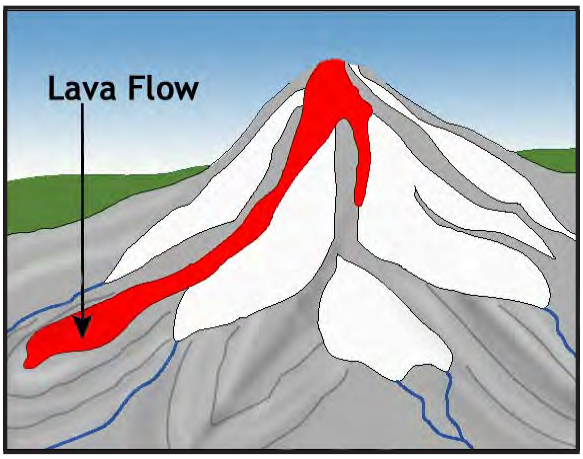


Ice Age glaciation on Mount Rainier—
Ice-age glaciers buried much of Mount Rainier. Some rock ridges remained exposed.



Eruption of lava during ice ages—
Some lava flows disintegrated as pyroclastic flows. Others melted holes in the glacier, but later were buried by flowing ice.

This lava flow met little resistence on the rock ridge, and flowed a great distance. It cooled and hardened.

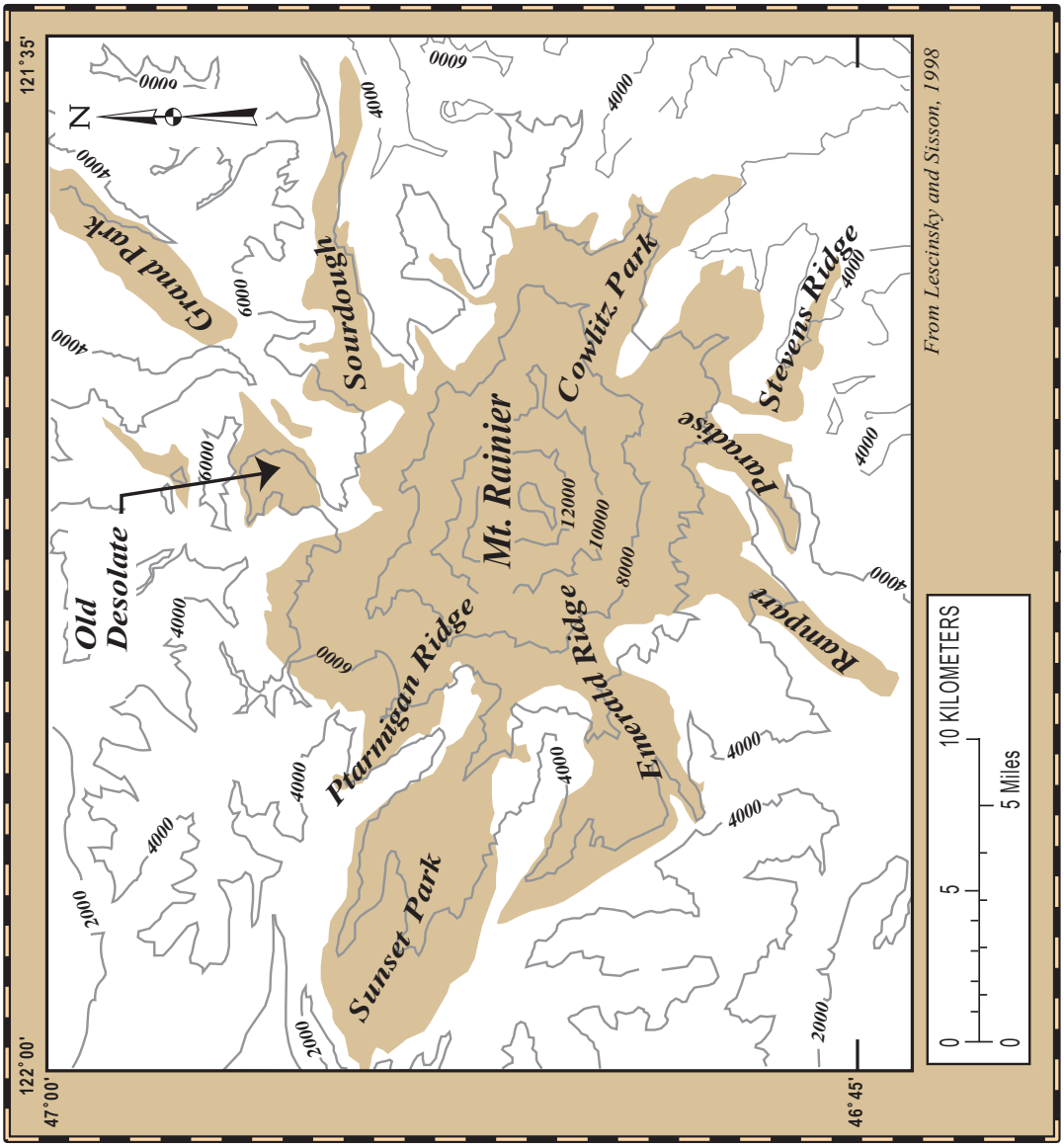


Lava ridges and glaciers today—
Glaciers melted at the end of the ice age. Stack of lava flows remain as ridges.

Glacier Scratches (Striations) on Lava Rock At Mount Rainier

Photo by Carolyn Driedger, USGS

Volcanic Rocks of Modern Mount Rainier

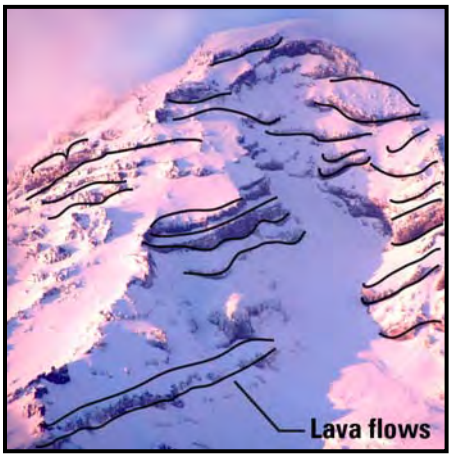


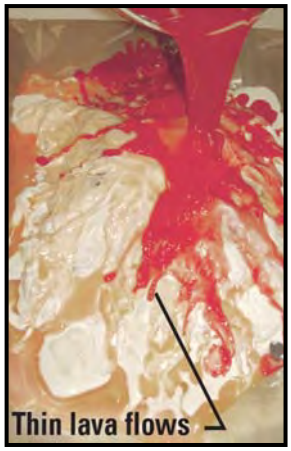
From Lescinsky and Sisson, 1998

Graphic Page

Lava Flows—
Experimental and Real World Comparisons

Lahar deposits—*Snow and ice meltwater from pyroclastic flows formed this lahar deposit, which is represented by the flow of melted ice cream in the experiment.*





Thin lava flows on the cone—*Thin lava flows eroded by glaciers are represented by thin wax lava flows that hardened on the volcano model.*

Lava flow ridges—*A thick stack of lava flows built the ridges on both sides of Nisqually Glacier. Similar far-traveled wax lava flows poured down the volcano model to the tray bottom.*

Lahar in a Jar!

Grade Level: 6–10

Learner Objectives:

Students will:

- Recognize lahars as the principal volcano hazard at Mount Rainier
- Become familiar with some of the more significant lahars that originated on Mount Rainier
- Recognize the role of lava flows, pyroclastic flows, landslides, and glaciers that initiate debris flows and lahars
- Recognize that an abundance of surface water and loose, weakened rock makes Mount Rainier highly susceptible to lahars and debris flows
- Observe how only a small amount of water is required to initiate a debris flow or lahar
- Become familiar with the nature of lahars and debris flows, and the proper usage of the terms

Setting: classroom

Timeframe: 50 minutes

USGS
science for a changing world

Living with a Volcano in Your Backyard–An Educator's Guide with Emphasis on Mount Rainier

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

Explore how small amounts of water can mobilize loose rock to form lahars by making a small lahar within the safety of a beaker or jar and analyzing it using scientific methods.

Teacher Background

Lahars are fast flowing torrents of rock, mud, and water

Lahars, also known as volcanic mudflows or ***debris flows***, are worthy of attention because they are the principal volcanic hazard in the valleys that head on Mount Rainier. The word lahar is an Indonesian term that refers to any rapidly flowing and gravity-driven mixture of rock, mud, and water that rushes down the slopes of a volcano. Lahars have been known to travel distances of more than one 100 kilometers (60 miles) at speeds of 60 kilometers per hour (40 miles per hour).

While many scientists treat the terms lahar and debris flow synonymously, scientists and officials working at Mount Rainier seek to reduce confusion locally by modifying word usage. They reserve the word lahar for large flows of eruption or ***landslide*** origin with potential to travel to densely populated valleys, and use debris flow for much smaller events caused by glacier floods and precipitation, which stay generally within park boundaries.

Activity last modified: September 5, 2014

Materials:

- 100 millileter or larger graduated cylinder
- Wide-mouth 1 liter beaker
- Large wooden spoon or paint stirrer
- 200 to 400 millileters of lahar deposit or rock debris, as prepared in accompanying recipe
- Calculator
- Copies of *"Lahar in a Jar"* student page
- 1-meter-long (3-foot-long) flat board or gutter
- Graphic *"Three Prominent Lahars at Mount Rainier"*
- Graphic *"Mount Rainier and Emmons Glacier"*
- Graphic *"Extension Maps of Lahar Hazard Zones"*
- Graphic *"Debris Flow on Tahoma Creek, 1986"*
- Graphic *"Mount Rainier Lahar Hazards Zone"*
- Graphic *"Tahoma Creek After Debris Flow, 1986"*

Vocabulary: Beaker, debris flow, flank collapses, glacier outburst flood, graduated cylinder, hydrothermal alteration, lahar, landslide, lava flow, pyroclastic flow

Skills: Observation, record, calculation, prediction

Benchmarks:

See benchmarks in Introduction.

Once witnessed, lahars and debris flows are seldom forgotten

The ground shakes and rumbles in a way similar to that of an approaching train. Dust plumes rise into the air above the flow front and small pebbles splash skyward. The flow, tan or gray in color, looks and behaves like a river of flowing concrete. Boulders crush and grind vegetation, which releases a strong stench of organic oils that hangs in the air long after the event is over. Where valley walls widen, lahars spread, drain and cease motion. Boulders and trees that had been buoyed and pushed to flow margins come to rest as blocky ridges along the flow's margin.

The speed of a lahar and debris flow depends upon its volume and the slope gradient. Some of the faster flows have been clocked at speeds of 30 to 60 kilometers per hour (20 to 40 miles per hour). Lahars may last for hours or days; debris flows generally last for half an hour to several hours. Both leave behind an inhospitable surface of tightly-packed mud, boulders, and vegetative debris.

Abundant water and rock debris make Cascade volcanoes highly susceptible to lahars and debris flows

Eruptions have built vast volcanic slopes at high elevation that are scattered with lava fragments and that retain snow and glacier ice. Mount Rainier's slopes are covered by approximately 4.4 cubic kilometers (1 cubic mile) of snow and ice, an amount equivalent to that on all the other Cascade volcanoes combined!

Most lahars form during volcanic eruptions, but landslides can also produce lahars.

Almost all lahars happen during volcanic eruptions when hot ***pyroclastic flows*** and ***lava flows*** interact with snow and ice. This scenario repeated at Mount Rainier many times has resulted in thick sequences of lahar layers beneath the floors of some valleys.

Not to be discounted are large landslides, known as ***flank collapses***, that can also produce lahars. The largest landslide-induced lahars have occurred during eruptive periods and involved rock that had been weakened by long-term exposure to hot acidic groundwater, a process called ***hydrothermal alteration***.

What triggers a flank collapse? Accepted mechanisms include instability at the onset of or during volcanic eruptions, large earthquakes, intense ground deformation by rising magma and perhaps long-term exposure to gravity. While the chance of a flank collapse is greatest during eruptive periods, the possibility exists of failure during noneruptive times.

Rocks at the head of the Puyallup River valley are more prone to landslides than rocks elsewhere on Mount Rainier, because they contain hundreds of millions of cubic meters (cubic yards) of hydrothermally altered and weakened rocks. At least seven landslide-initiated lahars have covered valley floors in the southern Puget Sound area over the past six thousand years.

Small events caused by rainfall and glacier flood

Conditions that favor debris flow formation are glacier outburst floods in mid-summer and intense rainfall in late fall. These events are small when compared to lahars produced during eruptions, having a thickness of only tens of meters (feet) and traveling only a few kilometers (miles) from their source. Lahars can reach a thickness of 100 meters (300 feet) or more and travel far from source. Debris flows happen once or twice a year at some Cascade volcanoes, whereas lahars happen much less frequently.

What to do if in danger from a debris flow or lahar

Most large-volume lahars are associated with volcanic unrest and eruptions. Usually earthquakes or other precursory activity at a volcano serve as a warning that an eruption is immiment. While debris flows happen frequently and large volume lahars happen infrequently, the necessary response is the same. Get to high ground off the valley floor.

Procedure

What to do Before Class Begins:

- Decide if you are going to do a large group demonstration or have the students work independently or in small groups.
- Collect materials.
- Make copies of student page Lahar in a Jar.
- Prepare to show graphics.

Lahar Debris Recipe

Obtain and mix ingredients to the volume proportions shown below. Mix a batch that is sufficient to provide 400 milliliters to each student group. All ingredients should be dry.

Note that while scientists generally measure contents by weight, this activity provides a general conversion from percent weight to volume so that the activity can be conducted with ease in the field or classroom. This method does not account for porosity (air spaces between the particles) of the solids.

Quantities provided make enough lahar material for (10) 400 milliliter experiments. Place the following in a dry 5-gallon bucket or other container:

- 2.0 L gravel from a driveway (pea to marble-size)
- 3.0 L sand from a sand box or river bank
- 2.0 L garden soil (soil with high clay content and minimal organic matter works best. Look for clay loam or silt loam commercially)
- 0.6 L dry potters clay powder (available from pottery supply stores)

Sidebar 1

Some Significant lahars and debris flows at Mount Rainier

The Osceola Mudflow

A volcanic eruption about 5,600 years ago triggered a flank collapse that removed 3 cubic kilometers (0.7 cubic mile) from the summit and eastern flank of Mount Rainier. Because the landslide contained a lot of water and also picked up snow melt and river water, it transformed into a lahar that rushed down the White and Nisqually River Valleys as far as northern Puget Sound. In the White River Valley, the lahar deposited a layer of debris that ranged from approximately one 1 meter (3 feet) to 60 meters (200 feet) thick, and covered the region now occupied by the communities of Enumclaw, Buckley, Auburn, Kent, Sumner, and Puyallup. The lahar left behind giant mounds of orange-colored debris that are visible east of the communities of Enumclaw and Ashford. The Osceola Mudflow is the largest lahar known to have occurred on Mount Rainier.

The Electron Mudflow

A landslide initiated this mudflow (lahar) around 500 years ago. Weakened rock on the west flank of Mount Rainier collapsed and slid into the Puyallup River Valley, where it transformed into a lahar that flowed approximately 100 kilometers (60 miles), all the way to the outskirts of Puyallup and perhaps to Puget Sound. This lahar deposited sediment as thick as 30 meters (100 feet), and buried the base of trees in an old growth forest. Construction workers excavating ground for utilities continue to find large logs and stumps buried by the lahar. There is no conclusive evidence that an eruption triggered the Electron Mudflow although it may have happened at the onset of or during minor eruptive activity. The Electron Mudflow reminds us of the possibility that lahars may have noneruption origins.

The National Lahar

The National Lahar is one of the larger lahars formed from the melting of snow and ice during eruptive activity. This lahar swept down the Nisqually River Valley to the Puget Sound 100 kilometers, (60 miles) away, between 2,200 and 500 years ago. Between Ashford and the western entrance of Mount Rainier National Park, it deposited a 3-meter (10-foot) thick layer on the valley floor. Loose rock layers deposited by the National Lahar look like large boulders set into a matrix of fine-grained material.

Debris flows

Debris flow activity at Mount Rainier has been significant in the valleys of Tahoma Creek, Kautz Creek, Van Trump Creek, Nisqually River, and the West Fork of the White River, where loose debris has been deposited during eruptions or left behind from glacier recession. Periods of intense debris flow activity tend to occur during glacier recession, or when excessive water from rainfall or snowmelt flows across loose rock deposited by the retreating glacier.

Years of some prominent debris flow events

Tahoma Creek 1967, 1968, 1970, 1971, 1979, 1981, 1986–2006

Kautz Creek 1947, 1961, 1985, 1986, 2005, 2006

Pyramid Creek 2005, 2006

Van Trump Creek 2001, 2003, 2005, 2006

Nisqually River 1926, 1932, 1934, 1955, 1968, 1970, 1972, 1986

West Fork White River 1987, 2006

Activity Procedure:

Introducing Lahars and Debris Flows:

Introduce students to lahars and debris flows through class discussion and graphics, and then conduct the experiment.

1. Instruct students to list some of the distinctive components and characteristics of Mount Rainier that are visible in the photograph entitled "***Mount Rainier and Emmons Glacier***." Lead the discussion towards these three features: glaciers, loose rocks, steep slopes. Ask them to explain how volcanic heat, glaciers and snow might interact.Introduce the concept of a lahar as a mixture of rock, mud, and water that rushes down the slopes of a volcano and its river valleys. Rapid melting of snow and ice during eruptions generally cause lahars, though landslides can also initiate them.

2. Instruct students to hypothesize about what happens when an excess of stream water, originating with intense snowmelt in mid-summer or extreme rainfall, flows across valley bottoms strewn with loose rock. Explain that these conditions can lead to debris flows.

3. Instruct students to hypothesize whether or not Mount Rainier is a potential site for lahars. They should explain their reasoning. ***Yes, it is the site of frequent debris flows (almost annually). There is an abundance of loose volcanic rock from eruptions and glacier action, and water from snow and ice melt and rain. In addition, rock fall and landslides can initiate lahars.***

4. Tell students to use their knowledge of debris flows and lahars to identify the types of terrain over which lahars and debris flows generally travel. ***Answer: in river valleys.***

5. Use the graphic "***Tahoma Creek Debris Flow, 1986***" to illustrate the appearance of a lahar on Tahoma Creek on the west side of Mount Rainier National Park. Use the graphic "***Three Prominent Lahars***" to follow the pathway of three major Mount Rainier lahars—Osceola, Electron, and National. These three prominent lahars provide the basis for lahar hazard zones on the graphics "***Mount Rainier Lahar Hazards Map***" and "***Extension Maps of Lahar Hazard Zones***." Display the lahar hazards map and ask students which valleys would be affected by lahars and debris flows on each side of the volcano. Ask students to name the communities that are at risk.

6. Explain to students that debris flows tend to happen during intense rainfall and periods of rapid snowmelt at Mount Rainier. By definition, debris flows travel over terrain within the park and do not generally flow beyond park boundaries. Follow the pathway of some recent debris flows.

7. Determine whether you live, work, or go to school on the debris from one of the lahars shown on the lahar hazard map. Discuss how lahars are significant to your community. Ask students to find the safest locations near their communities.

Make a lahar in a jar

Learn how only a small amount of water in motion can mobilize loose rock to form a lahar. Conduct this activity either as a teacher demonstration or in small groups.

1. Divide class into groups of 3 to 4 students.

2. Distribute "***Lahar in a Jar***" student page.

3. Instruct students to place approximately 400 milliliters of loose lahar material from recipe sample onto a large piece of paper and break up any large clumps of dirt and debris. Dump the loose rock into a ***beaker***. Press it firmly with your hands to remove spaces from between the particles. Record the exact volume on the student page.

4. Ask students to predict how much water they think is required to make the deposit flow like a lahar. 10 ml? 100 ml? More? Students record their prediction on the student activity sheet.

5. Fill the ***graduated cylinder*** with water and record the starting amount of water on the student page.

6. Instruct the students to begin pouring water in the beaker in increments of 10 ml.

7. Students should stir the loose rock after each addition of water.

8. After each addition of water, students should tilt the beaker to the side and gently rotate it sideways to determine if the mixture "flows" around the jar sides as a lahar would. The consistency initially is like that of dry dirt, but with the addition of water, changes to the consistency of cookie dough and later to that of thick cake batter. Decrease the amount of water added each time as your lahar begins to flow. Remember, it does not take much water to get debris flowing.

9. Students sum the amount of water used after the rock debris forms a lahar in the jar and record the amount on the student page.

10. Instruct students to compare the total volume of lahar and water and determine the percent water required to produce a lahar in a jar. Ask whether the amount of water was as predicted. ***Answer: will probably be between 20 to 40 percent, depending on the material used. At Cascade Volcanoes, the water content in debris flows and lahars is generally between 30 and 45 percent.***

11. Each student group should pour their lahar onto the inclined gutter or board for all of the class to see. Ask for hypotheses about what happens when slope of the gutter or board is changed, then test the hypotheses. Inquire about any interesting observations made of the lahar mixture. ***The lahar may flow in single or multiple surges. Velocity of the flow increases with slope.***

12. Ask students to follow the path of energy transformation, and to write about this, or draw a diagram on the reverse side of their student pages. ***Students should report that the lahar while still in the jar has potential energy. Kinetic energy is released as the lahar slides down the gutter or board.***

13. Ask students what conditions exist on Cascade volcanoes that promote development of lahars. ***Answers: Loose rock, abundant water, steep slopes, heat.***

Adaptations

- Provide students with sand, clay, garden soil and gravel and instruct them to hypothesize about what happens when the amount of clay is increased and decreased. Instruct students to design and conduct experiments with different proportions of materials.

- Obtain rock debris from other sources in your community, such as streambeds, lahar deposits, gardens, etc., and repeat Lahar in a Jar again. Compare results with your lahar recipe mixture.

Extensions

- Instruct students to draw a diagram and (or) a flow chart that illustrates the initiation and activity of lahars and debris flows.

- Use library and Internet searches to learn more about the lahar history of Mount Rainier and the other snow-clad volcanoes of the Cascades.

- This experiment does not account for the porosity (air space between the particles) of the solids. Instruct students to design an experiment that accounts for porosity.

Assessment

Use the questions in the "***Introducing Lahars and Debris Flows***" and "***Making a Lahar in a Jar***" to assess students' understanding of the conditions required to form lahars and debris flows. Look for evidence that students understand the following concepts: debris flows and lahars form where there is an abundance of rock debris, groundwater, and free-flowing surface water; that only a small amount of water is required do initiate a debris flow or lahar; lava flows, pyroclastic flows, landslides and glaciers, and weakened rock make Mount Rainier susceptible to lahars and debris flows; that lahars are the principal eruptive hazard at Mount Rainier, even many kilometers (miles) distant. As the activity progresses, look for evidence that students think globally, and recognize that lahars and debris flows occur on volcanoes worldwide. Understanding the character and chronology of these events at a volcano helps scientists identify communities at risk from lahars today. Students should recognize that knowledge of lahars and debris flows enables scientists to identify when and where people are at risk; this knowledge ultimately can help citizens live responsibly and improves the health and well-being of communities.

References

Driedger, C.L., and Fountain, A.G., 1989, Analysis of recent glacial outburst floods on Mount Rainier: Annals of Glaciology, 1988, pp. 51−59.

Scott, K.M., Vallance, J.W., and Pringle, P.T., 1995, Sedimentology, behavior, and hazards of debris flows at Mount Rainier, Washington: U.S. Geological Survey Professional Paper 1547, 56 p., 1pl.

Vallance, J.W., and Scott, K.M., 1997, The Osceola Mudflow from Mount Rainier: sedimentology and hazard implications of a huge clay-rich debris flow: Geological Society of America Bulletin, February, 1997, v. 109, no. 2: p. 143–163, 6 tables.

Vallance, J.W., Driedger C.L., and Scott W.E., Diversion of meltwater from Kautz Glacier initiates small debris flows near Van Trump Park, Mount Rainier, Washington: Washington Geology, v. 30, no. 1/2 July 2002, pp. 17–19.

Walder, J.S., and Driedger, C.L., 1994, Geomorphic change caused by outburst floods and debris flows at Mount Rainier, Wash.,: U.S. Geological Survey Water Resources Investigation Open-File Report 93−4093, 93 p.

Walder, J.S., and Driedger, C.L., 1994, Rapid Geomorphic change caused by glacial outburst floods and debris flows along Tahoma Creek, Mount Rainier, Wash., USA: Arctic and Alpine Research, v. 26, no. 4, pp. 319−327.

Walder, J.S., and Driedger, C.L., 1994, Frequent outburst floods from South Tahoma Glacier, Mount Rainier, USA: relation to debris flow, meteorological origin and implications for subglacial hydrology: Journal of Glaciology, v. 41, no. 137, pp. 1–10.

Walder, J.S., and Driedger, C.L., 1993, Glacier-generated debris flows at Mount Rainier: U.S. Geological Survey Fact Sheet, Open-File Report 93–124, 2 p.

Zehfuss, P.H., Atwater, B.F., Vallance, J.W., Brenniman, H., and Brown, T.A., 2003, Holocene lahars and their by-products along the historical path of the White River between Mount Rainier and Seattle: in Swanson, T.W., ed, Western Cordillera and adjacent areas: Boulder, Colorado, Geological Society of America Field Guide 4, p. 209–223.

Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

Photo Credits

1. Mount Rainier and Emmons Glacier, Photo by Carolyn Driedger, USGS.
2. Debris Flow on Tahoma Creek on July 26, 1988, Photo by G.G. Parker, USGS.
3. Tahoma Creek after Debris Flows, 1988, Photo by Carolyn Driedger, USGS.

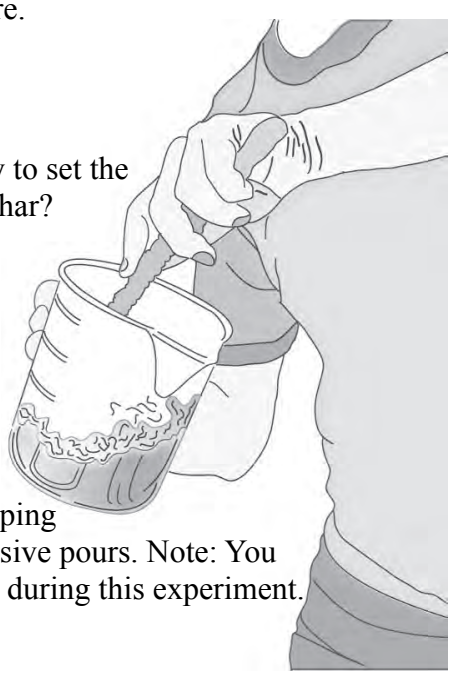
Student Page

Team Names _____

Lahar in a Jar

Instructions: *Follow the procedures below to make a small lahar in a jar. You will mix known volumes of rock debris and water. Give your mixed lahar a run down a gutter or board provided by your teacher.*

1. Place approximately 200 to 400 milliliters of "lahar" into a beaker. Break up any large clumps of dirt and debris. Record the exact volume here.



2. Make a prediction. How much water will be necessary to set the rock debris sample into motion as a small, in-the-jar lahar? 10 ml? 100 ml? Record your prediction.

3. During this experiment, you will pour water into the beaker repeatedly, in increments of approximately 10 ml. In the space below, develop a procedure for keeping track of the amount of water that you tip during successive pours. Note: You may need to fill the graduated cylinder more than once during this experiment.

4. Pour water into the beaker in increments of approximately 10 ml. Stir the lahar rocks and water with a spoon or a stick after each addition of water. Tilt the beaker and gently rotate it sideways to observe if the mixture "flows" around the jar sides as a lahar would move. Repeat as much as necessary, and test for flowing. When the mixture begins to flow, STOP! Add no more water! Note that the mixture first appeared as dry dirt, but with the addition of water, has changed to the consistency of cookie dough and now resembles thick cake batter.

Student Page

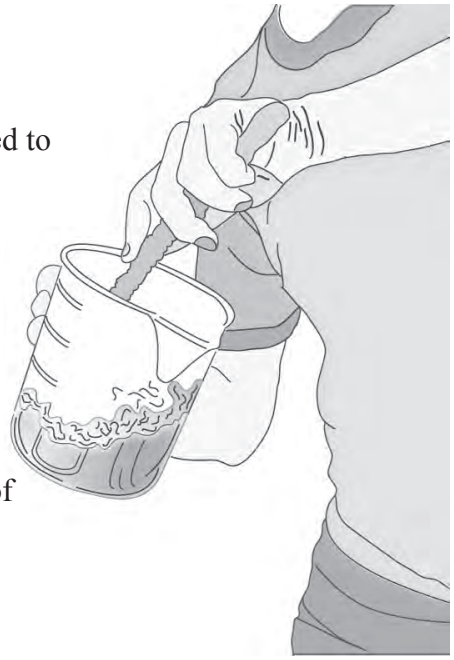
Team Names _____

Lahar in a Jar-continued

5. Compare the total volume of water to the cumulative volume of lahar rocks and water. Use the space below to calculate the percent water required to form a lahar in the beaker. Record your result here.

$$\textbf{Percent water} = \frac{\textbf{ml water added}}{\textbf{ml lahar deposit + ml of water added}} \times 100$$

6. Determine whether the actual percent of water required to make a lahar is more or less than your prediction.



7. After completion of this experiment, preserve your sample for its run down a gutter or board as provided by your teacher. Explain why the slopes of Cascade volcanoes are an ideal location for the development of debris flows and lahars.

8. Describe or draw a diagram of the energy transformations that happen as a lahar rushes down the flanks of a volcano and comes to rest.

Teacher Page

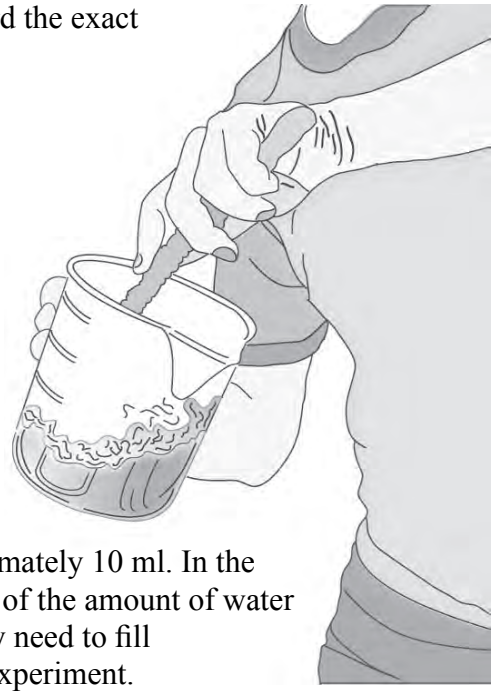
Lahar in a Jar—Answers

Instructions: *Follow the procedures below to make a small lahar in a jar. You will mix known volumes of rock debris and water. Give your mixed lahar a run down a gutter or board provided by your teacher.* ***Answers provided on the teacher page are derived from a trial run with the mixture of lahar material noted in the lahar recipe. Answers will vary, depending upon your sample's clay content, compaction, density, and moisture content.***

1. Place approximately 400 milliliters of "lahar" into a beaker. Break up any large clumps of dirt and debris. Record the exact volume here.

ANSWER:

400 ml



2. Make a prediction. How much water will be necessary to set the rock debris sample into motion as a small, in-the-jar lahar? 10 ml? 100 ml? Record your prediction.

ANSWER:

20 ml in this trial run

3. During this experiment, you will pour water into the beaker repeatedly, in increments of approximately 10 ml. In the space below, develop a procedure for keeping track of the amount of water that you tip during successive pours. *Note:* You may need to fill the graduated cylinder more than once during this experiment.

Students might choose to keep track of water increments added, or subtract the final reading from the top reading. Students will need to fill the graduated cylinder more than once during this experiment.

4. Pour water into the beaker in increments of approximately 10 ml. Stir the lahar rocks and water with a spoon or a stick after each addition of water. Tilt the beaker and gently rotate it sideways to observe if the mixture "flows" around the jar sides as a lahar would move. Repeat as much as necessary, and test for flowing. When the mixture begins to flow, STOP! Add no more water! Note that the mixture first appeared as dry dirt, but with the addition of water, has changed to the consistency of cookie dough and now resembles thick cake batter.

In this trial run, we added 130ml of water before the mixture began to "flow" when the beaker was rotated.

Lahar in a Jar—Answers-continued

5. Compare the total volume of water to the cumulative volume of lahar rocks and water. Use the space below to calculate the percent water required to form a lahar in the beaker. Record your result here.

ANSWER:

25 percent water but answer will range from 20 to 40 percent

6. Determine whether the actual percent of water required to make a lahar is more or less than your prediction.

ANSWER:

In this trial run, the actual value exceeded the predicted value.

7. After completion of this experiment, preserve your sample for its run down a gutter or board as provided by your teacher. Explain why the slopes of Cascade volcanoes are an ideal location for the development of debris flows and lahars.

ANSWER:

There is an abundance of surface water and loose volcanic rocks on the steep slopes of Cascade stratovolcanoes.

8. Describe or draw a diagram of the energy transformations that happen as a lahar rushes down the flanks of a volcano and comes to rest.

ANSWER:

The rock debris embedded within riverbeds and embankments holds potential energy Kinetic energy is released as the debris flow or lahar mobilizes the rock debris and carries it down valley.

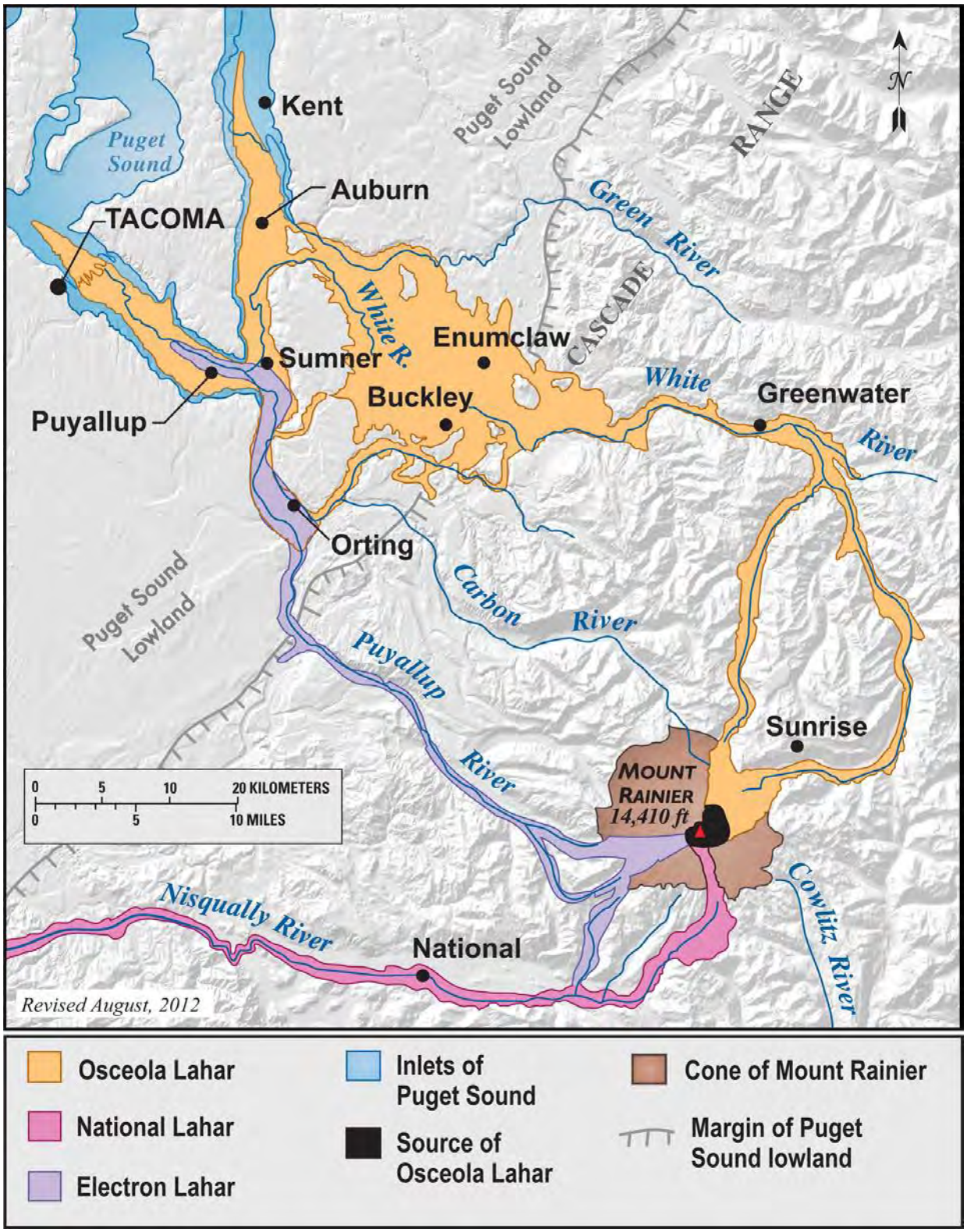
Graphic Page

Mount Rainier and Emmons Glacier

Photo by Carolyn Driedger, USGS

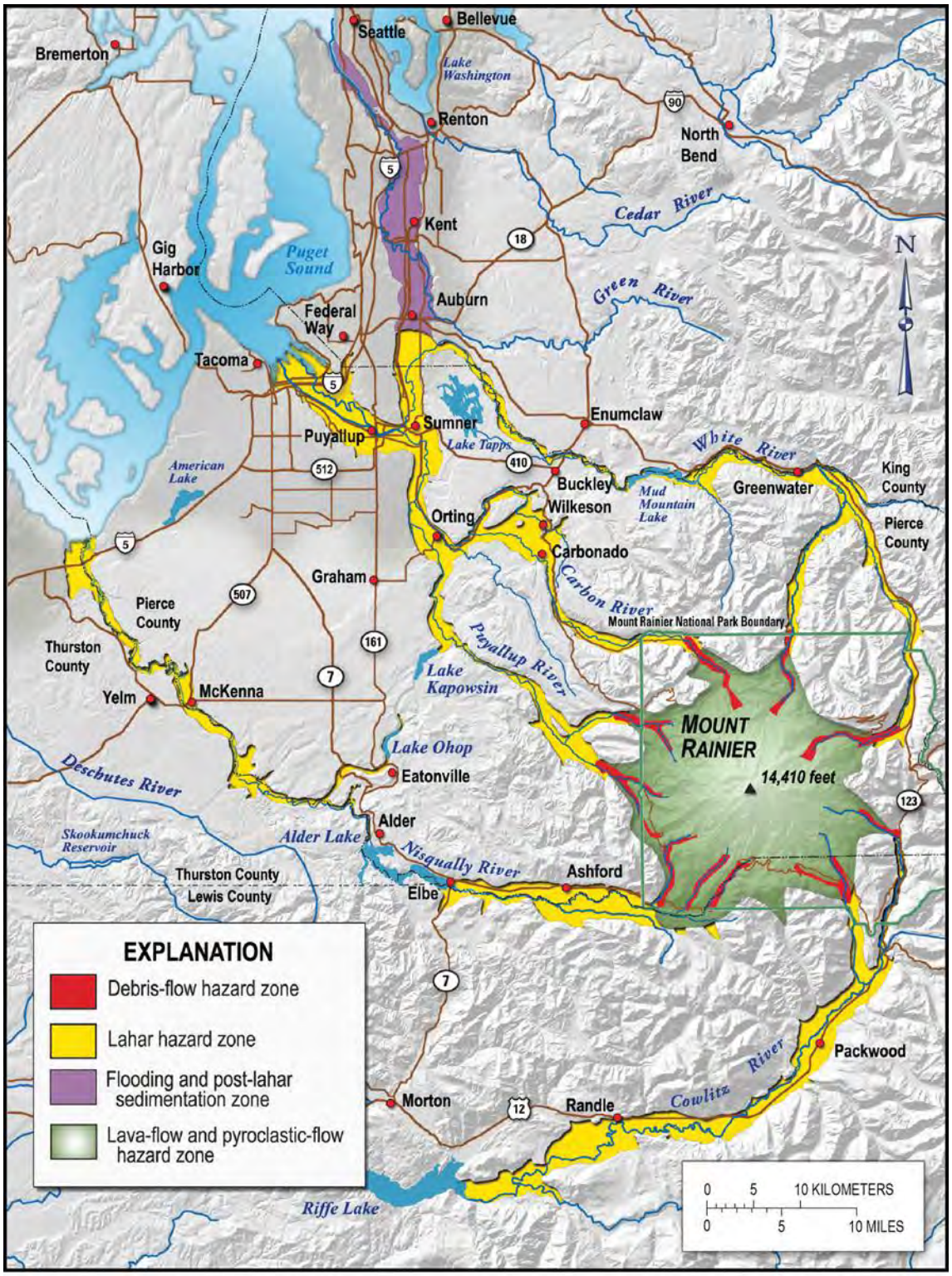
Graphic Page

Three Prominent Lahars—Map



Graphic Page

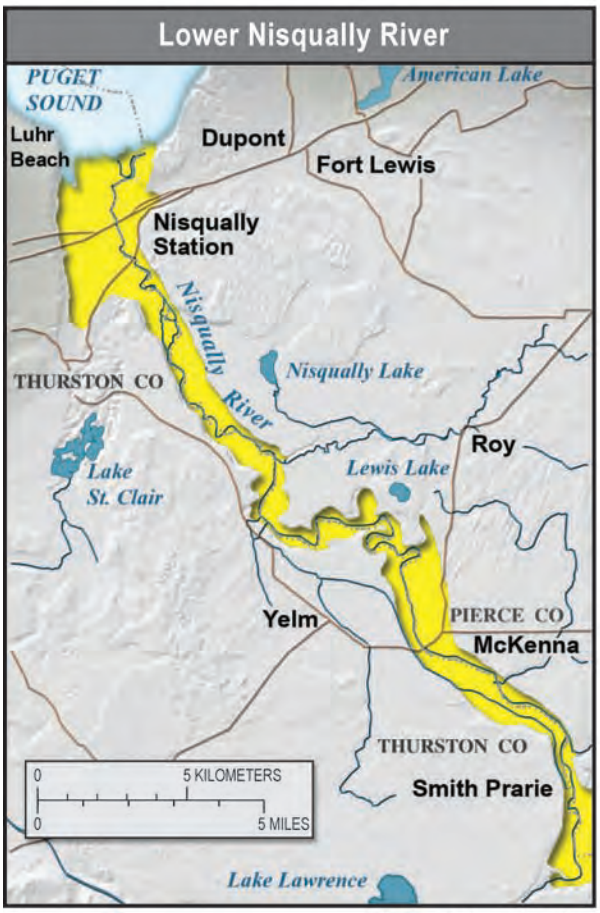
Map of Lahar Hazard Zones



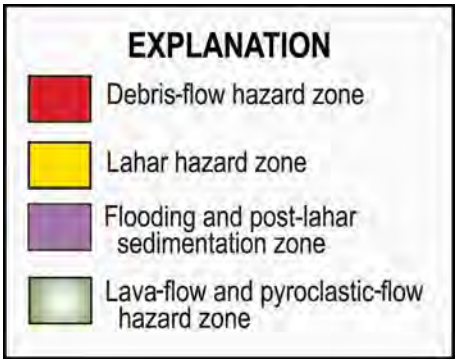
Revised September 5, 2014

Extension Maps of Lahar Hazard Zones

Revised March 15, 2011



Revised March 15, 2011



Graphic Page

Debris Flow on Tahoma Creek, 1988

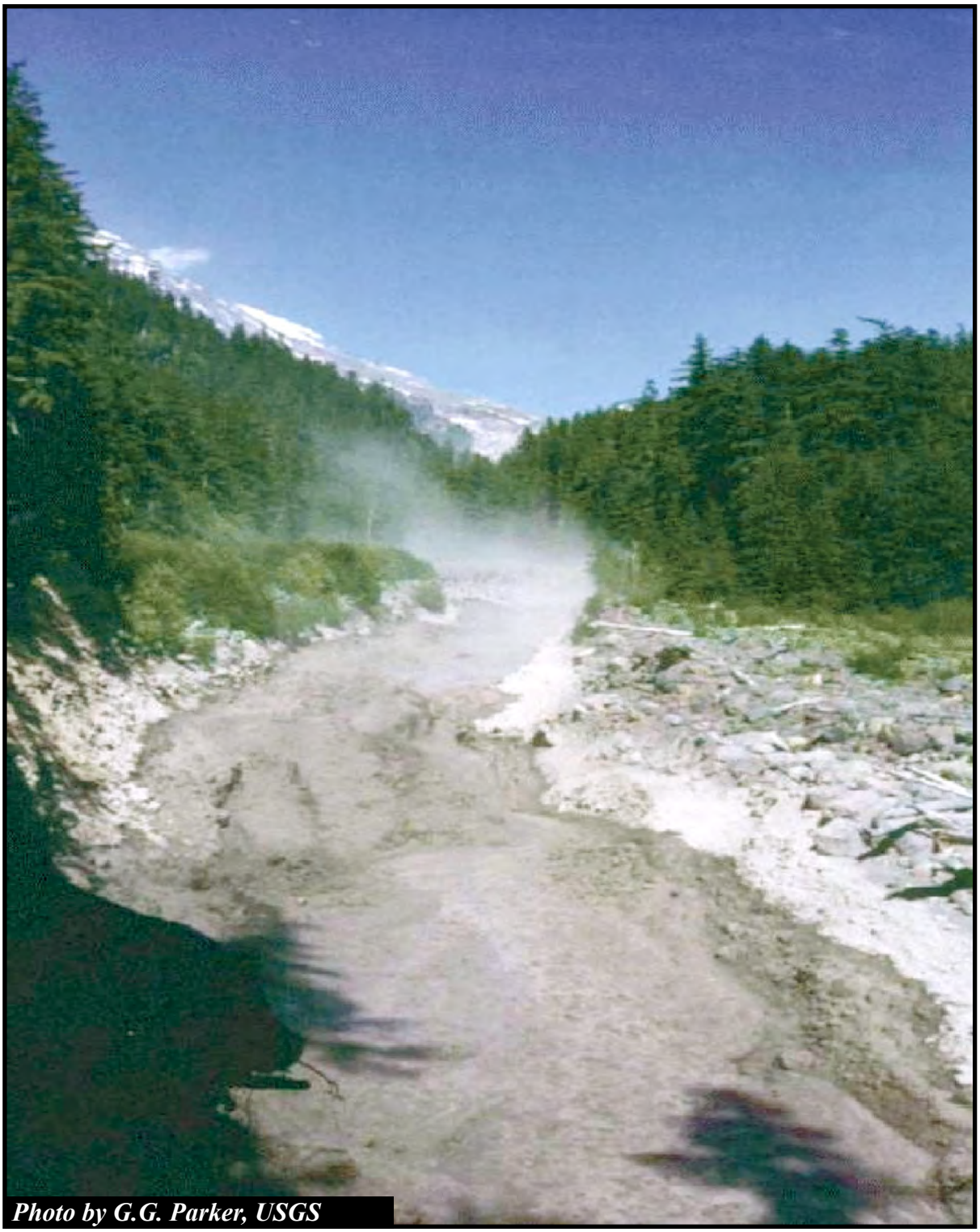


Photo by G.G. Parker, USGS

Graphic Page

Tahoma Creek After Debris Flows, 1988

Photo by Carolyn Driedger, USGS

Rock Rubble Review

Grade Level: 3–9

Learner Objectives:

Students will:

- Identify correctly the meaning of volcano terms
- Review the implication of volcano terms used in Chapter 2

Setting: *Geocharades* in classroom; *Volcano on the Run* in field or gym; *Volcano Anatomy Crossword*

Timeframe:

Geocharades—30 minutes
Volcano on the Run—40 minutes
Volcano Anatomy Crossword—30 minutes

Materials:

Geocharades

- Index cards
- Pens or pencils

Volcano on the Run

- *"Volcano on the Run"* teacher page
- Boundary markers (i.e., flagging, bandanas or construction cones

Volcano Anatomy Crossword

- Class copies of *"Volcano Anatomy Crossword"*
- Class copies of *"Volcano Anatomy"* clues
- Pencils or pens

Vocabulary: Ash, crater, debris flow, earthquake, eruption, fractures, fumarole, gas, glacier, hydrothermal alteration, lahar, landslide, lava, magma, magma chamber, magma conduit, pyroclastic flow, rockfall, rubble, seismologist, tephra, volcanologist

Skills: Application, interpretation, listening

Benchmarks:

See benchmarks in Introduction.

USGS science for a changing world

Living with a Volcano in Your Backyard-An Educator's Guide with Emphasis on Mount Rainier

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

Students use charades to review volcanic processes in "***Geocharades***," engage in a physically active review of volcano processes in "***Volcano on the Run***,"and review volcano terms in "***Volcano Anatomy Crossword***."

Activity last modified: Septemer 5, 2014

1. ***Before class begins, review the "True" and "False" questions provided. You may wish to develop additional or alternate questions.***
2. ***Select a large field or gym for the Volcano on the Run activity.***
3. ***Mark the boundaries for the game. There should be two "safe" lines or zones at opposite ends of the game area and a central line or zone at the midway.***

Procedure

Conduct "***Geocharades***," "***Volcano on the Run***," "***Volcano Anatomy Crossword***," or any combination of these activities about volcanic processes as a review activity or assessment.

Adaptations: Other Review Options

- ***The Match Making Game.*** Make cards with the definitions of volcanic processes and other cards with pictures of the processes. Mix up the cards and lay them upside down. Take turns flipping over two cards at a time and see if students can match a definition to a picture.
- ***Vocabulary Stories.*** Ask students to write a story using vocabulary words selected from the activities in Chapter 2
- ***Storyboarding.*** Instruct students to draw a storyboard of one of the geologic processes discussed in Chapter 2.
- ***Field Trip Fun.*** On a field trip to Mount Rainier National Park, ask students to describe or "read" a landscape in selected locations and identify the various geologic processes that shaped it. This may be done as an informal class discussion or in individual student journals.

Assessment

Use this activity as a learning tool, or as an assessment of students' knowledge about volcano terminology. After completing this activity, students should be able to recognize and define the terms. Assess each student's ability to answer the questions correctly and record them.

References

Kennedi, C.A., Brantley, S.R., Hendley J.W., II, and Stauffer, P.H., 2000, Volcanic ash fall–A "hard rain" of abrasive particles: U.S. Geological Survey Fact Sheet 027–00 (revised April 2002), 2 p.

Myers, B., Brantley, S.R., Stauffer, P.H., and Hendley, J.W., II, 1997, What are volcano hazards? (revised March, 2008): U.S. Geological Survey Fact Sheet 002–97, 2 p.

Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

Geocharades Game

What to do before class begins:

1. Before class begins make geology process cards by writing each of the following vocabulary words on an index card. Add additional relevant words if desired.

subduction	*Ring of Fire*
glaciation	*plate tectonics*
lahar	*ashfall*
eruption	*pyroclastic flow*
rising magma	*landslide*
lava flow	*hydrothermal alteration*

2. Laminate the cards for durability (optional).

Procedure

1. Divide the class into groups or teams of 3 to 4 students each.
2. Instruct students to decide on a geology-oriented team name.
3. Distribute geology process cards to each group.
4. Provide teams five minutes to brainstorm, plan, and practice how they will act out a silent skit that visually describes their assigned geological term. Teams should select a spokesperson and must incorporate every member into the skit.
5. Ask one team at a time to perform their skit.
6. After each skit, the other teams should discuss and reach consensus on which geologic process they think was portrayed.
7. A spokesperson from each team informs the class of their team's guess and explains why they chose it.
8. Direct the group to perform it again if no one gets it right.
9. Introduce scoring to the activity to inspire more creative or higher quality skits. Each team gets one point for correctly guessing another group's process. The acting team also gets a point for every group that correctly guesses their process. You can also deduct points if students do not collaborate or use consensus-building skills.
10. Repeat until all the processes have been covered.
11. Discuss any processes that need more clarification.

Volcano on the Run Game

Procedure

The teacher can choose a favorite scheme for team competition regarding true and false questions. Here is one suggestion.

1. Divide the class into two teams, A and B. Teams face each other in parallel lines and spaced at arms length apart near the center of a field or gym.

2. Designate parallel lines approximately ten strides behind each team to represent a "True" and a "False" line. Mark these lines with flagging or bandanas.

3. A teacher or student referee asks students questions from the "***Volcano on the Run***" question sheet and (or) makes up other true or false questions. The teacher must say "go" before students begin movement.

4. If the answer is true, students run toward the "True" line. If the answer is false, students run to the "False" line. Once a student runs in one direction, they cannot change their mind and turn toward the opposite line. If they attempt to do so, they are called out of the competition. The teacher or a designated student counts and writes down the number of students at the true and the false line for each question. Discuss the correct answer after students respond to the question and run to a position.

5. When all questions have been asked, or when you designate an ending time, tally the number of people on each team who have chosen the correct line. The team with the most correct choices wins the competition.

Volcano Anatomy Crossword

Procedure

1. Give each student a "***Volcano Anatomy***" Crossword and Clues list.

2. Ask each student to work independently or with a partner to complete the crossword puzzle.

Teacher Page

Volcano on the Run

	Questions	Answers
1.	Cascade volcanoes are no longer a threat to people because they erupted a long time ago.	False
2.	A volcano's shape remains the same throughout its lifespan.	False
3.	Glaciers can influence the movement of lava flows.	True
4.	Magma is defined as molten rock on Earth's surface.	False
5.	Volcanic gases threaten the lives of people thousands of kilometers (miles) from an erupting volcano because they travel in high concentration for long distances.	False
6.	Lava flows can break apart during eruptions, and form avalanches of hot rock and gas called pyroclastic flows.	True
7.	Tephra is a word used to describe all volcanic rocks.	False
8.	Volcanic ash consists of burnt plant material.	False
9.	Thick layers of wet and heavy volcanic ash can destroy buildings and trees.	True
10.	With the addition of water, pyroclastic flows can form lahars.	True
11.	Volcanic ash clouds can be a threat to aviation.	True
12.	Buildings and trees are unaffected by the force of a moving lava flow.	False
13.	The appearance of lava rocks is influenced by the conditions under which they cooled.	True
14.	Volcanic ash is generally non-poisonous, though it can be abrasive to equipment and can make vision and breathing difficult for people and animals.	True
15.	You can run faster than a lahar.	False
16.	Volcanic bombs erupted from the volcano fall to the ground thousands of kilometers (miles) from an erupting volcano.	False
17.	Past behavior at a volcano provides some indication of the type of eruptions that might happen in the future.	True
18.	The safest place to be during a lahar warning is on the valley floor.	False
19.	Scientists find that weakened rock can collapse as a landslide and form a lahar.	True
20.	Lahars happen most often during noneruptive times.	False
21.	Heated and acidic ground water is capable of changing the texture of rocks from hard to soft.	True
22.	Lahars can cause floods because they fill river channels with rocks and mud.	True
23.	The Law of Superposition states that older rock layers will be deposited on top of rock layers that are younger.	False
24.	The following statement describes a common sequence of events that happens during eruptions at Mount Rainier: lava flows break apart as pyroclastic flows, which then melt snow and ice and form lahars.	True

Student Page

Volcano Anatomy Crossword

CLUES

ACROSS:

2. Ejection of volcanic materials into the atmosphere or onto the Earth's surface
6. Masses of moving ice on the volcano
7. Large rocks thrown from the volcano
9. Scientist who studies volcanoes
11. Fragments of rock thrown from a volcano
15. Molten rock within the earth
16. Avalanche of hot rock and gas
17. Sliding of a mass of loosened rock down an hillside
18. Volcano releases this usually invisible substance into the atmosphere
19. Depression usually at the summit of a volcano
21. Cracks in the rock that magma follows to the surface
22. Once molten magma that has hardened by cooling on Earth's surface
23. Scientist who studies earthquakes

DOWN:

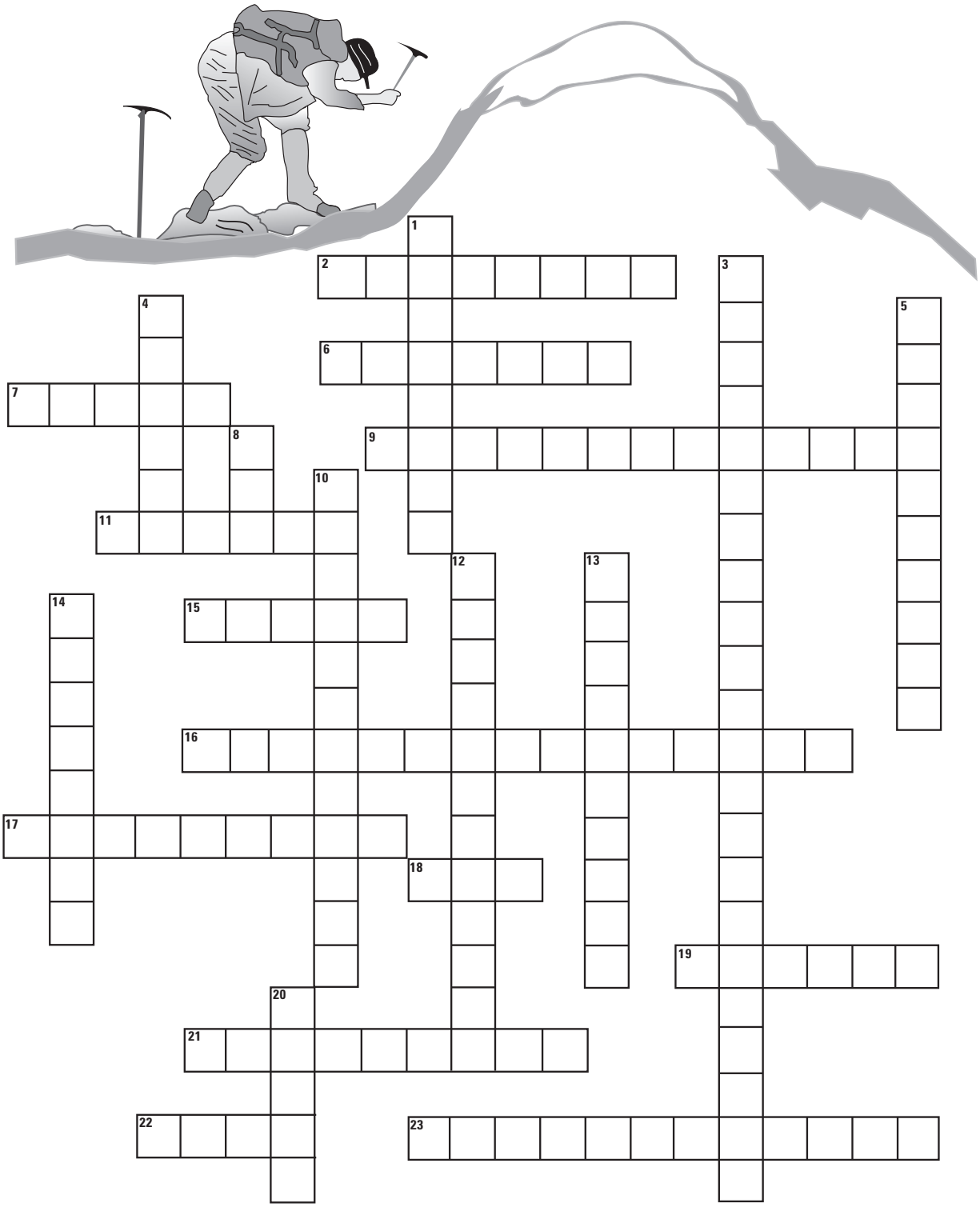
1. Vent that emits steam and gases
3. Chemical process that causes weakening of rock
4. Loose and crumbling rock on the top of a lava flow
5. Shaking of the earth
8. Tiny fragments of rock erupted in to the atmosphere
10. The throat of a volcano
12. Area where magma resides beneath the volcano
13. Moving mass of water, mud and boulders that rushes down valley for a few kilometers (miles) from the volcano
14. Falling rocks
20. Moving mass of water, mud and boulders that rush down valleys for tens of kilometers (miles) from a volcano

Words in the Puzzle:

ash
bombs
crater
debris flow
earthquake
eruption
fractures
fumarole
gas
glacier
hydrothermal alteration
lahar
landslide
lava
magma
magma chamber
magma conduit
pyroclastic flow
rockfall
rubble
seismologist
tephra
volcanologist

Student Page

Volcano Anatomy Crossword



Teacher Page

Volcano Anatomy Crossword

ANSWERS

ACROSS:

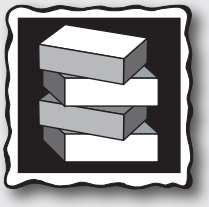
2. eruption
6. glacier
7. bombs
9. volcanologist
11. tephra
15. magma
16. pyroclastic flow
17. landslide
18. gas
19. crater
21. fractures
22. lava
23. seismologist

DOWN:

1. fumarole
3. hydrothermal alteration
4. rubble
5. earthquake
8. ash
10. magma conduit
12. magma chamber
13. debris flow
14. rockfall
20. lahar

Earth Blocks: Modeling Geologic Events One Layer at a Time

Living with a VOLCANO in Your Backyard
MOUNT RAINIER



Grade Level: 6–2

Learner Objectives:

Students will:

- Use the "Law of Superposition" to determine the chronological order of geological events
- Practice logic and observation by modeling rock layers at Mount Rainier
- Draw information and conclusions from a model

Setting: Classroom or outdoors

Timeframe: 45 minutes (or one class session)

Investigate Age Relationships By Playing the Hand Stacking Game—5 minutes

Demonstrate How to Use Earth Blocks—15 minutes

Explore Mount Rainier's History with Earth Blocks—25 minutes

USGS science for a changing world

NATIONAL PARK SERVICE

Living with a Volcano in Your Backyard-An Educator's Guide with Emphasis on Mount Rainier

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

Students explore a riverbank with a geologist and learn about the Law of Superposition by arranging and interpreting Earth Blocks.

Materials:

Investigate Age Relationships By Playing the Hand Stacking Game

- Graphic *" Lahar Layers in the Nisqually River Valley"*

Demonstrate the Use of Earth Blocks

- Copies of *"Discover Layers—In the Field with a Geologist"* student reading sheet
- 6 to 8 sets of Earth Blocks (provided in the kit or photocopied)
- Graphic *"Modeling the Sequence of Layers with Earth Blocks 1 through 6"*

Explore Mount Rainier's History Using Earth Blocks

- Copies of *"Explore Mount Rainier's History with Earth Blocks"* student page
- Graphic *" Earth Blocks—Example"*

Activity last modified: September 5, 2014

Vocabulary: Deposit, Electron Mudflow, glacier, lahar, lava flow, National Lahar, Law of Superposition, pyroclastic flow, radiometric dating, Round Pass Mudflow, stratigraphy, tephra, volcano

Skills: Compare, identify, discuss, infer, interpret, model, analyze

Benchmarks:

See benchmarks in Introduction.

Teacher Background

Geologists generally accept that events of the future will resemble those of the past. For this reason, they investigate the origin of rocky layers (***deposits***) set down by previous volcanic events. They recognize that understanding a ***volcano's*** general behavior patterns now can lead to a society that is better prepared because they can anticipate likely types of future volcanic activity.

Geologists have developed ingenious methods to identify the age, origin, and sequence of events that formed the rocky layers set into place by ***lava flows***, ***pyroclastic flows***, ***tephra*** fall, ***lahars*** and ***glacier***, stream and erosional processes. They conduct complex chemical analyses to determine the composition of rocks, their source, and the process that formed them. They perform sophisticated laboratory methods to identify the age of rock layers. Yet, one of the most useful methods requires little more than good observational skills, a small trowel or rock hammer, notebook and map, and a basic understanding of the ***Law of Superposition***. This fundamental principle, which states that younger layers will be on top of layers that are older, is one of the guiding principles of geological investigation.

This activity provides a glimpse into the methods used by geologists as they study the rocky layers at Mount Rainier. Students manipulate "***Earth Blocks***" into the likely sequences observed at Mount Rainier, and practice their logic skills as they employ the Law of Superposition. See the activity "***Shoebox Geologist***" for more in-depth information about the layers described here.

Sidebar 1 What is Radiometric Dating?

Some materials contain unstable radioactive isotopes that break down (decay) over time into stable isotopes. Scientists know the decay rate for certain isotopes and use this information to determine the age of rock deposits. The age of material is determined by comparing the amount of radioactive isotopes remaining in a material to the known decay rate of the isotopes in the material. The most common isotope used in *radiometric dating* is Carbon-14, which is found in charcoal and organic debris.

Earth Blocks

"***Earth Blocks***" represent different rock and sediment layers deposited by lahars, tephra fall, pyroclastic flows, lava flows and glaciation. "***Earth Blocks***" can be used in other activities throughout this chapter and on field trips to demonstrate layered sequences.We encourage students and teachers to use the blocks to model layers of rock and rock debris deposits that they may find at home or school.

How the blocks are used:

1. Students stack the blocks to build a layered sequence.
2. Students make observations about the processes that produced the layers.
3. Students interpret the layers by ranking them in age and describing what events occurred to produce the sequence.

The Blocks:

Some of the blocks show dates, which were obtained by a variety of dating methods including radiometric dating. Large lahar events that have happened at Mount Rainier have specific names and are given their own blocks. Blocks for specific tephra layers also show the volcano of origin.

Use the videos Understanding Volcanic Hazards and Perilous Beauty—The Hidden Dangers of Mount Rainier to familiarize students with volcanic processes and Mount Rainier's geologic history.

Procedure

What to do Before Class Begins:

Demonstrate Use of Earth Blocks and Explore Mount Rainier's History Using Earth Blocks

1. For each student group, make copies of the color "***Earth Blocks***" graphics at the end of this activity. You may choose to laminate or mount the cards on a hard surface such as cardboard or foam core.

2. Display the graphic "***Earth Blocks—Example***."

Investigate Age Relationships By Playing the Hand Stacking Game

Play the "***Hand Stacking Game***" to learn about the Law of Superposition. Also note the ideas in "***Extensions***."

1. Project the graphic "***Lahar Layers in the Nisqually River Valley***" to introduce students to what these layered sequences look like at Mount Rainier. Give examples of the types of deposits found at Mount Rainier (stream, glacial, lava flow, tephra, and lahar).

2. Explain to students that geologists interpret the geologic history of an area by studying layers. One method they use is called relative age dating. Students explore this concept by playing the "***Hand Stacking Game***" described below.

3. Divide the class into groups of four or five people.

a. Instruct one person in each group to place their hand flat on the table. The next person places their hand on top. Continue to stack hands until no more hands remain to be stacked. Ask which hands represent "newer" and "older" layers. See other ides in "***Extensions***."

c. Discuss the "Law of Superposition." This seemingly simple scientific principle was not recognized and understood until the seventeenth century. Think about why it took so long for the "law" to be recognized.

Demonstrate Use of Earth Blocks

Learn how geologists interpret layers by reading a story and using "***Earth Blocks***."

1. Give each student a copy of the student page "***Discover Layers—In the Field with a Geologist***" and instruct them to read it.
2. After students complete their reading, use the "***Earth Blocks***" to show them examples of layers observed by the geologist in the field. Hold up an example of each type of block for everyone in the class to see. Explain what blocks represent. Point out any dates or information on the origin of the "***Earth Blocks***" so students know where to find this information in the future. Demonstrate their use with actual "***Earth Blocks***" or optionally with the graphic "***Earth Blocks—Examples***."

EXAMPLE

(Top)

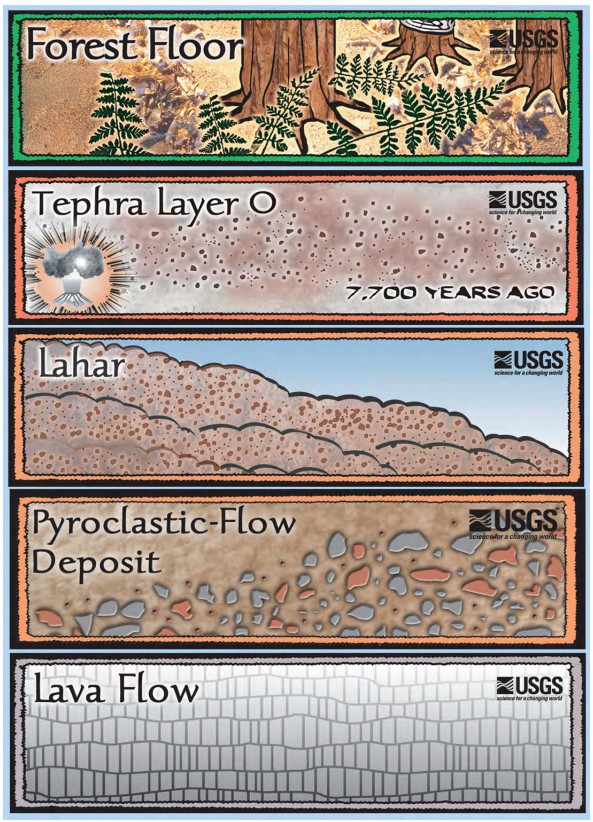
Forest Floor

Tephra 0 (7,700 years old)

Lahar

Pyroclastic Flow Desposit

Lava Flow (40,000 years) old



(Bottom)

Explore Volcano History with Earth Blocks

Students model layers using "***Earth Blocks***" and write interpretations on a student page.

1. Divide the class into groups of two or three students and give each a set of "***Earth Blocks***."
2. Provide each student with the four "***Explore Mount Rainier's History with Earth Blocks***" student pages.
3. Students arrange blocks into the layer sequences described on their student pages. With the teacher aiding, students should identify the geologic events that built each layer in their "***Earth Blocks***" sequence and answer questions on the student page.
4. Lead a class discussion. What interpretations did students make about the layers?

Adaptations

- Alternatively, students answer questions directly from the geologist notebook pages without use of the "***Earth Blocks***."
- ***Students draw their own Earth Blocks on strips of papers*** and arrange them in correct order before answering the questions.
- ***Take a field trip*** with your students to a nearby outcrop of rock layers, whether a riverbank, valley wall, or distant view of a volcano. Bring appropriate blocks, such as stream gravels, glacial deposits, etc. Instruct students to place blocks directly on the outcrop, or line them up in the appropriate order.
- ***Ask students to develop their own "Earth Blocks"*** that model an outcrop in their community or at other Cascade volcanoes.

Extensions

- ***Clothes hamper geology.***
  Introduce the concept of layers and the "Law of Superposition" by instructing students to envision a clothes hamper in their bedrooms.They come home from school on Monday and take off a red shirt and throw it into the hamper. On Tuesday, they toss in a green shirt. On Wednesday, they put in a yellow shirt, on Thursday, a purple shirt, and on Friday, a blue shirt. Each shirt represents a layer deposited by the student. Ask students which layer is oldest and which is the youngest? From this, ask students to derive the "Law of Superposition." Alternatively, students pile up jackets and sweaters worn that school day.

- ***Snow bank stratigraphy.***
  If you live in an area where snow banks develop during the winter, take students to one of them and ask them to interpret the relative ages of the layers while hypothesizing about the events that created the layers.

- ***The earth's ticking clock—Radiometric dating***.
  Use this extension activity to explain how radiometric dating works. Provide each student with a graham cracker and ask students to take exactly one minute to eat half of the graham cracker. After the one minute of eating the first half, instruct them to eat half of the remaining graham cracker, and split the remaining amount in half. Ask students to repeat this until the amount of graham cracker is so small that they can no longer divide it in half. The amount of time it takes for half of the graham cracker to be eaten is known as the half-life. Carbon-14 has a half-life of 5,730 years. Make sure students keep track of how long it takes them to reach the point when the graham cracker can no longer be split apart. At this point, the amount of cracker left represents the amount of Carbon-14 remaining when the sample has completely degraded to one molecule. The molecule cannot be split and so there is essentially no Carbon-14 left in the sample. Instruct the students to plot the relative size of the cracker (one half, one quarter, one eighth, etc.) versus time on graph paper. If the students were to find a sediment layer with a graham cracker in it that had degraded to one-eighth its original size, how old would the sediment layer be? Make an analogy to Carbon-14 dating.

- ***Design earth blocks with character.***
  Make a set of "***Earth Blocks***" that include common physical characteristics found in the different tephra layers at Mount Rainier. You can find this information in published geologic papers on the website of the USGS Volcano Hazards Program. See **Internet Resources Page**.

Assessment

Look for students' understanding of the Law of Superposition. As the activity progresses, students should recognize that this principle enables scientists to determine the chronological order in which geological events happened. Students should understand why this law is helpful to volcanologists who seek to know the geological story or an area. Their understanding of past events helps them to determine the most likely geological events for the future, and ultimately the hazards. This process in due course saves lives and property and improves the well being of nearby communities.

Use questions on the student pages to assess students' ability to apply the principle of Superposition to real-world situations. After completing this lesson, students should be able to design their own data and observation tables. Students who select an incorrect response may be able to provide a justification for their answer that demonstrates understanding of the principle.

References

Cas, R.A.F., and Wright, J.V., 1987, Volcanic Successions Modern and Ancient—A geological approach to processes, products and successions: London, Allen and Unwin, 528 p.

Fisher, R.V., and Schmincke, H.U., 1984, Pyroclastic rocks: New York, N.Y., Springer-Verlag, 472 p.

Scott, K.M., Vallance, J.W., and Pringle, P.T., 1995, Sedimentology, behavior, and hazards of debris flows at Mount Rainier, Washington: U.S. Geological Survey Professional Paper 1547, 56 p., 1 pl.

Vallance, J.W., and Scott, K.M., 1997, The Osceola Mudflow from Mount Rainier: Sedimentology and hazard implications of a huge clay-rich debris flow: Geological Society of America Bulletin, February, 1997, v. 109: no. 2: p. 143–163, 6 tables.

Zehfuss, P.H., Atwater, B.F., Vallance, J.W., Brenniman, H., and Brown, T.A., 2003, Holocene lahars and their by-products along the historical path of the White River between Mount Rainier and Seattle: *in* Swanson, T.W., ed, Western Cordillera and adjacent areas: Boulder, Colo., Geological Society of America Field Guide 4, p. 209–223.

Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

Photo Credits

1. Lahar Layers in the Nisqually River Valley, Photo by Carolyn Driedger, USGS.

Student Page

Name _____

Discover Layers—In the Field with a Geologist

In the deep river valleys of the Cascade Range, hikers can observe eroded riverbanks made entirely of loose sand, cobbles, and boulders. Geologists use these layers to make interpretations about geologic events of the past. Now envision yourself visiting the riverbank with a geologist who is on the job in one of those river valleys.

You and the geologist wear sturdy boots and carry backpacks filled with collection bags, tape measures, notebooks, cameras and trowels, in addition to your first aid kit, snack food, water and extra clothing. After a short hike from the car, the two of you reach the riverbank and lean back for a full view. Together, you take photographs, measure the thickness of layers, and make sketches in your notebooks. The geologist reminds you that by the Law of Superposition, the oldest layers are on the bottom and the youngest are at the top. Next, you approach the riverbank. You use trowels to dig into the layers to obtain samples. You roll the dusty rock particles around in your hand, and examine them with a hand lens. In your notebooks you record information about the color and texture of the particles, and you are careful to describe where in the riverbank these samples were found. The two of you are always on the lookout for buried wood and leaves that can provide clues about the age and origin of the rocky layers. The geologist reaches into a backpack and pulls out a handful of white cloth collection bags, each with a blank paper label and string closure. Together, you fill the bags with samples of rocks, wood and charcoal, and you are careful to label the contents of each bag as you close it. When you return to the office, the two of you will use this evidence to develop a hypothesis about how and when the valley landscape was formed. With evidence recorded in your notebooks, in photographs, and on sample bag labels, you hike up valley to repeat the process at more locations along the riverbank.

Many different geologic events created the layers found along the riverbank including lahars (mudflows), pyroclastic flows, tephra (ash) fallout, glaciers, streams, lava flows, and organic composition. Your teacher will demonstrate the use of "***Earth Blocks***," which represent layers that geologists observe in the field.

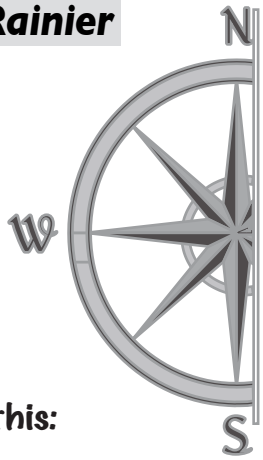
Student Page

Name _____

Explore Mount Rainier's History with Earth Blocks

Instructions: *Arrange the "Earth Blocks" in order—from oldest at the bottom to youngest at the top. Using the field notes below as your guide, answer all the questions on the following page. Use the "Law of Superposition."*

Observations on a High Mountain Ridge at Mount Rainier



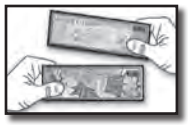
August 23
Latitude: 46°50' N Longitude: 121°45' W
Elevation: 3,069 meters (10,070 feet) On a high ridge west of Nisqually Glacier. Clear skies but chilly 10° C (50° F.) Saw two mountain goats and a marmot. A small avalanche of unstable rock broke loose and tossed dust into the air—lucky I did not get hit by any rocks!

Exposure on ridge is 6 meters (20 feet) high and looks like this:

(TOP)
Forest floor
Glacial deposits
Tephra (age unknown)
Tephra "Y" from Mount St. Helens, 3,700 years ago
Glacial deposits formed 10,000 years ago
Lava Flow
Pyroclastic flow
Lava flow
Lava flow 380,000 years ago
(BOTTOM)

Student Page

Name _____



Explore Mount Rainier's History with Earth Blocks-continued

Questions for Observations on a High Mountain Ridge at Mount Rainier:

1. What is the age of Tephra layer Y?

2. Find the pyroclastic flow layer.
Is the pyroclastic flow older or younger than Tephra layer Y? Explain your choice.

3. Find the tephra layer of unknown age. What can you learn about its age?

4. Are the lava flows and pyroclastic flows related? Explain how.

5. Write a paragraph about the geologic processes that occurred on this high mountain ridge.

Student Page

Name _____

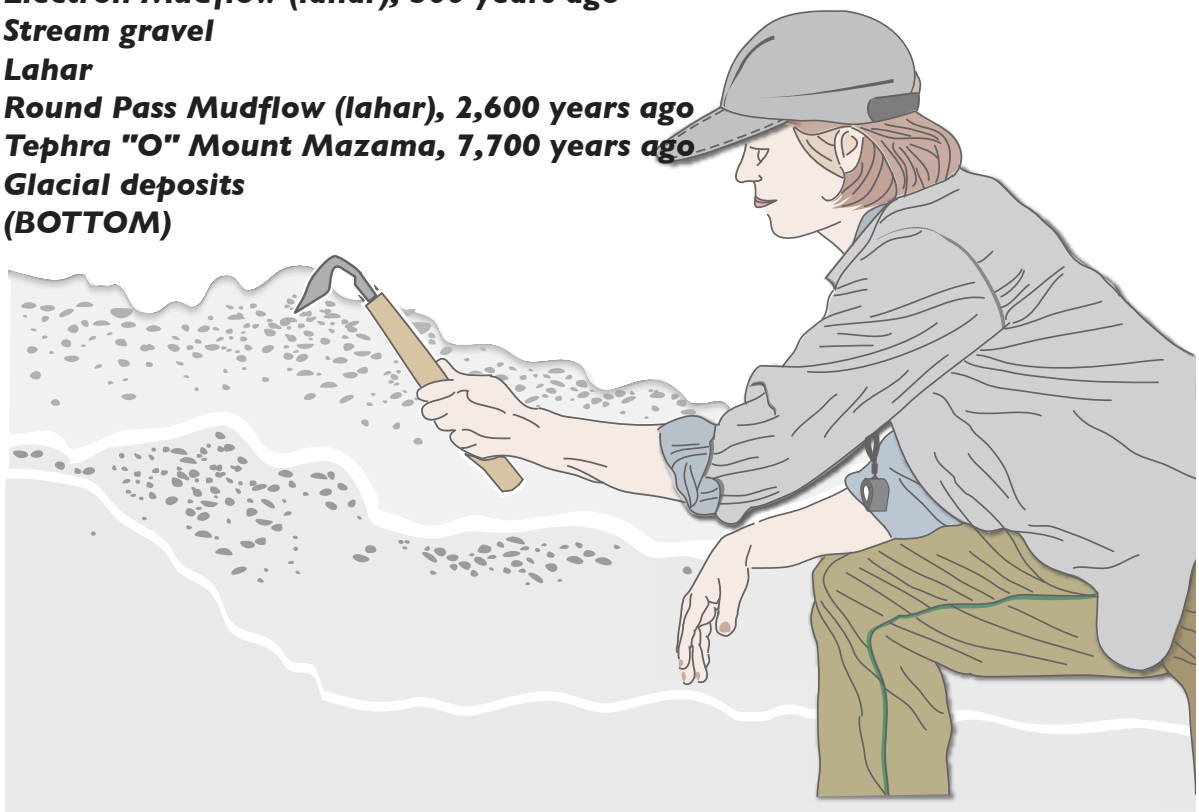
Explore Mount Rainier's History with Earth Blocks

Observations of a Valley Riverbank at Mount Rainier

August 25
Latitude: 46°44' N Longitude: 121°60' W
Elevation: 427 meters (1,400 feet) In the west side riverbank, Nisqually River valley just upstream of the Longmire bridge crossing. The river is low for this time of year. Lots of deer and mosquitoes!

Riverbank is about 4.5 meters (15 feet) high:

(TOP)
Forest Floor
Stream gravel
Lahar
Stream gravel
Lahar
Stream gravel
Electron Mudflow (lahar), 500 years ago
Stream gravel
Lahar
Round Pass Mudflow (lahar), 2,600 years ago
Tephra "O" Mount Mazama, 7,700 years ago
Glacial deposits
(BOTTOM)



Student Page

Name _____

Explore Mount Rainier's History with Earth Blocks-continued

Questions for Observations of a Valley Riverbank at Mount Rainier:

1. The age of the undated lahar between the Round Pass Mudflow and the Electron Mudflow is ____ years to ___ years old.

2. Name the principal geological process that follows after lahars (mudflows). Explain why.

3. Count how many lahars occurred in this valley between the Electron Mudflow (include it) and the present.

4. Write a paragraph about the geologic processes that occurred in the valley.

5. Summarize the similarities and differences between volcanic layers on the ridge and in the valley riverbank.

6. Rearrange your earth blocks into some new pattern. List the events from bottom to top. Write a paragraph that describes the events that formed these layers.

Teacher Page

Explore Mount Rainier's History with Earth Blocks—Answers

Questions for Observations on a High Mountain Ridge at Mount Rainier:

1. What is the age of Tephra layer Y?
Tephra layer Y fell to the ground during an eruption 3,700 years ago.

2. Find the layer of rock rubble left behind by a pyroclastic flow. Is the pyroclastic flow older or younger than Tephra layer Y? Explain your choice.
We know that the pyroclastic flow is older because it is a lower layer than Tephra Y.

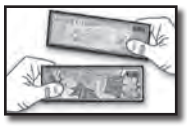
3. Find the tephra layer of unknown age. What can you learn about its age?
The age of the undated tephra is between 3,700 years and the present.

4. Explain how the pyroclastic flows and lava flows are related.
Both formed during an eruption. The pyroclastic flow formed when hot gas-rich lava flows broke apart and tumbled down the sides of the volcano.

5. Write a paragraph about the geologic processes that occurred on this high mountain ridge.
Volcanic eruptions caused two lava flows. Collapse of hot ash clouds, or lava flows caused pyroclastic flows. Another lava flow covered the pyroclastic flow. A glacier spread loose rock over the ridge. Tephra from an eruption of Mount St. Helens covered the ridge. A second tephra layer formed. A glacier left behind loose rocks on the valley floor. Soil from the forest floor covers all of the layers underneath.

Teacher Page

Name _____



Explore Mount Rainier's History with Earth Blocks—Answers-continued

Questions for Observations of a Valley Riverbank at Mount Rainier:

1. The age of the undated lahar layer between the ***Round Pass Mudflow*** and the ***Electron Mudflow*** is ____ years to ___ years old.
The tephra was formed between 2,600 and 500 years ago.

2. Name the principal geological process that follows after lahars (mudflows). Explain why.
Stream water transports loose sediments and redeposits it as layers of stream gravel.

3. Count how many lahars occurred in this valley between the Electron Mudflow (include it) and the present.
Three lahars (including the Electron Mudflow) occurred.

4. Write a paragraph about the geologic processes that occurred in the valley.
Glacial deposits were first to form. Later, tephra from ancient Mount Mazama covered the glacial deposits. The Round Pass Mudflow and another lahar covered the valley floor. This surface was buried by gravel carried there by stream flow. The Electron Mudflow covered the valley floor. It was followed by more stream flow, which left stream gravel on the surface. Twice more, lahars flowed down valley and stream gravel covered the valley floor. Now a forest covers the valley floor.

5. Summarize the similarities and differences between volcanic layers on the ridge and in the valley riverbank.
The ridge top consists of lava flows and tephra layers, while the valley riverbank principally consists of lahar and stream gravel layers. Both areas have been ashioned by a variety of geologic processes.

6. Rearrange your earth blocks into some new pattern. List the events from bottom to top. Write a paragraph that describes the events that formed these layers.

Graphic Page

Lahar Layers in the Nisqually River Valley

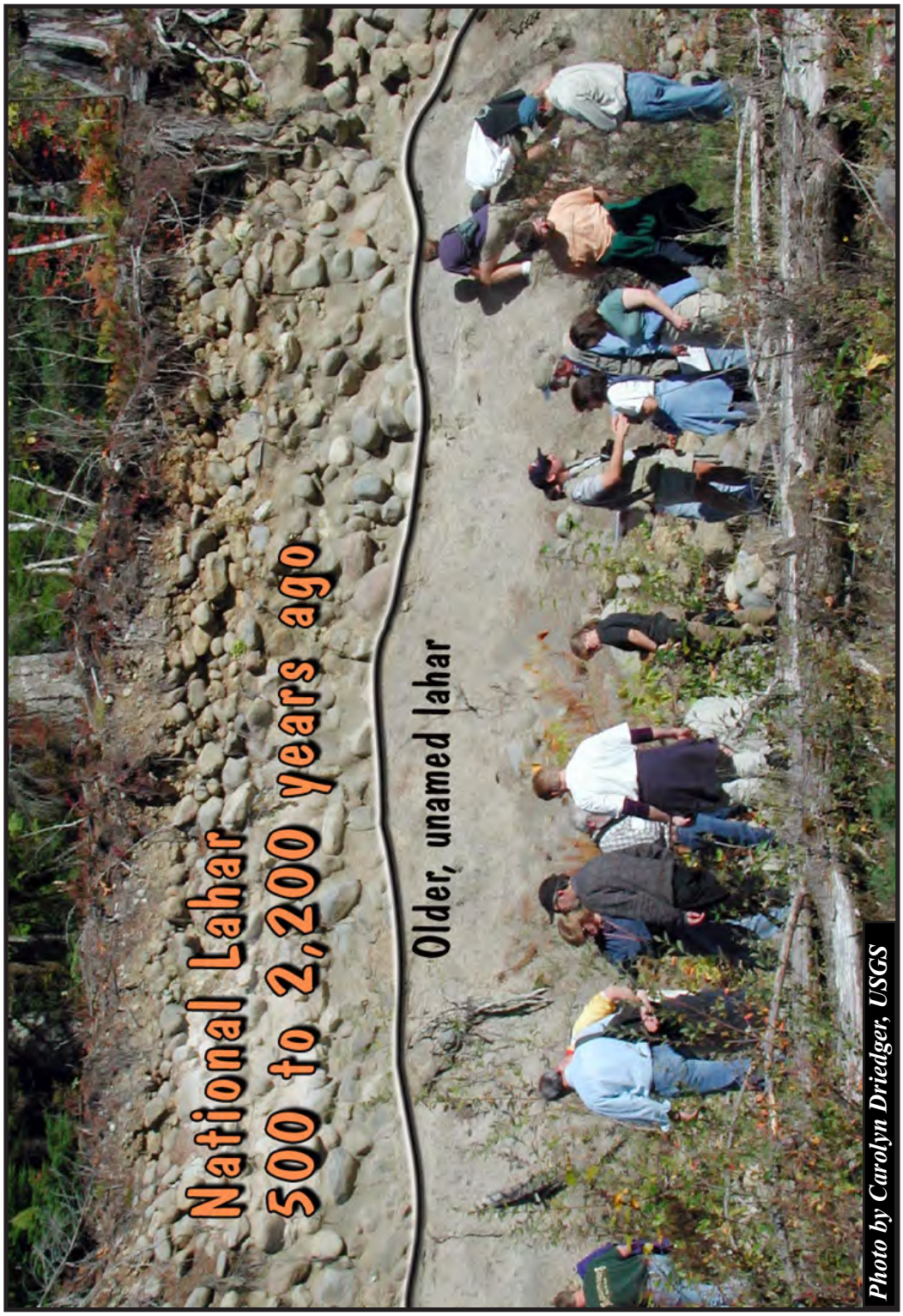
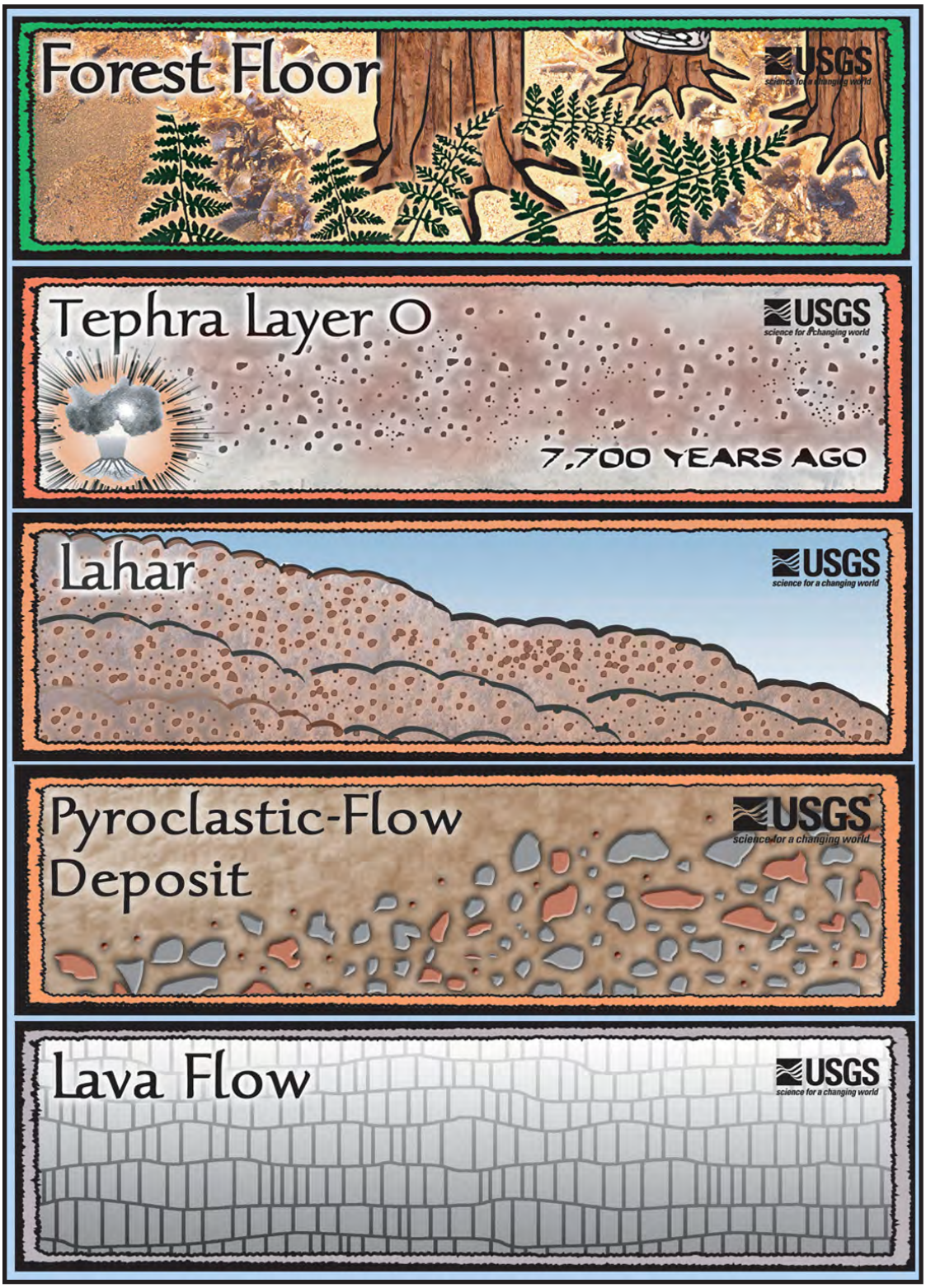


Photo by Carolyn Driedger, USGS

Graphic Page

Earth Blocks—Example

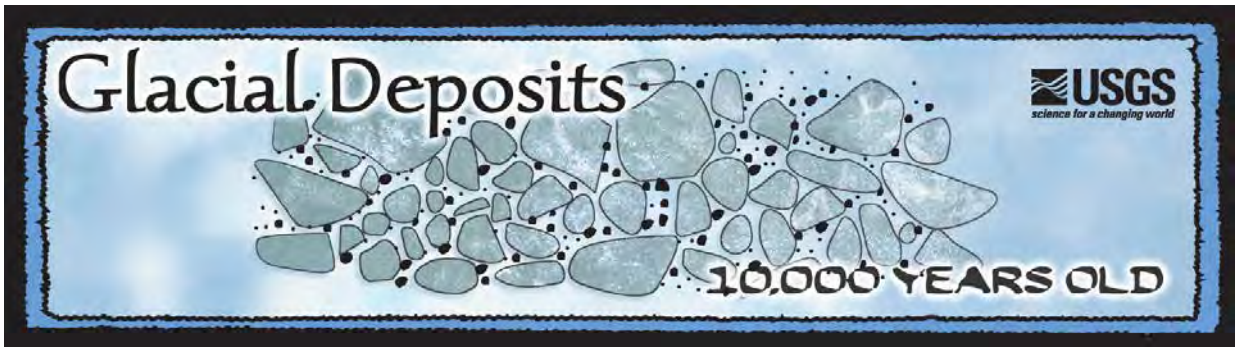


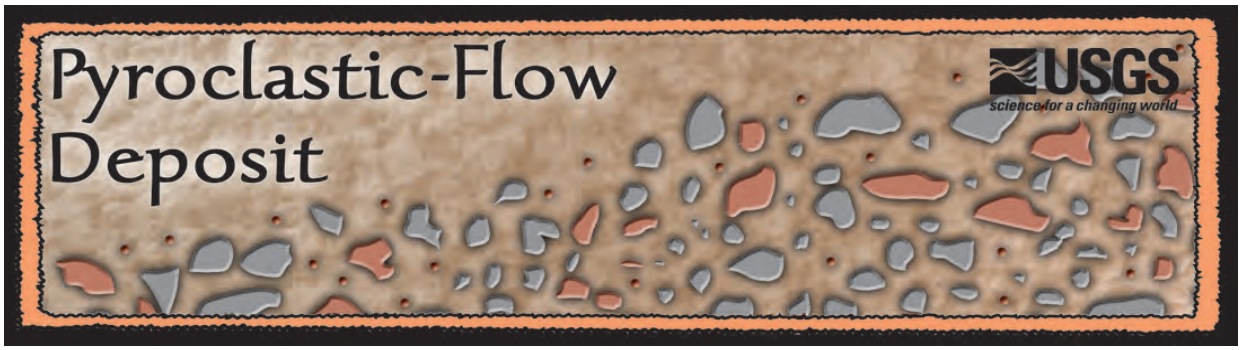
Earth Blocks For Activities

Tephra
USGS
science for a changing world

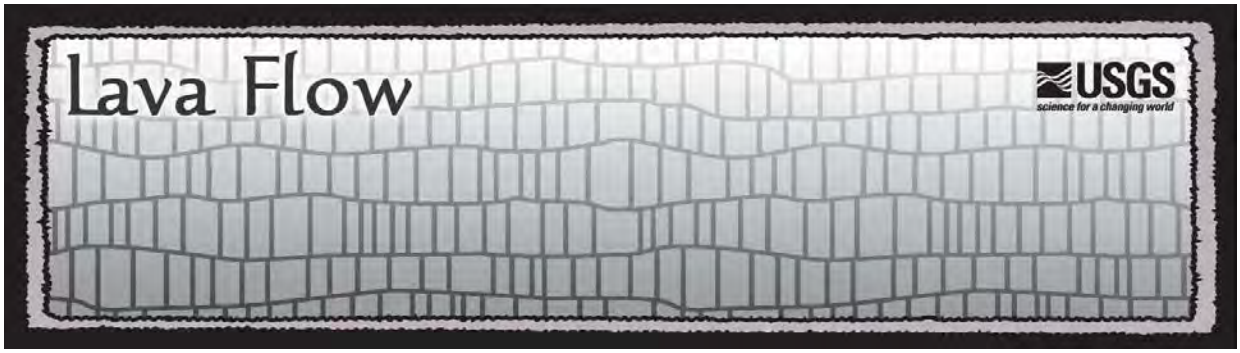
Tephra
USGS
science for a changing world

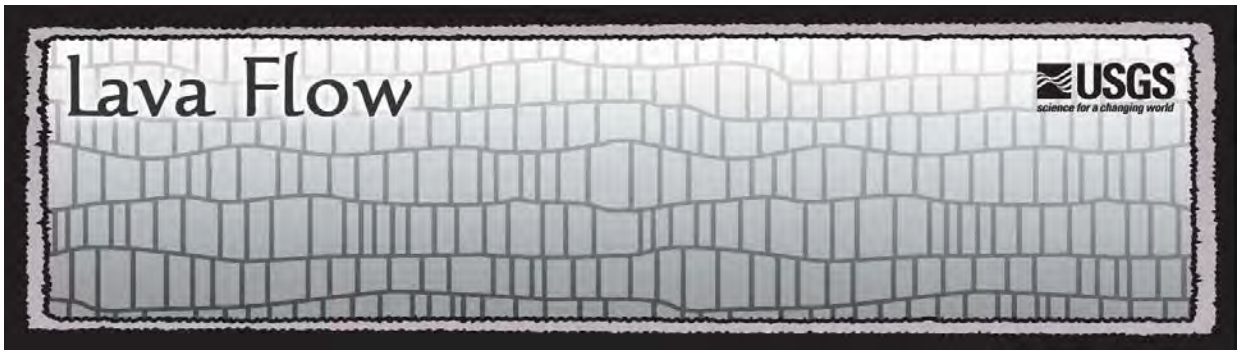
Tephra Layer Y
USGS
science for a changing world
MOUNT ST. HELENS
3,700 YEARS AGO

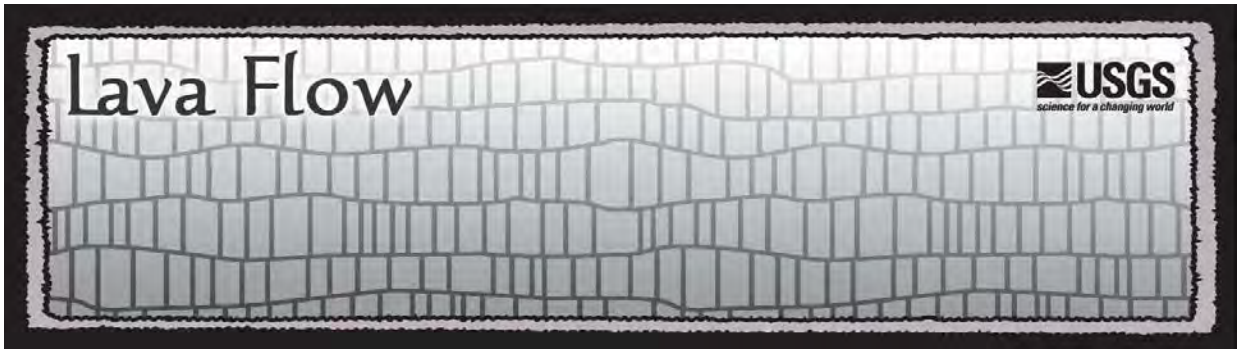

Glacial Deposits
USGS
science for a changing world
10,000 YEARS OLD

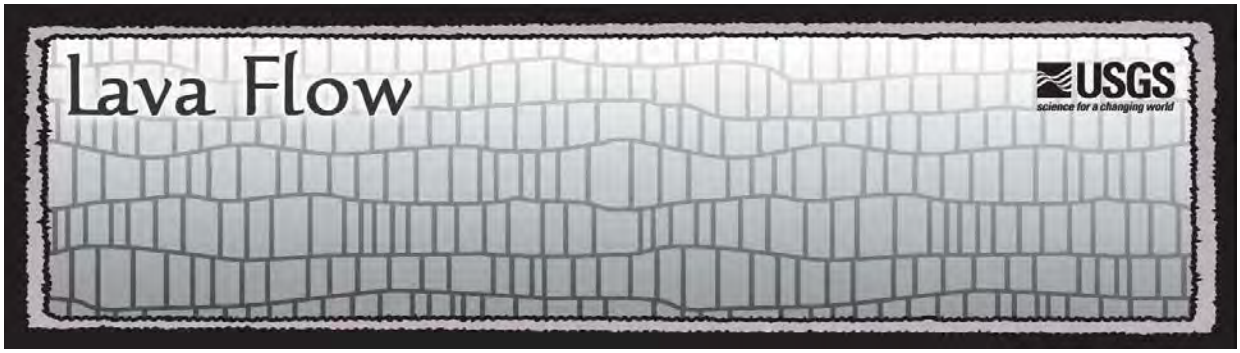

Pyroclastic-Flow Deposit
USGS
science for a changing world

Pyroclastic-Flow
Deposit
USGS
science for a changing world

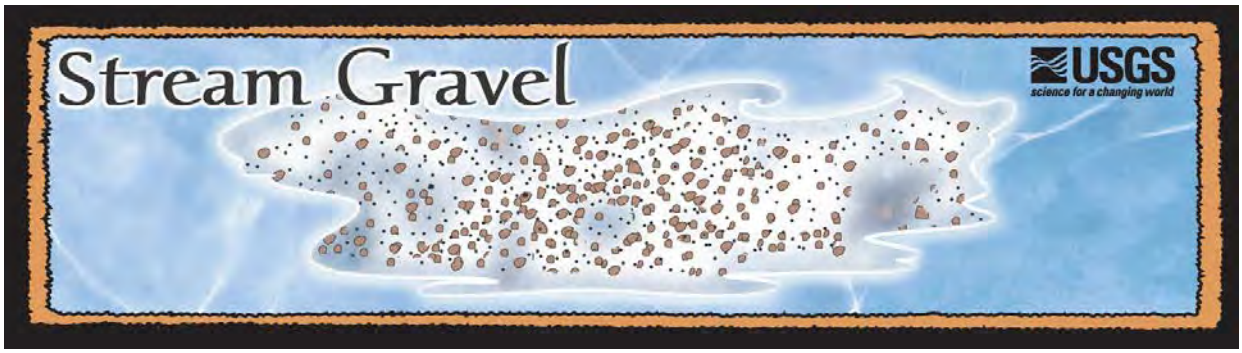

Lava Flow
USGS
science for a changing world

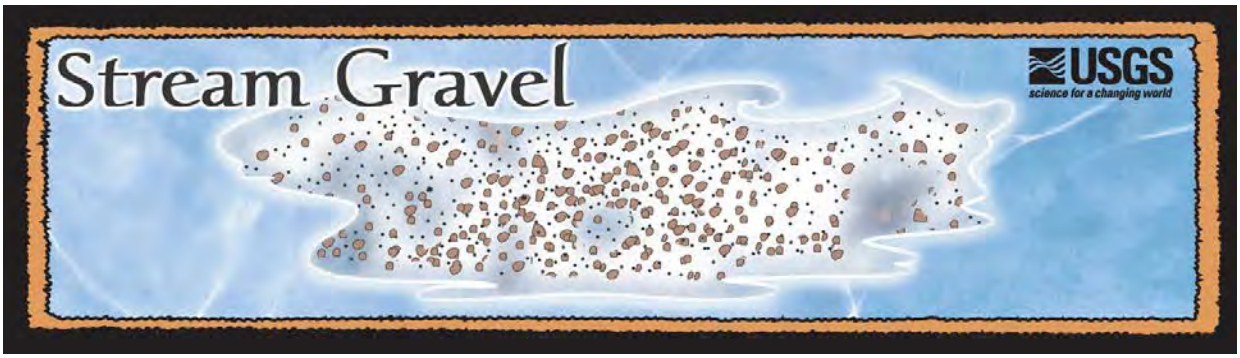

Lava Flow
USGS
science for a changing world

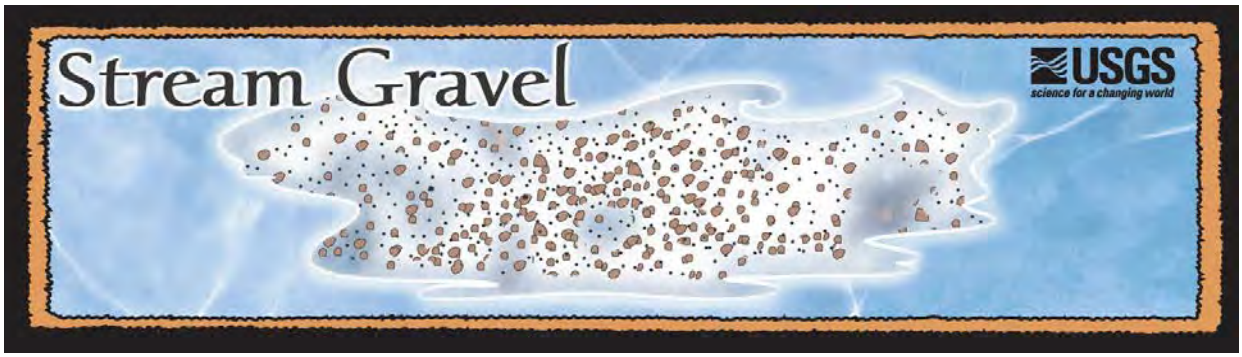

Lava Flow
USGS
science for a changing world

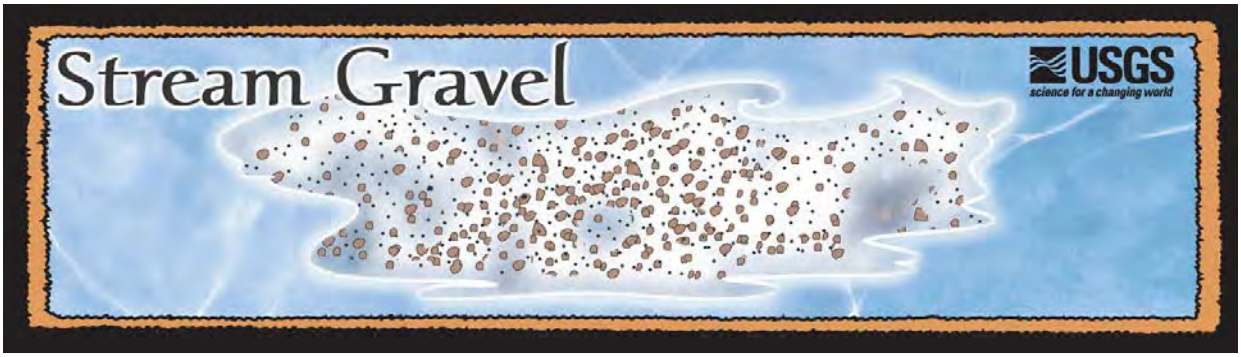

Lava Flow
USGS
science for a changing world

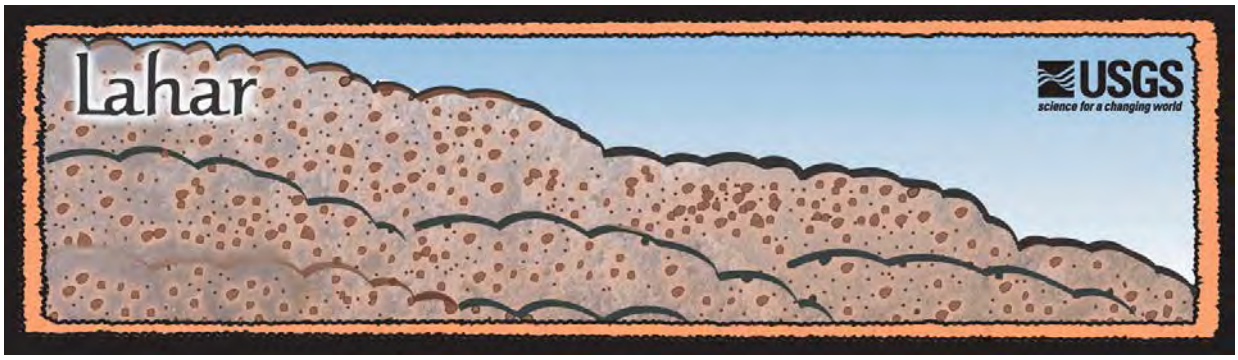
Lava Flow
USGS
science for a changing world
≈380,000 YEARS AGO

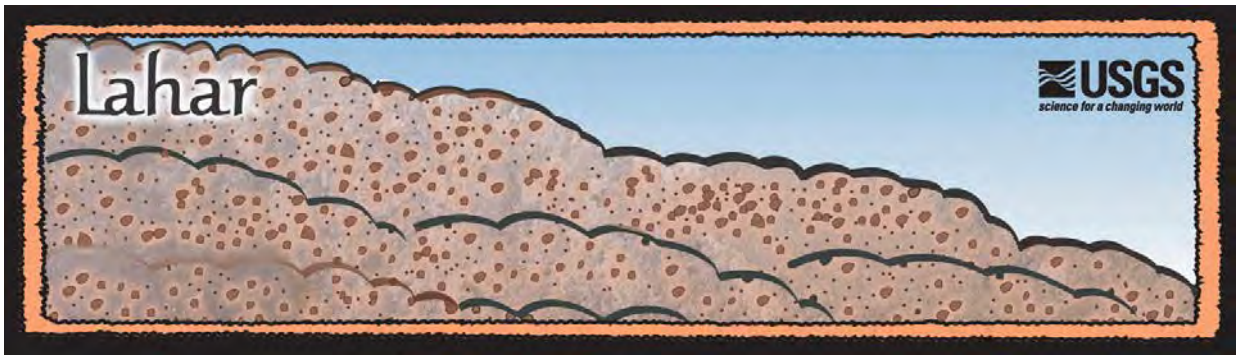

Stream Gravel
USGS
science for a changing world

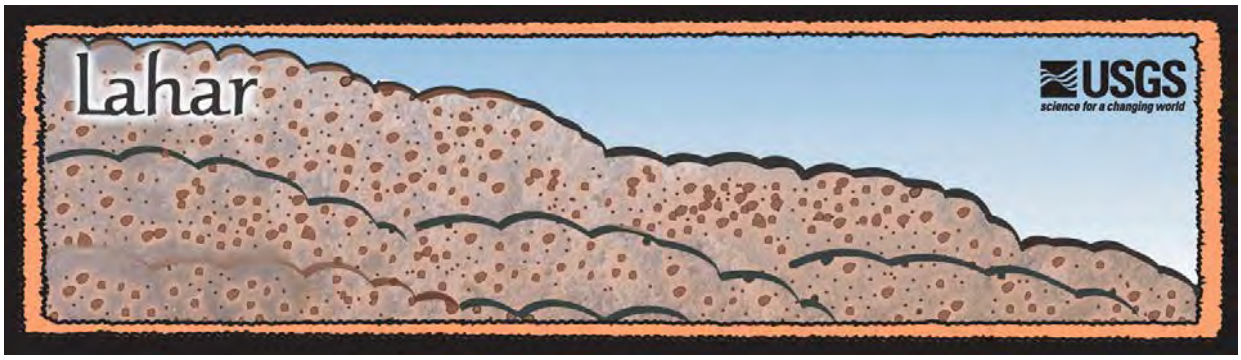

Stream Gravel
USGS
science for a changing world

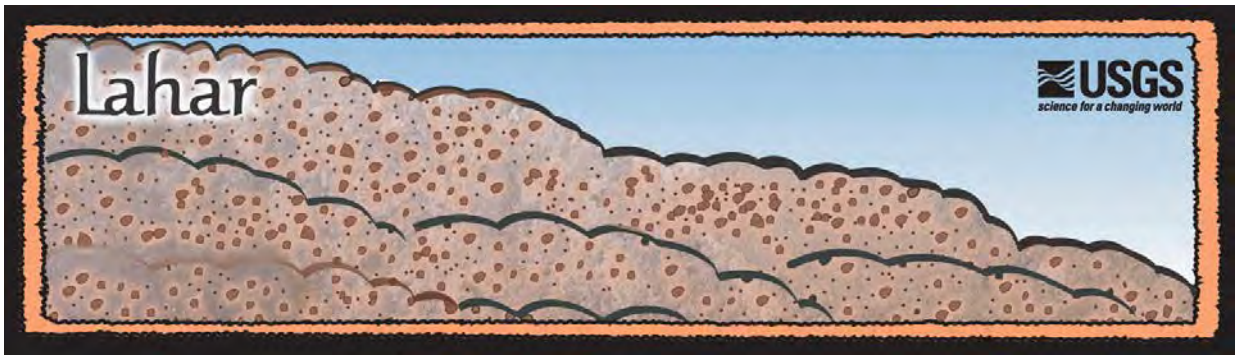

Stream Gravel
USGS
science for a changing world

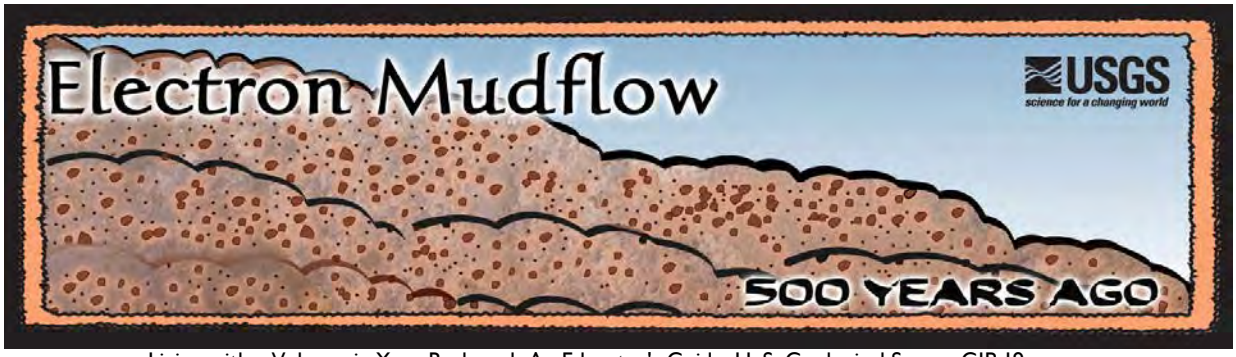

Stream Gravel
USGS
science for a changing world

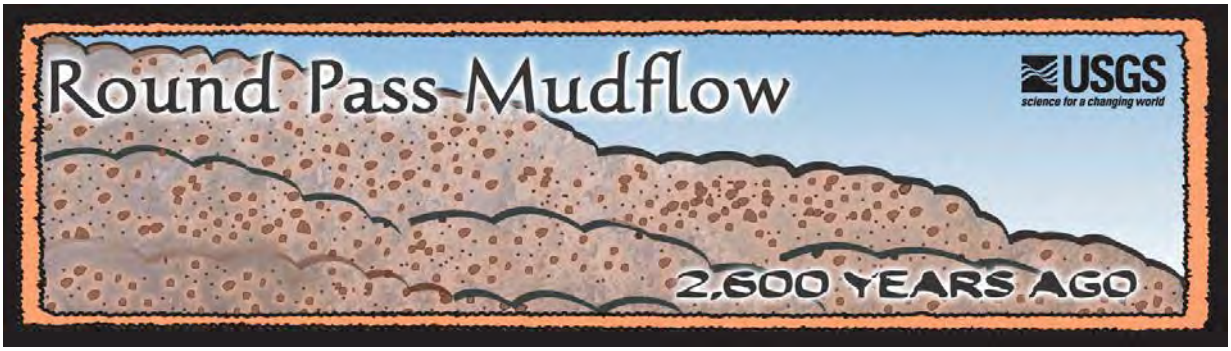

Lahar
USGS
science for a changing world


Lahar
USGS
science for a changing world

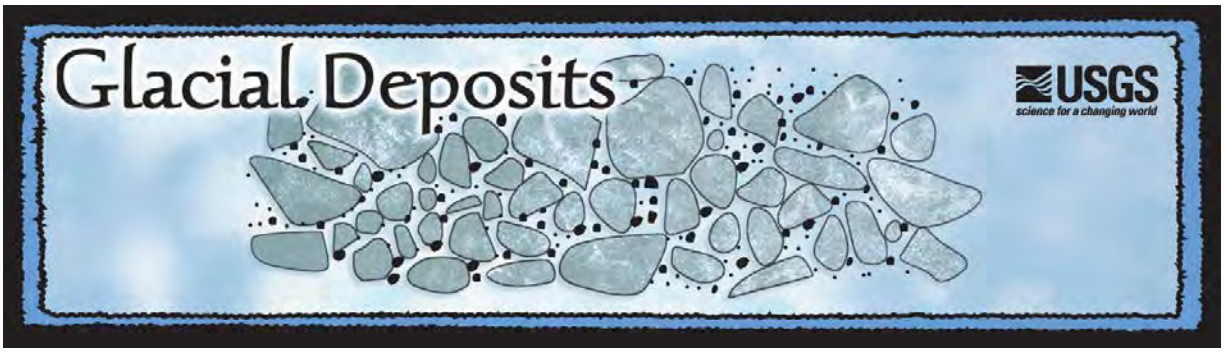

Lahar
USGS
science for a changing world


Lahar
USGS
science for a changing world

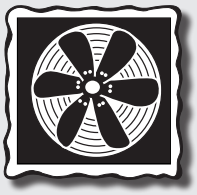

Electron Mudflow
USGS
science for a changing world
500 YEARS AGO


Round Pass-Mudflow
USGS
science for a changing world
2,600 YEARS AGO

Tephra Layer O
USGS
science for a changing world
MOUNT MAZAMA


Glacial Deposits
USGS
science for a changing world

Volcano Fan Club



Grade Level: 6–9

Learner Objectives:

Students will:

- Recognize how wind influences the dispersion pattern of tephra.
- Understand the energy transformations that occur during tephra fall.
- Recognize how volcano researchers assess the area of tephra fall

Setting: classroom (or an easy to clean area)

Timeframe: 50 minutes

Volcano Fan Club—50 minutes

Materials:

Blowing in the Wind

- Copies of *"Volcano Fan Club"* student page
- Copies of *"Volcano Fan Club"* experiment instructions
- 3 fans with 3-speed settings

continued on page 2...

USGS
science for a changing world

Living with a Volcano in Your Backyard-An Educator's Guide with Emphasis on Mount Rainier

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

Students simulate tephra transport by placing ingredients in front of a running fan, and mapping the resultant layers.

Teacher Background

What is tephra?

The term ***tephra*** refers to fragments of volcanic rock and lava of all sizes that are blasted into the atmosphere by explosions or carried upward in ***eruption columns*** or ***lava fountains***. Large pieces of tephra fall to the ground first. Smaller pieces stay aloft for longer periods of time which allows the wind to blow tiny particles to a great distance from the volcano.

Volcanic ash refers to the tiniest pieces of tephra, smaller than 2 millimeter (0.1 inch) in diameter, which is a bit larger than the size of a pinhead. It is formed during explosive eruptions by the shattering of magma. Volcanic ash is not a product of combustion, such as ash formed by the burning of paper or wood. It is hard and very abrasive, mildly corrosive, and is electrically conductive, especially when wet.

Building tephra deposits

Once ejected into the air, the wind carries tephra particles. How far a tephra particle travels depends upon wind speed and size of the eruption. Coarse and heavy particles fall on or near the volcano; fine-grained, light-weight particles travel farther. The resulting tephra layer on the ground is progressively thinner and finer-grained with increasing

continued on page 3...

Activity last modified: September 5, 2014

- 3 checkerboard plastic table cloths or butcher paper or computer plotter paper similar in size to standard picnic table cloths
- 3 rolls of masking tape
- 3 sets of washable markers
- 3 spoons
- 1 cup cocoa powder
- 1 cup oatmeal
- 1 cup rice grains
- 1 cup cornmeal
- brush or broom or vacuum cleaner
- measuring stick

Vocabulary: Eruption column, lava, lava fountains, Law of Superposition, tephra, volcanic ash

Skills: Observing, predicting, analyzing, graphing, cooperating, interpreting

Benchmarks:

See benchmarks in Introduction.

distance downwind from the volcano. Viewed on a map, the plume trace and tephra layers are generally in the shape of an elongated oval. At high wind speeds the tephra layer is long and narrow. At lower wind speeds the tephra layer is shorter and wider. When there is no wind, the tephra deposit may be circular around the vent.

During successive eruptions tephra might fall in a similar pattern, overlapping or covering completely the older layer. Geologists establish the relative ages of layers by looking at the order in which the layers were deposited. As stated by the ***Law of Superposition***, layers that are younger will be deposited on top of layers that are older.

Meteorological records show that at Cascade Range volcanoes, the wind blows most often from west to east. This trend in wind direction during ancient eruptions is revealed in multiple tephra layers that are thickest on the east side of the Cascade Range.

The extensions in this activity provide opportunities for students to determine the path of volcanic ash after its eruption from a Cascade Range volcano.

Four clues to reading a tephra deposit

Geologists rely on four principal lines of evidence when they interpret tephra layers and identify their volcano of origin:

1. Tephra layers are thickest near and on the source volcano.
2. Coarse tephra falls to the ground before finer-grained tephra.
3. Younger layers overlie older layers.
4. A unique chemical signature exists at many volcanoes that allows researchers to match tephra with its source volcano. This fourth clue holds great importance to geologists, though it is not addressed in this activity.

Once your students understand these concepts and conduct the activity, they can be part of the volcano fan club!

- ***Conduct the activity*** Volcanic Processes ***or, for older and mature classes, show the video*** Understanding Volcanic Hazards, ***which displays magnificient footage of tephra. This prepares your class for the activity***
- ***See the*** Soda Bottle Volcano ***activity for an understanding of how tephra is produced***
- ***See the*** Tephra Popcorn ***activity for a description of the different types of tephra***
- ***See the*** Tephra Explorer ***activity to learn more about tephra layers at Mount Rainier***

Procedure

What to do Before Class Begins:

Blowing in the Wind:

- Decide whether to conduct this activity with student groups or as a teacher demonstration, and whether you wish to do multiple runs.
- Select an area that is easy to clean and has enough space for all three experiment stations, 6 millimeters x 1.5 meters (20 feet x 5 feet).
- For each experiment station, prepare 1 cup of each tephra sample (cocoa cornmeal, oatmeal, and rice)—more if you plan to conduct multiple runs with varying conditions.

Activity Procedure:

Blowing in the Wind:

Simulate an eruption of tephra and analyze the resulting layers.

1. Tell students that once they complete this activity, they can become part of the volcano fan club!

2. Explain to students that they will make a series of tephra layers with household ingredients. They will collect, analyze and graph data before presenting results to the class.

3. If conducting this activity with student participation, divide students into three groups and assign each group a station. Each group will simulate a different wind speed.

4. Distribute the "***Blowing in the Wind***" student page. Review the experiment instructions on the student page.

5. Instruct students to record their data on the student page. Keep in mind that each square on the table cloth represents one square kilometer (or mile).

6. When students finish the experiments, and before cleanup, instruct each group to observe the other groups' "tephra" layers.

7. Instruct students to graph the distribution of the "tephra" layers, and to answer the questions on the student page.

8. Reassemble the class. Each group should present their results and graph to the reminder of the class. Discuss the similarities and differences in each group's results.

9. Lead a discussion. In what ways, does this experiment illustrate the four clues? How did wind speed affect the results? How does wind direction play a role in tephra distribution? How well does this activity illustrate the process of tephra dispersal from an erupting volcano? Why might tephra on the slopes of one volcano be found on the slopes of another? How might one eruption produce multiple tephra layers oriented in different directions? Hypothesize about what happens to tephra when it falls through rain.

Adaptations

- Instruct students to show results of their experiment in stylized illustrations or to diagram their results on a whiteboard.
- Instruct students to use a computer spreadsheet program to construct their data table and graph.
- Ask students to make their own tephra by crushing colorful pieces of cereal to make different sizes of tephra.
- Instead of a large fan, try using a hair dryer or hand-held mini-fan in the experiment.
- Change the wind direction by setting the fan at an angle to the paper.
- Add topography to the experiment. Instruct students to make hills and valleys by stuffing material under the table cloth or paper. Repeat the experiment and observe how topography affects tephra distribution.
- Illustrate the concept by showing layers of various types of candy in a candy jar.

Extensions

- ***Simulate effects of ash fall on a map landscape.***
  Simulate effects of ashfall on the region around a volcano. Obtain a large paper map that shows a volcano and surrounding landscape, including towns and cities, roads, airports and other features. Place children's toy plastic animals, cars, trucks, airplane, school buses and emergency vehicles on the map surface. Set up a fan on the volcano to create wind. Simulate volcanic ash, either with the use of real volcanic ash, or fine silt or clay, cocoa powder, or flour. Students use a spoon to ladle the "ash" in front of wind created by the fan. Students observe and discuss which areas are ash covered, and effects on animals, transportation, and communities. See Internet Resources for Web sites that describe effects of volcanic ash.

- ***Determine the path of volcanic ash using data at the American Meteorological Society's data pages.***
  This extension requires students to possess some understanding about meteorological maps and of atmospheric pressure and its control over wind direction and speed. Students estimate the travel direction and speed of an ash plume at a Cascade Range volcano. Instruct students to visit the American Meteorological Society's DataStreme Web pages (See Internet Resources Page for address). At the Web site, students observe the wind speed and direction in the upper air above a Cascade Range volcano of their choice. They note the pressure levels for 850 millibars, 700 millibars and 500 millibars, then assume that an eruption hurls volcanic ash to an altitude of 6 kilometers (approximately 20,000 feet). Students make predictions about the where the ash will travel to in 9 hours.

Assessment

For assessment, instruct students to show results of their experiment in an illustration, or to diagram or graph the class results on a whiteboard. Review the student page results and look for evidence of student recognition that coarse materials fall first, followed by fine-grained material. Students should demonstrate ability to measure the area of the concentrated tephra; graph the data and interpret it. Instruct students to draw stylized diagrams of any tephra deposit formed by far-traveled winds, and by an eruption with no winds. Assess application to real-world situations by assigning interpretation of an additional ready-to-interpret data set of your choosing, and by asking questions about how this pattern of distribution might affect all regions of your state.

References

Frances, P., Oppenheimer, C., 2004, Volcanoes: New York, N.Y., Oxford University Press, 521 p.

Kenedi, C.A., Brantley, S.R., Hendley, J.W., II, and Stauffer, P.H., 2000, volcanic ash fall—A hard rain of abrasive particles: U.S. Geological Survey Fact Sheet 027–00, 2 p.

Myers, B., Brantley, S.R., Stauffer, P.H., and Hendley, J.W., II, 1997, What are volcano hazards? (revised March, 2008): U.S. Geological Survey Fact Sheet 002–97, 2 p.

Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

Student Page

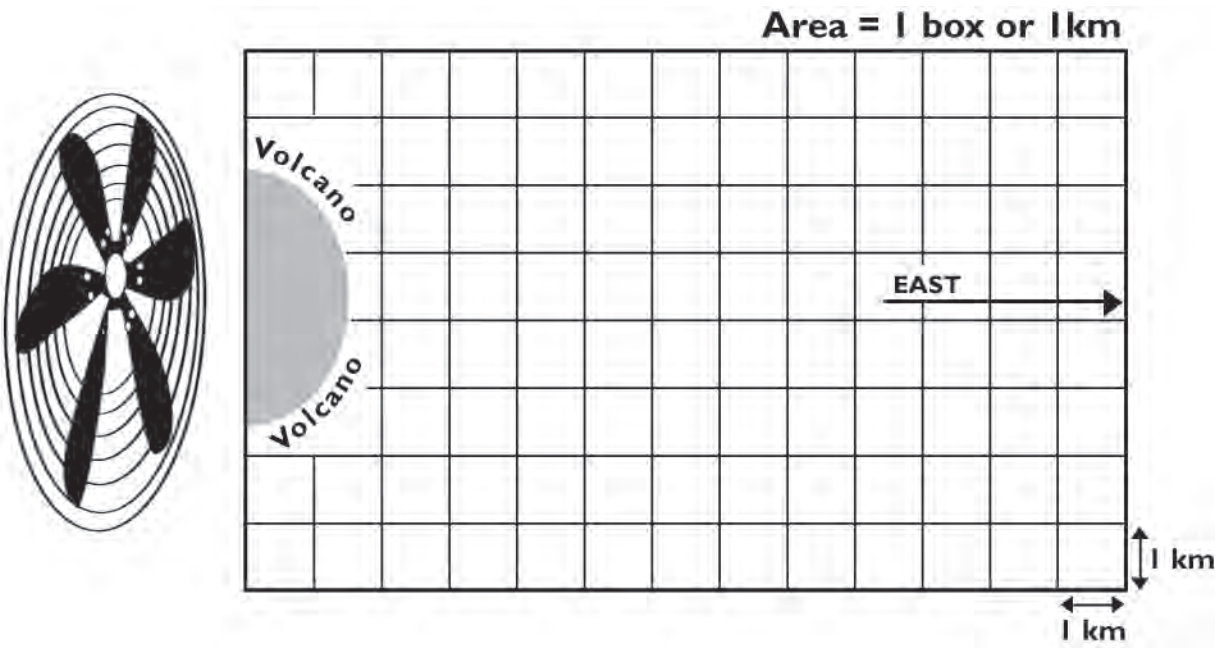
Name _____

Volcano Fan Club

Instructions:

The Setup:

1. Collect materials: student page, table cloth, fan, masking tape, washable marker, measuring stick, and tephra samples: cocoa powder, cornmeal, rice, and oatmeal.
2. Lay table cloth or paper flat across your work area. Tape the corners down, if necessary.
3. Place the fan at one end of the table cloth (see diagram).
4. Use the washable marker to draw a semicircle with a 15 centimeters, (6 inches) radius in front of the fan to represent the slopes of the volcano. Label the semicircle "Volcano."

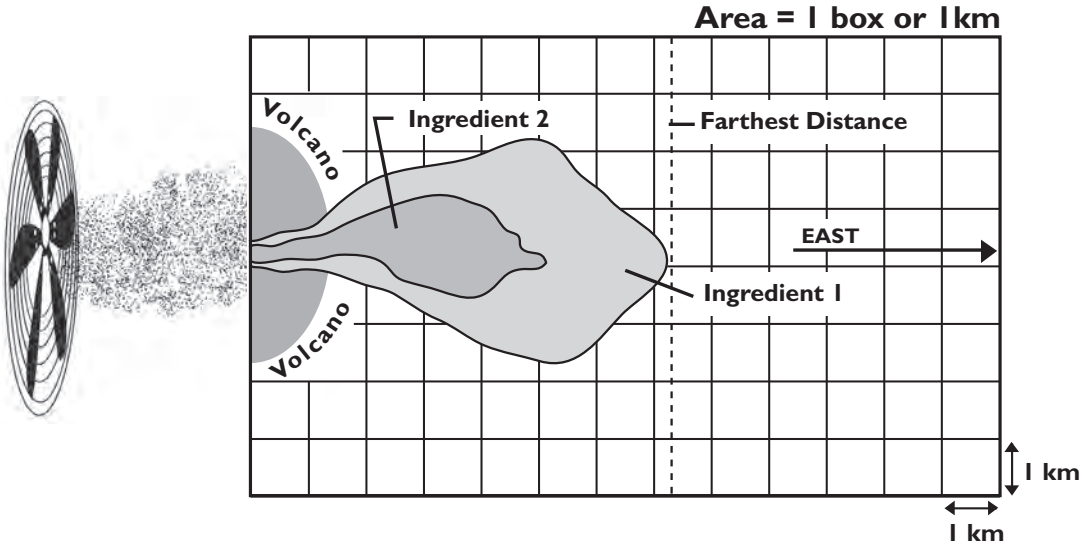


Student Page

Name _____

Volcano Fan Club-continued

Instructions:



The Experiment—Depositing Tephra

1. Read through all of the directions before beginning the experiment.
2. Make a prediction and hypothesis on your "***Volcano Fan Club***" (page 10).
3. Turn on the fan to the proper setting as assigned to your group. Use a spoon to gently sprinkle one ingredient at a time in front of the fan, as if releasing it into the wind. Place your hand to the same position relative to the fan each time.
4. Turn off the fan between releases of each ingredient.
5. Use a washable marker to outline the concentrated area of the deposit where the majority of the ingredients fell. This will require using your best judgment (the job is no easier for geologists who do similar mapping of tephra after volcanic eruptions!)
6. Measure the farthest distance traveled by each ingredient. Recall that the side of each square equals 1 kilometer. Record the results on the student page.
7. Count the total number of squares that are covered by each ingredient. Record the results in the space provided on the student page.
8. Repeat until all tephra samples have been used.
9. Complete the data sheet by calculating the area covered by each type of tephra. Record the results in square kilometers.
10. Prepare the results of your experiment as a bar graph to be shared with your class.

Student Page

Name _____

Volcano Fan Club-continued

Ingredients	Farthest Distance Traveled (km)	Area of Ash Cover (1 square = 1km2)	Other Observations

Instructions:

1. Make predictions about which ingredients will travel farthest, and which will cover the largest area.

2. Write a hypothesis based about your predictions.

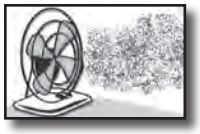
3. Conduct your experiment using "Volcano Fan Club" Instructions on page 9.
Record your data on the table above.

4. On the next page, graph results, and address the instructions below.

Experimental Wind Speed: _____ (high, medium or low)

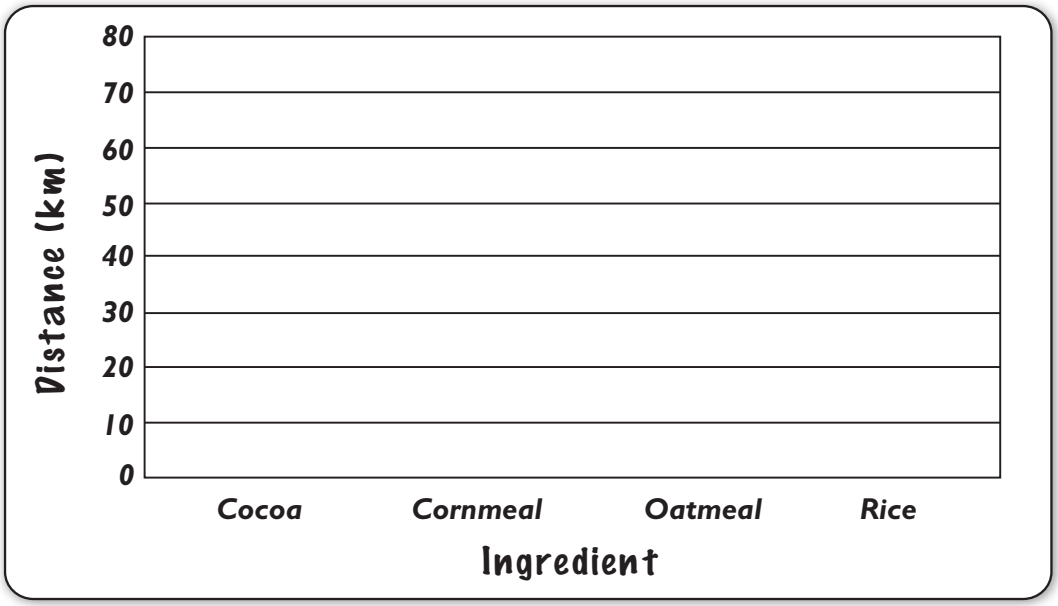
Student Page

Name _____

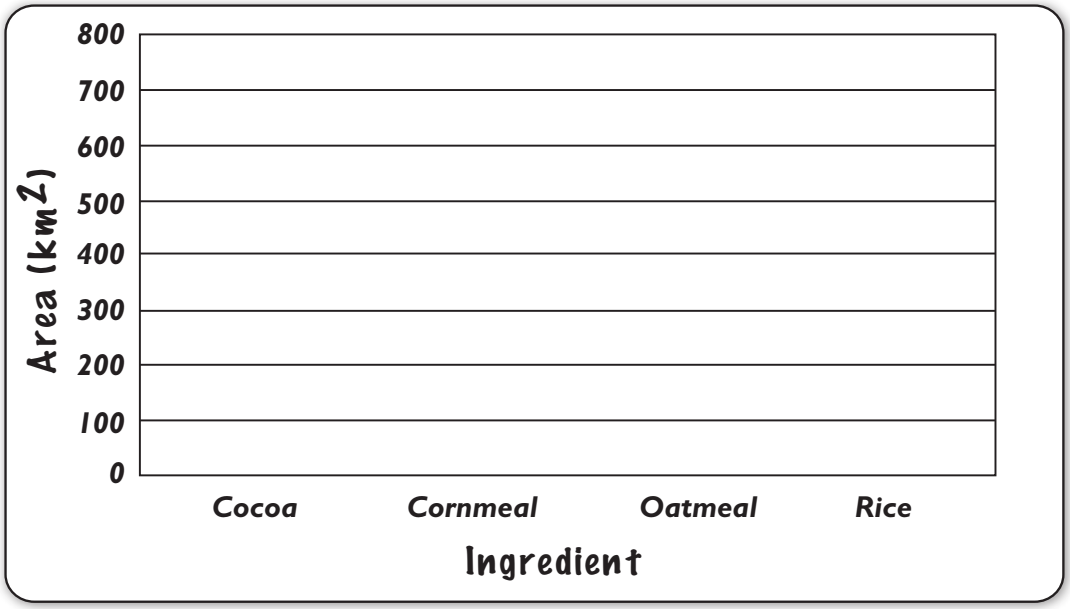


Volcano Fan Club-continued

Maximum Distance Traveled for Each Ingredient



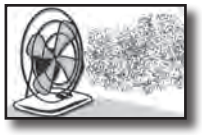
Area Covered for Each Ingredient



Student Page

Team Names _____

_____



Volcano Fan Club Results

Analyzing your results from the graphs:

1. Describe the relationship between tephra size and distance traveled. Explain these observations.

2. Describe the relationship between tephra size and area covered. What factors influence this relationship?

3. Write a conclusion and cite data as evidence.

4. Use your knowledge of tephra distribution to describe the atmospheric conditions that brought tephra from Mount St. Helens and ancient Mount Mazama (Crater Lake, Oregon) to the slopes of Mount Rainier. Describe at least one likely characteristic of this tephra.

5. Describe the energy transformations that occur when tephra erupts from a volcano, travels downwind, and falls to the ground.

Teacher Page

Volcano Fan Club Results—Answers

Instructions:

1. Each group's predictions will vary, based on the fan speed assigned to them.

2. Students might predict correctly that the smaller and lighter materials travel farther and spread more broadly in area than larger, heavier materials. Some students might note correctly that the aerodynamics of some ingredients might influence results.

Graph Results:

Graph results should indicate greater transport distance and area covered by the finer-grained materials, such as cocoa and cornmeal.

Analyzing your results from the graphs:

1. Describe the relationship between tephra size and distance traveled. Explain these observations.

   Graph results should indicate greater transport distance and area covered by the finer-grained materials, such as cocoa and cornmeal. This results from the greater capacity of rapidly moving air to transport particles before they settle, than slowly moving air.

   Note: Remember to discuss the similarities and differences in each group's results.

2. Describe the relationship between tephra size and area covered. What factors influence this relationship?

   Graph results should indicate greater area covered by fine-grained materials, caused by the easier transport of fine particles.

3. Write a conclusion and cite data as evidence.

   Fine-grained material can remain airborne even after coarse material falls to the ground. The area covered and distance of travel depends in part upon wind speed. Wind direction determines the ash plume direction of travel. Cite evidence from students' graphs.

Teacher Page

Volcano Fan Club Results—Answers -continued

4. Use your knowledge of tephra distribution to describe the atmospheric conditions that brought tephra from Mount St. Helens and ancient Mount Mazama (Crater Lake, Oregon) to the slopes of Mount Rainier. Describe at least one likely characteristic of this tephra.

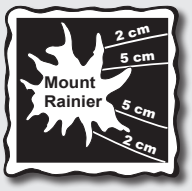
   Winds blowing from southwest to northeast were of sufficient velocity to transport tephra to the slopes of Mount Rainier. The tephra found on the slopes of Mount Rainier is medium to fine-grained material.

   Note: Encourage discussion about what additional atmospheric conditions (rain, jet stream, etc.) and eruption variables (amount of tephra erupted, height of the eruption cloud, etc.), might influence the path of an ash cloud.

5. Describe the energy transformations that occur when tephra erupts from a volcano, travels downwind, and falls to the ground.

   Tephra ejected from the volcano rises due to thermal energy, and gains potential energy with altitude. Once thermal energy is expended, tephra particles begin to fall. Kinetic energy is expended as the tephra particles fall towards the ground.

Tephra Explorer



Grade Level: 6–9

Learner Objectives:

Students will:

- Understand general distribution patterns of tephra dispersal by wind at Mount Rainier
- Understand how to interpret an isopach map
- Recognize that some tephra at Mount Rainier originated at other Cascade volcanoes

Setting: Classroom

Timeframe: 50 minutes (or 1 class session)

Materials:

- Copies of *"Make Your Own Tephra Isopach Map"* student page
- Graphic of *"Exploring Tephra Layers at Mount Rainier"*—
  Tephra Maps 1 through 6
- Projection copy or student copies of *"Exploring Tephra Layers at Mount Rainier"*
- Map of Cascades Volcanoes

USGS
science for a changing world

NATIONAL PARK SERVICE

Living with a Volcano in Your Backyard-An Educator's Guide with Emphasis on Mount Rainier

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

Students view distribution patterns of tephra layers found around Mount Rainier and discover their source.

Vocabulary: Isopach, pumice, scoria, silica, tephra, volcanic ash

Skills: Prediction, interpretation, map reading

Benchmarks:

See benchmarks in Introduction.

Activity last modified: September 5, 2014

Teacher Background

Tephra is a general term for fragments of rock and lava regardless of size that are blasted into the air by explosive eruptions. Tephra includes large rocks and small fragments, such as ***scoria***, ***pumice*** and ***volcanic ash***. At Mount Rainier, tephra is conspicuous as sandy material in colorful shades of orange, tan, yellow, gray, brown and white. Each tephra layer represents an eruptive event.

During an eruption, large pieces of dense rock, pumice and scoria drop on the slopes of the volcano while volcanic ash often remains aloft and is transported laterally. When volcanic ash and surrounding air cools, and air speed is insufficient to support it, the ash drops to the ground and forms a layer often in the shape of an elongated oval.

While Mount Rainier is the source for at least 40 recognizable tephra layers, not all of the tephra found within Mount Rainier National Park originated there. Wind carried volcanic ash from eruptions at Mount St. Helens to the slopes of Mount Rainier on at least two occasions, once between 3,700 and 3,800 years ago and in A.D.1480 (layers Yn and W respectively), and from ancient Mount Mazama (Crater Lake) in Oregon to broad regions of the Pacific Northwest around 7,700 years ago (layer O).

These rogue layers puzzled early researchers who found the ash in unexpected locations and who recognized that their chemical composition differed from rocks at Mount Rainier. By carefully mapping the thickness of each ash layer, geologists were able to see that the ash layer thickened away from Mount Rainier and thereby were able to trace the ash and pumice to its source. They confirmed their hypothesis, thereby matching the chemical composition of the tephra layers with their volcanic origin.

Far-traveled tephra from Mounts St. Helens and ancient Mazama have a ***silica*** content that typically ranges between 62 and 67 percent. Tephra from these two volcanoes appears white, gray, tan or orange in color. Mount Rainier rocks and tephra contain 55 to 64 percent silica. Its tephra typically appears darker in color than tephra from Mount St. Helens and Mount Mazama.

Teacher Tips

See "Volcano Fan Club" for more information on clues geologists use to interpret tephra layers.

See "Tephra Popcorn" for details about different types of tephra.

The "Soda Bottle Volcano" activity describes how tephra is formed.

Sidebar 1 Isopachs

Geologists measure the thickness of a tephra layer and note its grain size in numerous locations, then record thickness values on a map. Later, they draw lines of equal thickness called isopachs, in the same way that elevation is portrayed with contours on a topographic map. With an isopach map in hand, they can trace the layer to its thickest point on the slopes of the source volcano.

Sidebar 2 How Do They Name Tephra Layers at Mount Rainier?

At Mount Rainier, tephra layers are named using letters of the alphabet (Tephra O, Tephra Y, Tephra C, etc...). The letters are not in alphabetical order because when geologists first studied tephra layers at Mount Rainier, they did not know how many layers they would find. They named the layers after physical characteristics such as color. For example: Tephra O for orange, Tephra W for white, and Tephra Yn for yellow.

Procedure

Exploring Tephra Layers at Mount Rainier

Determine the origin of tephra layers on the flanks of Mount Rainier by studying maps and developing hypotheses based on tephra thickness and distribution. These tephra layers are some of the most prominent layers observable by visitors on the south side of Mount Rainier National Park.

1. ***Before class begins,*** determine whether you wish to project maps for all-class viewing or distribute a set of maps to each student or student group, and then make preparations. All students should receive a copy of the student page "***Make Your Own Tephra Isopach Map***."

2. ***Tell students that some tephra layers on the flanks of Mount Rainier originated at other volcanoes*** and explain how this at first perplexed geologists who assumed that the tephra had erupted from Mount Rainier. Explain to students that they will observe maps of tephra layers at Mount Rainier. Encourage them to develop hypotheses about how wind direction influences the pattern of tephra fallout.

3. ***Begin (and end) the activity with the "Tephra Isopach Map" student page,*** where students read that at Cascade volcanoes, the prevailing direction of air flow is towards the east, northeast, or southeast approximately 85 percent of the time. They are instructed to draw a hypothetical tephra layer—a partly teardrop shape that delineates the outermost limit of a recognized tephra layer. This tephra layer originates at the summit crater and extends away from the volcano, as blown by prevailing winds. Be sure that students recognize this as a vertical view, with the observer looking down upon a tephra layer on the ground. This step should advance students' understanding of the general pattern of tephra fallout at volcanoes, and help them to interpret tephra maps 1 and 2.

4. ***"Instruct the students to draw circles (contours)*** to separate the zeros from the ones, the ones from the twos, the twos from the threes, and the threes from the fours (see example on teacher page 10). These contours indicate areas of equal tephra thickness, known as isopachs. Explain that a tephra isopach map is a standard tool used by geologists who study volcanic eruptions.

5. ***Use overhead projection to display tephra maps 1 through 6*** or provide paper copies to each student or student group. For each map, students should identify the wind direction at the time of the tephra eruption and a probable source volcano. Students should make note of the location of their community relative to the probable volcanic source and assess whether tephra from each eruption has fallen there. Use the "***Map of Cascade Volcanoes***" as a guide to this investigation.

6. ***Promote further discussion*** about what happens when the wind direction changes during the course of an eruption or when rising tephra reaches atmospheric levels where winds blow in opposing directions. Tephra fallout patterns can become complex, such as during the eruptions of Mount St. Helens in the 1980s, when complex atmospheric conditions resulted in complicated small-scale patterns of tephra fall across Washington State.

7. ***Return to the student page "Make Your Own Tephra Isopach Map."*** Instruct students to use a different color marker or pen to add to their student page maps, by drawing 3 to 5 hypothetical isopachs for a potential future tephra fall on Mount Rainier from a large eruption at Crater Lake. (Isopachs should appear as curved lines from the south, with decreasing thickness towards the north.) Provide additional scenarios for students' drawing of isopachs, such as the pattern of a tephra layer that results from easterly winds (which would result with a teardrop shape facing west).

8. ***Invite discussion*** about how this information can assist geologists who investigate a volcano's history and hazards. Explore the types of information that geologists can obtain from these maps, such as the volcanic source, area and volume of tephra erupted, and wind direction at the time of eruption.

9. ***Lead a discussion of energy transformation,*** where rising tephra gains potential energy as it rises and looses energy as it falls.

Optional: Provide students with information about some Pacific Northwest tephra layers by distributing the information on the teacher pages.

Adaptations

- ***Use protractors with your study of tephra layers.*** Provide students with protractors and instruct them to determine precise compass directions of tephra fall for the "***Tephra Maps***," 1 through 6. For the student page "***Make Your Own Tephra Isopach Map***," choose some compass directions in degrees and instruct students to produce a tephra layer on the axis of the compass directions provided. Explore together what regions or communities would be affected by these hypothetical tephra eruptions.

Extensions

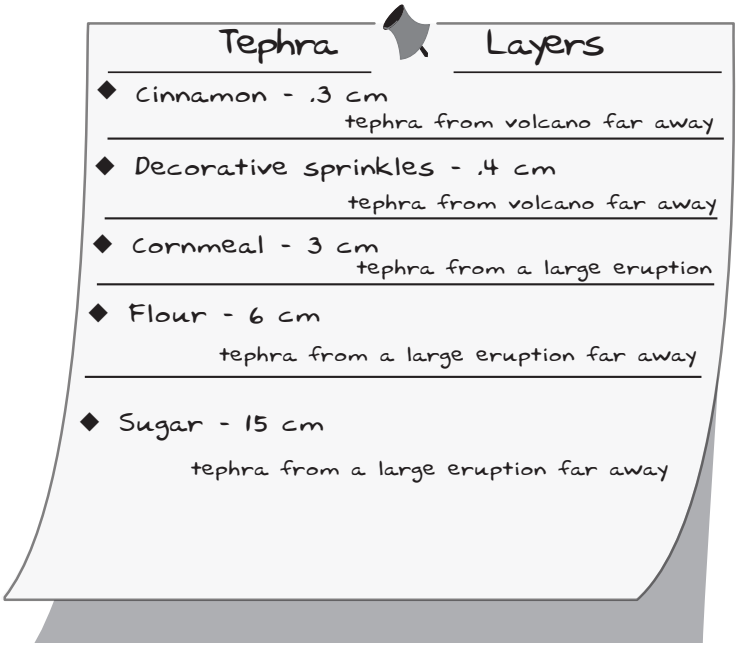
- ***Students Research the Tephra Layers Discussed in this Activity.*** Students conduct a library or Internet search for information about the tephra layers discussed in this activity.

- ***Use kitchen ingredients to make a cross-sectional representation of tephra layers stacked one upon the other. Assemble cornmeal, cinnamon, oatmeal, flour, decorative sprinkles, and different colors of sugar, paper and glue sticks.***

  1. Students draw a rectangle across one-half of a piece of construction paper.

  2. They take a pinch of each ingredient, and glue it on the paper from the bottom of the rectangle to the top. Each ingredient represents a layer of tephra.

  3. Students should label each layer, and then while observing the width of each layer on the paper and its relative particle size, add a few words about the eruptive event, such as "large eruption," "short eruption," "tephra from nearby eruption" and "tephra from far away."



Assessment

Look for students' understanding of the following concepts: 1) that wind disperses tephra; 2) tephra particle sizes are greatest near the volcano; 3) some tephra on the slopes of one volcano might have erupted from a different volcano. Students should understand that tephra layers provide a valuable record of previous eruptions. Students might indicate that this knowledge helps scientists determine the kinds of eruptions that happen at a given volcano, and ultimately the most likely eruption types for the future. Understanding what types of eruptions can happen in the future ultimately saves lives and property and improves the well being of nearby communities.

References

Mullineaux, D.R., 1974, Pumice and other pyroclastics in deposits at Mount Rainier National Park: U.S. Geological Survey Bulletin 1326, 83 p.

Crandell, D.R., 1969, Surficial geology of Mount Rainier National Park Washington: U.S. Geological Survey Bulletin 1288, 41 p.

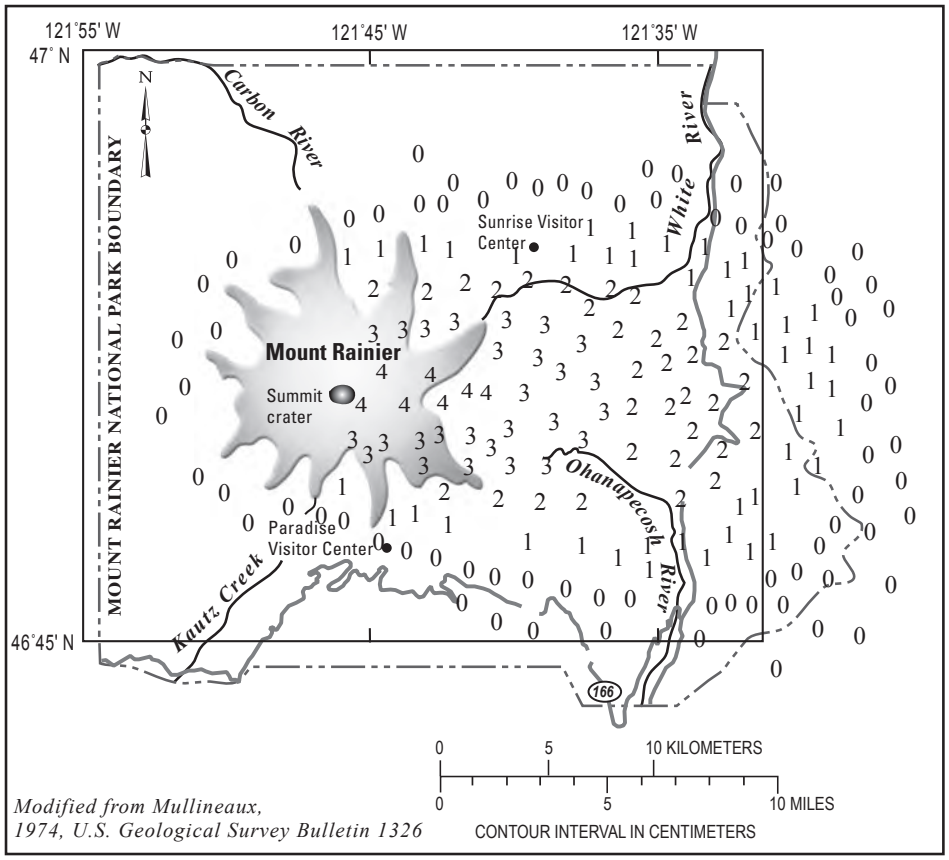
Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

Student Page

Name _____

Make Your Own Tephra Isopach Map

In the vicinity of the Cascade volcanoes, the prevailing direction of air flow (wind) is towards the east, northeast, or southeast approximately 85 percent of the time. Based on this information, make a prediction about the direction of tephra travel during an eruption of Mount Rainier. Draw a wind arrow on the map below.



Modified from Mullineaux, 1974, U.S. Geological Survey Bulletin 1326

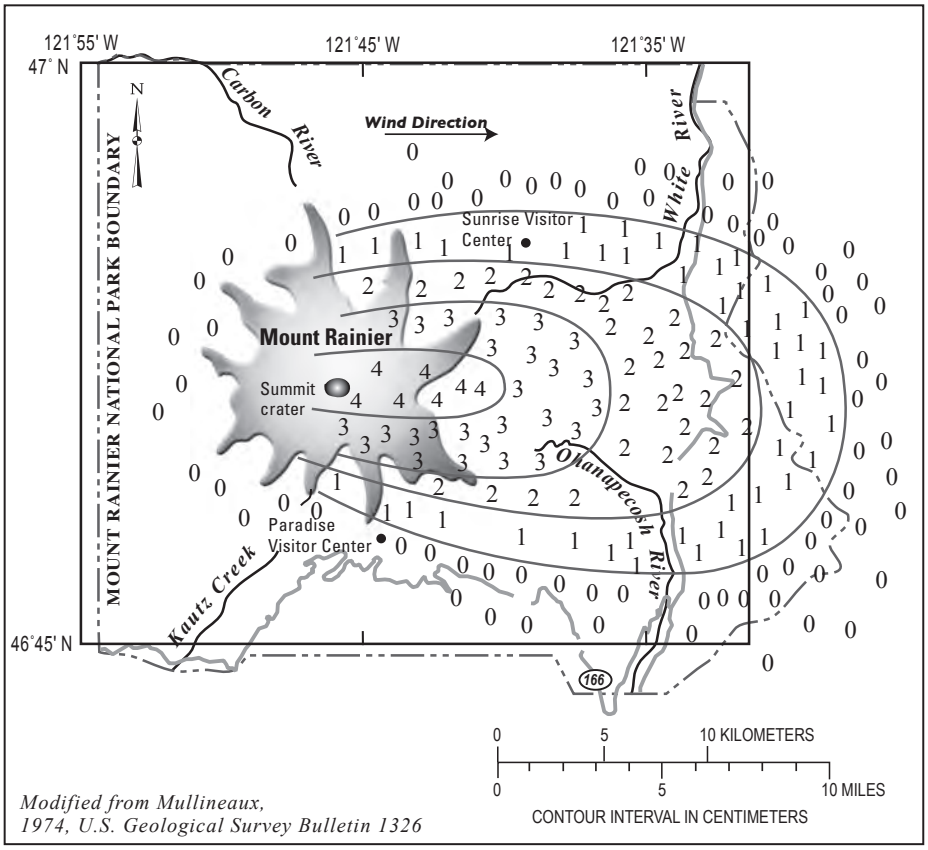
1. Develop an hypothesis that explains how the thickness of tephra fall will vary with increasing distance from the volcano.

2. Draw circles (contours) to separate the zeros from the ones, the ones from the twos. the twos from the threes, and the threes from the fours. These contours indicate areas of equal tephra thickness and are known as isopachs.

Teacher Page

Make Your Own Tephra Isopach Map

In the vicinity of the Cascade volcanoes, the prevailing direction of air flow (wind) is towards the east, northeast, or southeast approximately 85 percent of the time. Based on this information, make a prediction about the direction of tephra travel during an eruption of Mount Rainier. Draw a wind arrow on the map below.



Modified from Mullineaux, 1974, U.S. Geological Survey Bulletin 1326

1. Develop a hypothesis that explains how ash thickness will vary with increasing distance from the volcano.

ANSWER:
<u>The deposit will be thickest close to the volcano and thinner farther from the volcano.</u>

2. Draw circles (contours) to separate the zeros from the ones, the ones from the twos. the twos from the threes, and the threes from the fours. These contours indicate areas of equal tephra thickness and are known as isopachs.

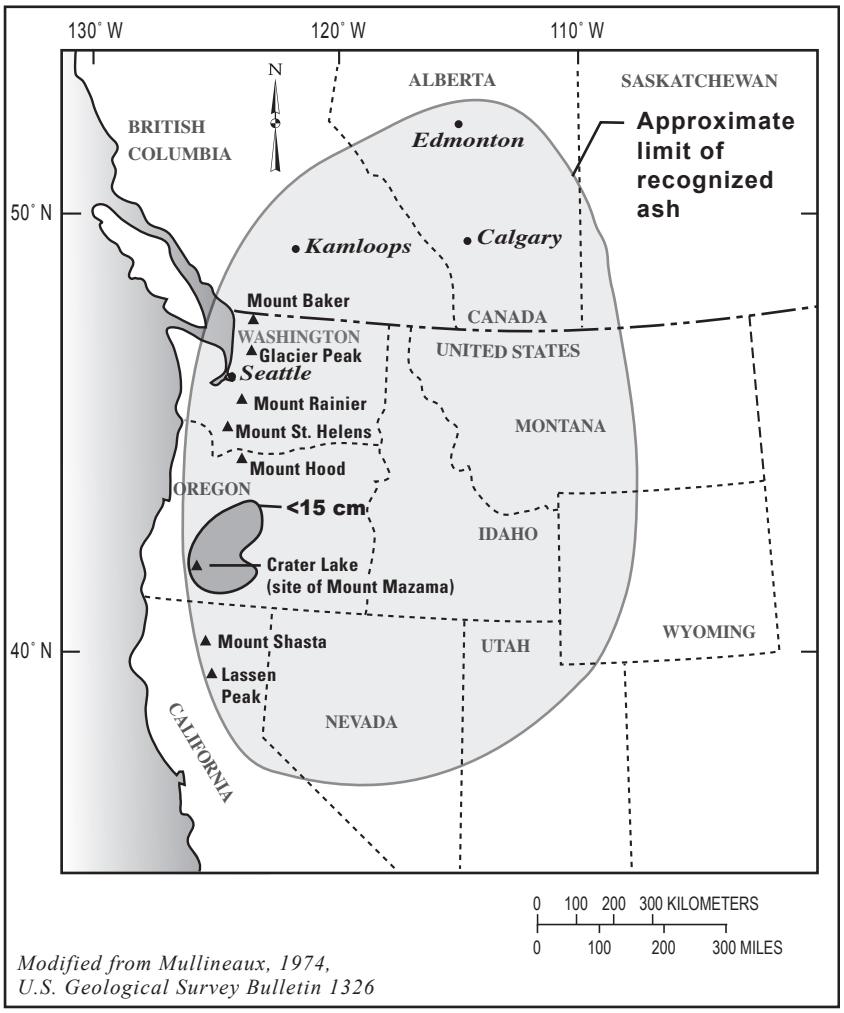
ANSWER:
<u>(see map above)</u>

Student Page

Name _____

Exploring Tephra Layers at Mount Rainier

Instructions: *On Tephra maps 1 through 6, identify the wind direction at the time of the tephra eruption and the probable source volcano.*



Modified from Mullineaux, 1974, U.S. Geological Survey Bulletin 1326

Tephra Map 1

*Wind Direction:*_____

*Source Volcano:*_____

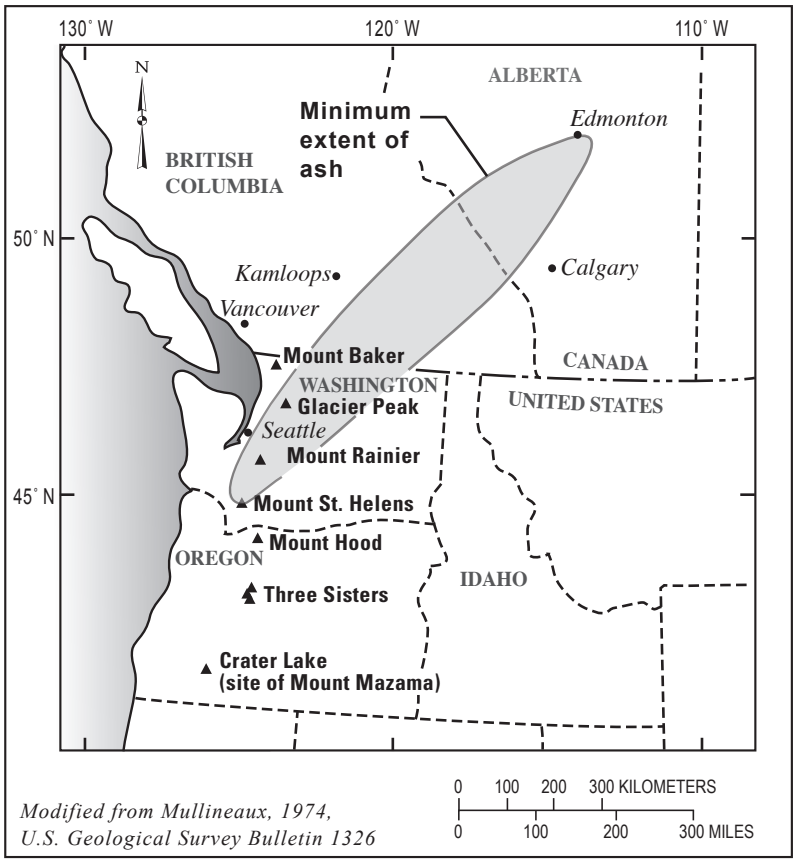
Explain your answer below:

Student Page

Name _____

Exploring Tephra Layers at Mount Rainier -continued

Instructions: *On Tephra maps 1 through 6, identify the wind direction at the time of the tephra eruption and the probable source volcano.*



Modified from Mullineaux, 1974, U.S. Geological Survey Bulletin 1326

Tephra Map 2

*Wind Direction:*_____

*Source Volcano:*_____

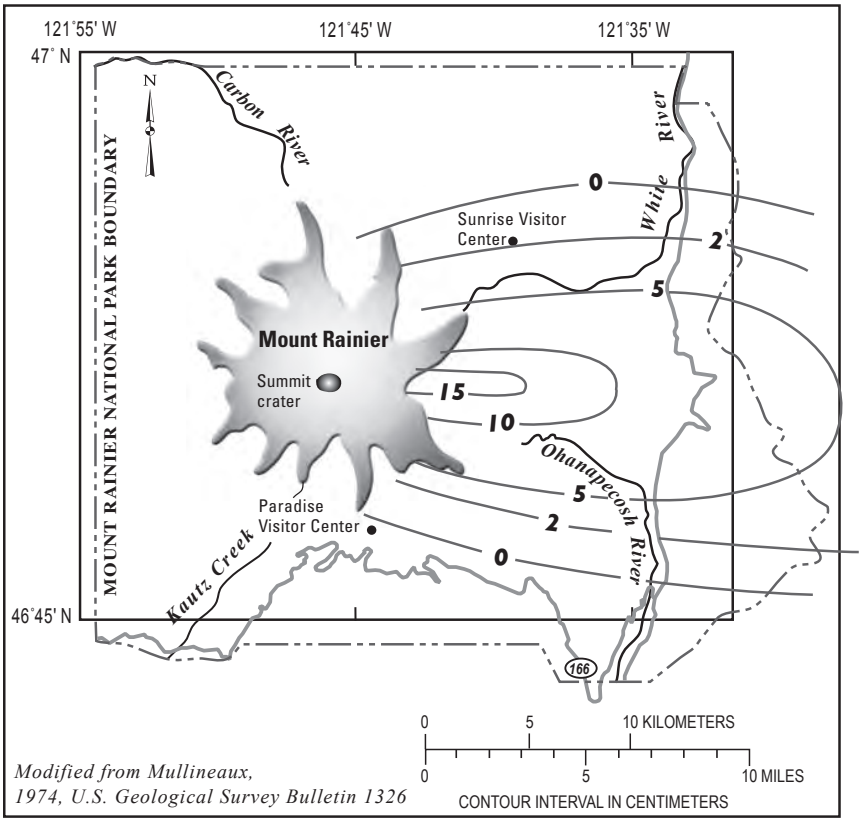
Explain your answer below:

Student Page

Name _____

Exploring Tephra Layers at Mount Rainier -continued

Instructions: *On Tephra maps 1 through 6, identify the wind direction at the time of the tephra eruption and the probable source volcano.*



Modified from Mullineaux, 1974, U.S. Geological Survey Bulletin 1326

Tephra Map 3

*Wind Direction:*_____

*Source Volcano:*_____

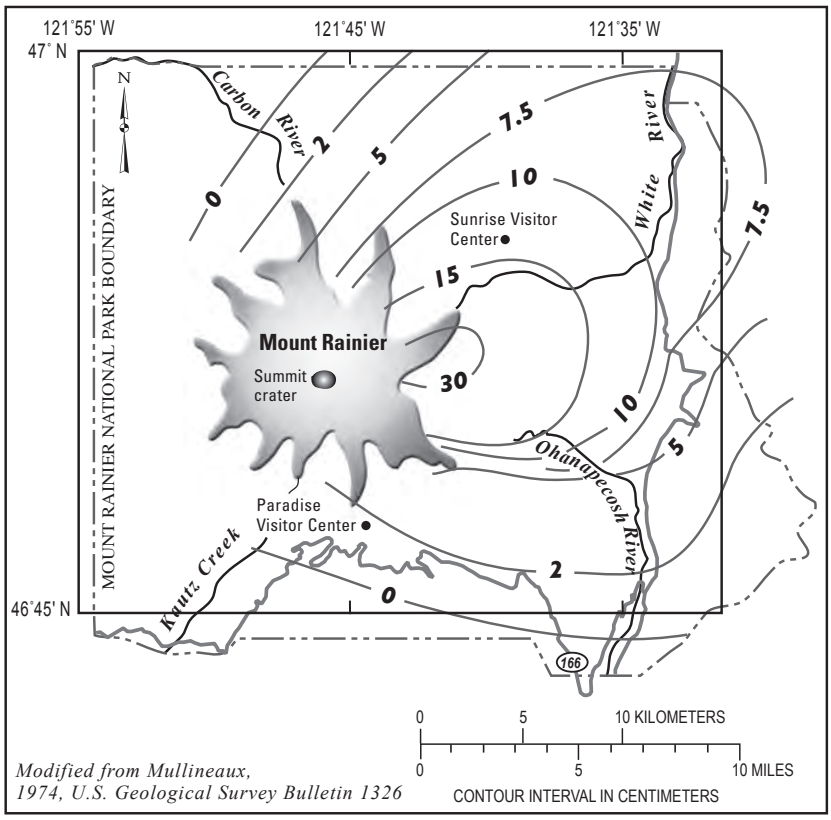
Explain your answer below:

Student Page

Name _____

Exploring Tephra Layers at Mount Rainier -continued

Instructions: *On Tephra maps 1 through 6, identify the wind direction at the time of the tephra eruption and the probable source volcano.*



Tephra Map 4

*Wind Direction:*_____

*Source Volcano:*_____

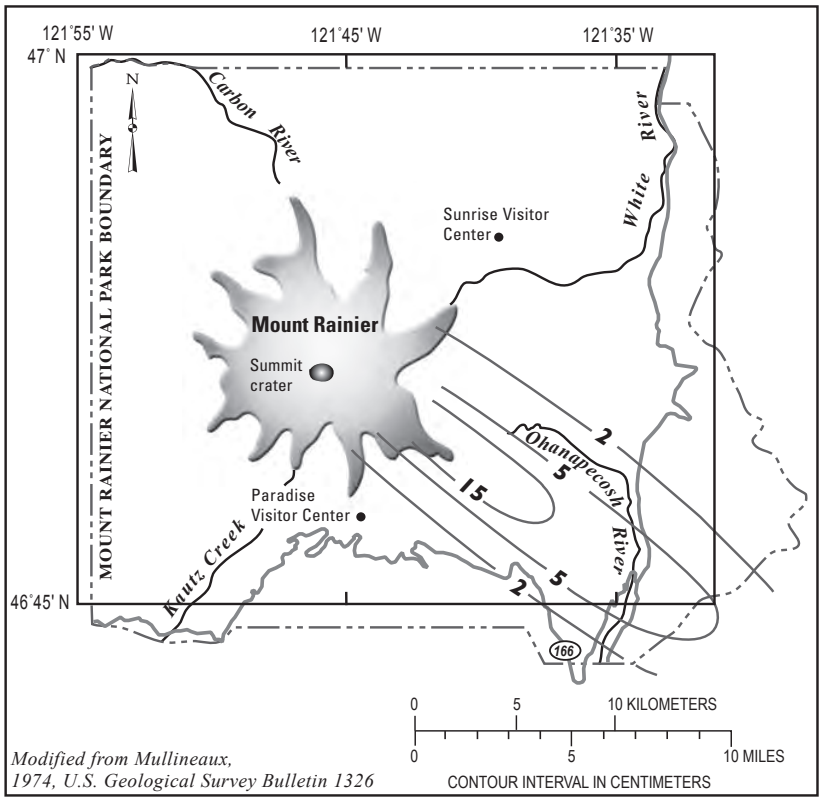
Explain your answer below:

Student Page

Name _____

Exploring Tephra Layers at Mount Rainier -continued

Instructions: *On Tephra maps 1 through 6, identify the wind direction at the time of the tephra eruption and the probable source volcano.*



Modified from Mullineaux, 1974, U.S. Geological Survey Bulletin 1326

Tephra Map 5

*Wind Direction:*_____

*Source Volcano:*_____

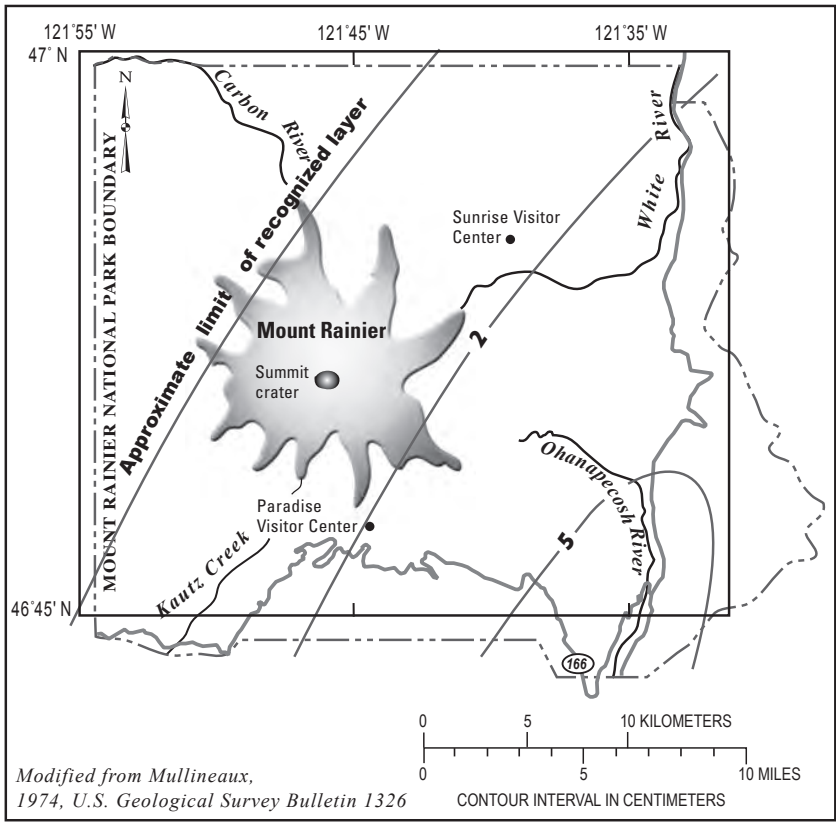
Explain your answer below:

Student Page

Name _____

Exploring Tephra Layers at Mount Rainier -continued

Instructions: *On Tephra maps 1 through 6, identify the wind direction at the time of the tephra eruption and the probable source volcano.*



Modified from Mullineaux, 1974, U.S. Geological Survey Bulletin 1326

Tephra Map 6

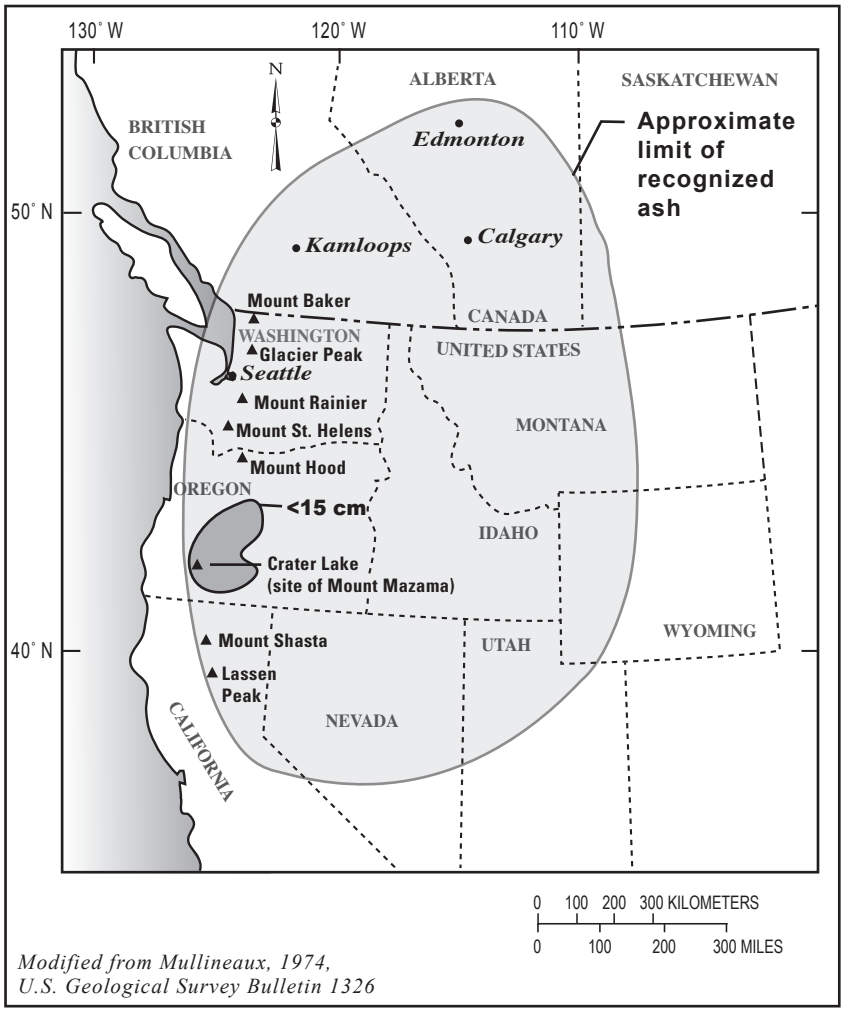
*Wind Direction:*_____

*Source Volcano:*_____

Explain your answer below:

Teacher Page

Exploring Tephra Layers at Mount Rainier—Answers



Modified from Mullineaux, 1974, U.S. Geological Survey Bulletin 1326

Tephra Map 1

*Wind Direction:*_____

*Source Volcano:*_____

Tephra O:

Wind Direction: ***From Southwest***

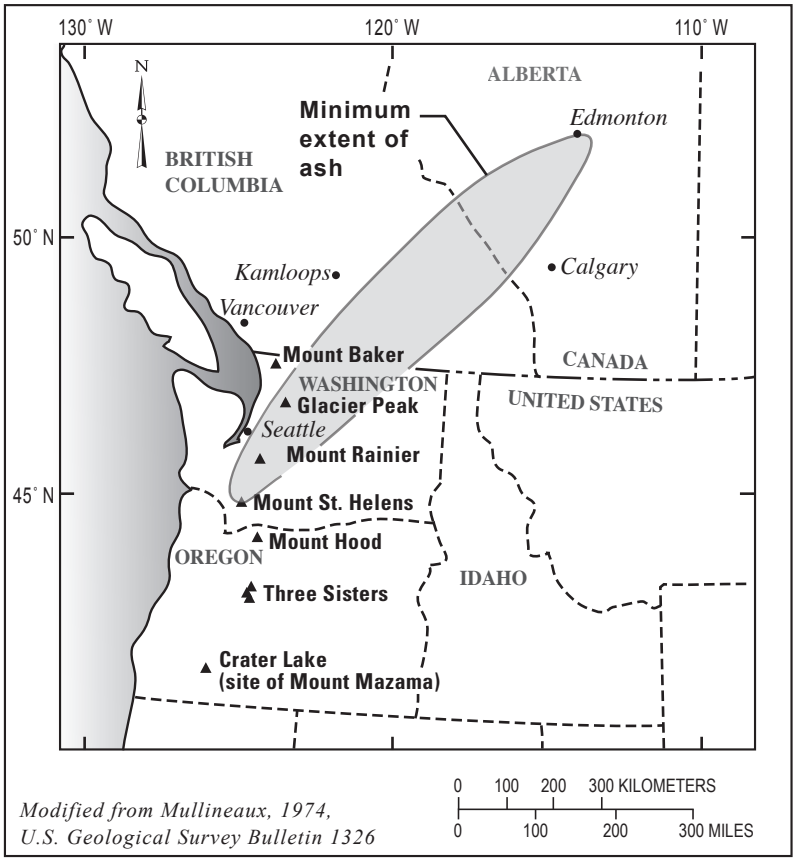
Source Volcano: ***Ancient Mount Mazama (Crater Lake)***

Age: ***7,700 years ago***

Description: Tephra layer O originated from ancient Mount Mazama about 400 kilometers (250 miles) south of Mount Rainier, during a cataclysmic eruption that geologists recognize as the largest known eruption in the Cascades during the past 10,000 years. The eruption emptied the magma chamber, which caused collapse of the summit crater and formed a deep depression that filled with water to become Crater Lake. Wind transported the tephra over much of the northern United States and southwest Canada. At Mount Rainier, tephra layer O is generally about 5 centimeters thick (2 inches). Layer O is recognizable in road and trail cuts by its flourlike texture and commonly yellow-orange color.

Teacher Page

Exploring Tephra Layers at Mount Rainier—Answers-continued



Modified from Mullineaux, 1974, U.S. Geological Survey Bulletin 1326

Tephra Map 2

*Wind Direction:*_____

*Source Volcano:*_____

Tephra Yn:

Wind Direction: ***From Southwest***

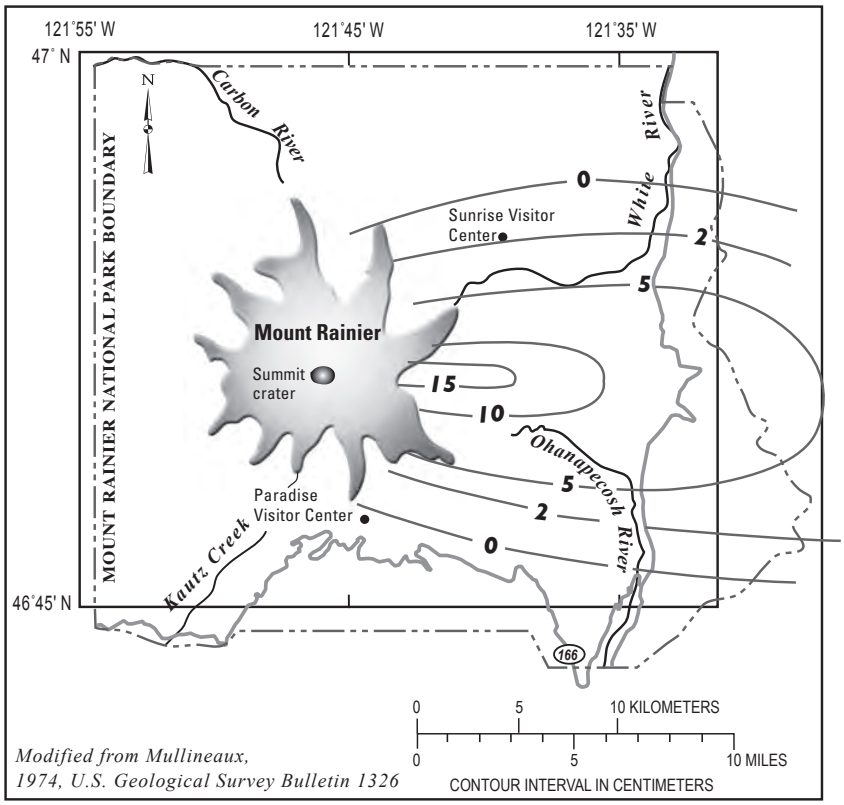
Source Volcano: ***Mount St. Helens***

Age: ***3,700–3,800 years ago***

Description: Between 3,700 and 3,800 years ago, an enormous eruption at Mount St. Helens, about 80 kilometers (50 miles) southwest of Mount Rainier, erupted the tephra that formed layer Yn. This eruption was many times larger than the well known eruption of May 18, 1980. Layer Yn varies in thickness from 0 to 46 centimeters (18 inches) at Mount Rainier National Park. Layer Yn is recognizable by its grainy texture and light-yellow to brown color.

Teacher Page

Exploring Tephra Layers at Mount Rainier—Answers-continued



Modified from Mullineaux, 1974, U.S. Geological Survey Bulletin 1326

Tephra Map 3

*Wind Direction:*_____

*Source Volcano:*_____

Tephra D:

Wind Direction: ***From West***

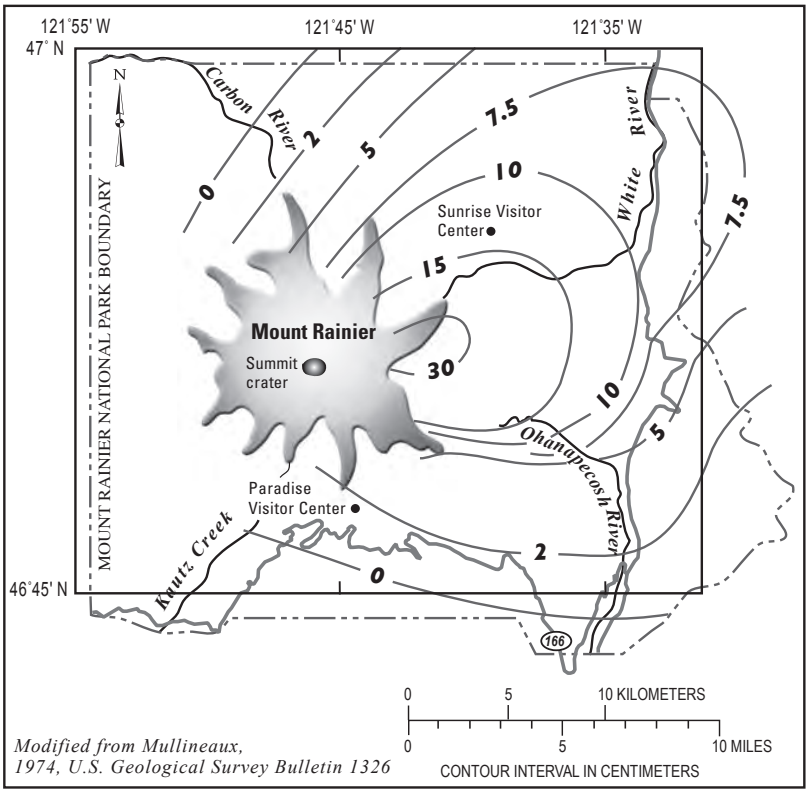
Source Volcano: ***Mount Rainier***

Age: ***6,600–7,400 years ago***

Description: Tephra layer D consists of pumice, scoria and volcanic bombs erupted from Mount Rainier between 6,600 and 7,400 years ago. Wind blew this material to the eastern slopes of the volcano, where it exists to a maximum thickness of 15 centimeters (6 inches). Tephra layer D is recognizable by its coarse texture and yellow to red-brown color. This eruption, one of many in this eruptive period, might have been large enough to form lahars in nearby river valleys.

Teacher Page

Exploring Tephra Layers at Mount Rainier—Answers-continued



Modified from Mullineaux, 1974, U.S. Geological Survey Bulletin 1326

Tephra Map 4

*Wind Direction:*_____

*Source Volcano:*_____

Tephra C:

Wind Direction: ***From West/Southwest***

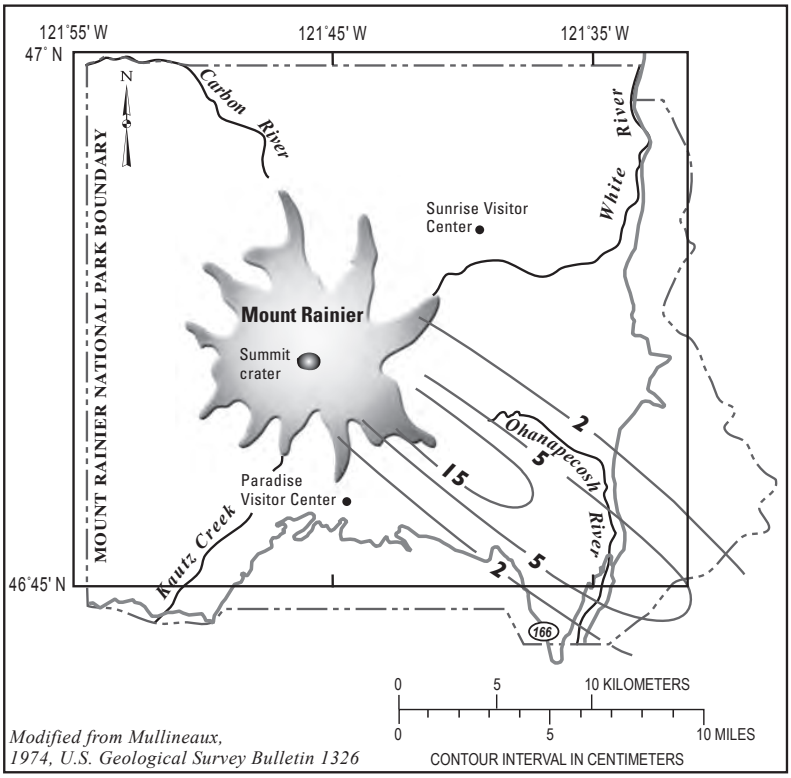
Source Volcano: ***Mount Rainier***

Age: ***2,200 years ago***

Description: Tephra layer C is the thickest and most widespread tephra layer of Mount Rainier origin within the park. The tephra fell on mountain's southern, eastern and northern flanks to a maximum thickness of 30 centimeters (12 inches) near the summit on the eastern flank. Tephra C exists over a broad area, possibly because wind direction fluctuated while the volcano was erupting. The eruption tossed some melon-sized rocks into the air. Winds deposited them 10 kilometers (6 miles) from the volcano! Tephra layer C is coarse-grained and varies in color from nearly-white pumice to dark brown scoria and gray rock fragments. It is coarse grained. Pieces of Tephra C, that are walnut to fist-sized, cover the ground in the vicinity of Sunrise Visitor facilities. The eruption that produced layer C was large enough to form lahars in nearby river valleys.

Teacher Page

Exploring Tephra Layers at Mount Rainier—Answers-continued



Modified from Mullineaux, 1974, U.S. Geological Survey Bulletin 1326

Tephra Map 5

*Wind Direction:*_____

*Source Volcano:*_____

Tephra L:

Wind Direction: ***From Northwest***

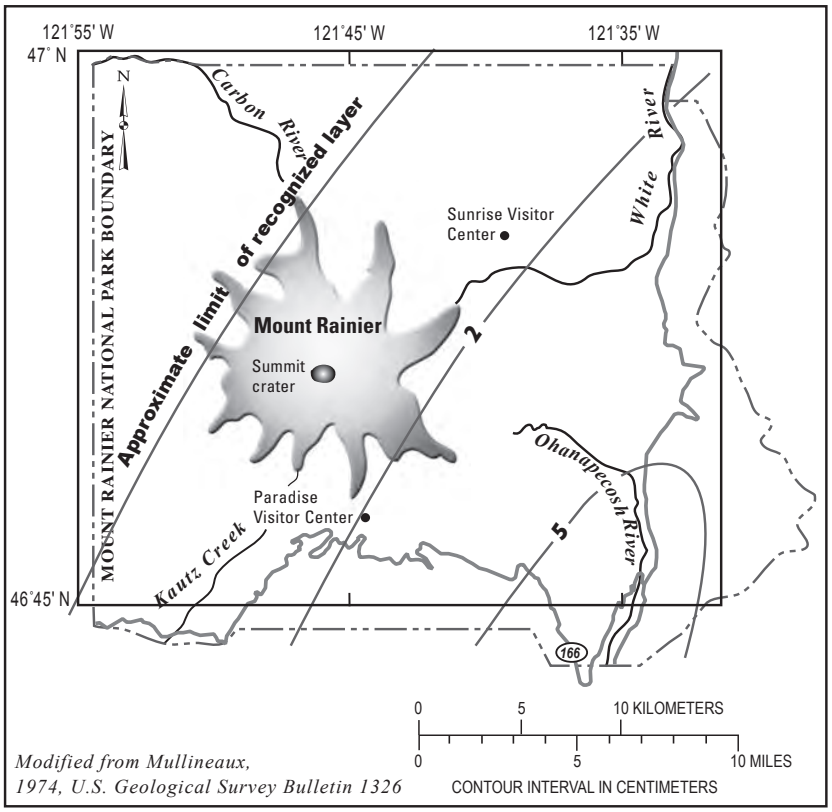
Source Volcano: ***Mount Rainier***

Age: ***7,200 years ago***

Description: Tephra layer L erupted from Mount Rainier and covered much of the eastern and southeastern slopes of the mountain. The narrow band of layer L to the southeast indicates that the wind was strong and blew consistently in this direction during the eruption. Tephra layer L is yellowish-brown in color. It contains pumice, ash and volcanic bombs.

Teacher Page

Exploring Tephra Layers at Mount Rainier—Answers-continued



Modified from Mullineaux, 1974, U.S. Geological Survey Bulletin 1326

Tephra Map 6

*Wind Direction:*_____

*Source Volcano:*_____

Tephra W:

Wind Direction: ***From Southeast***

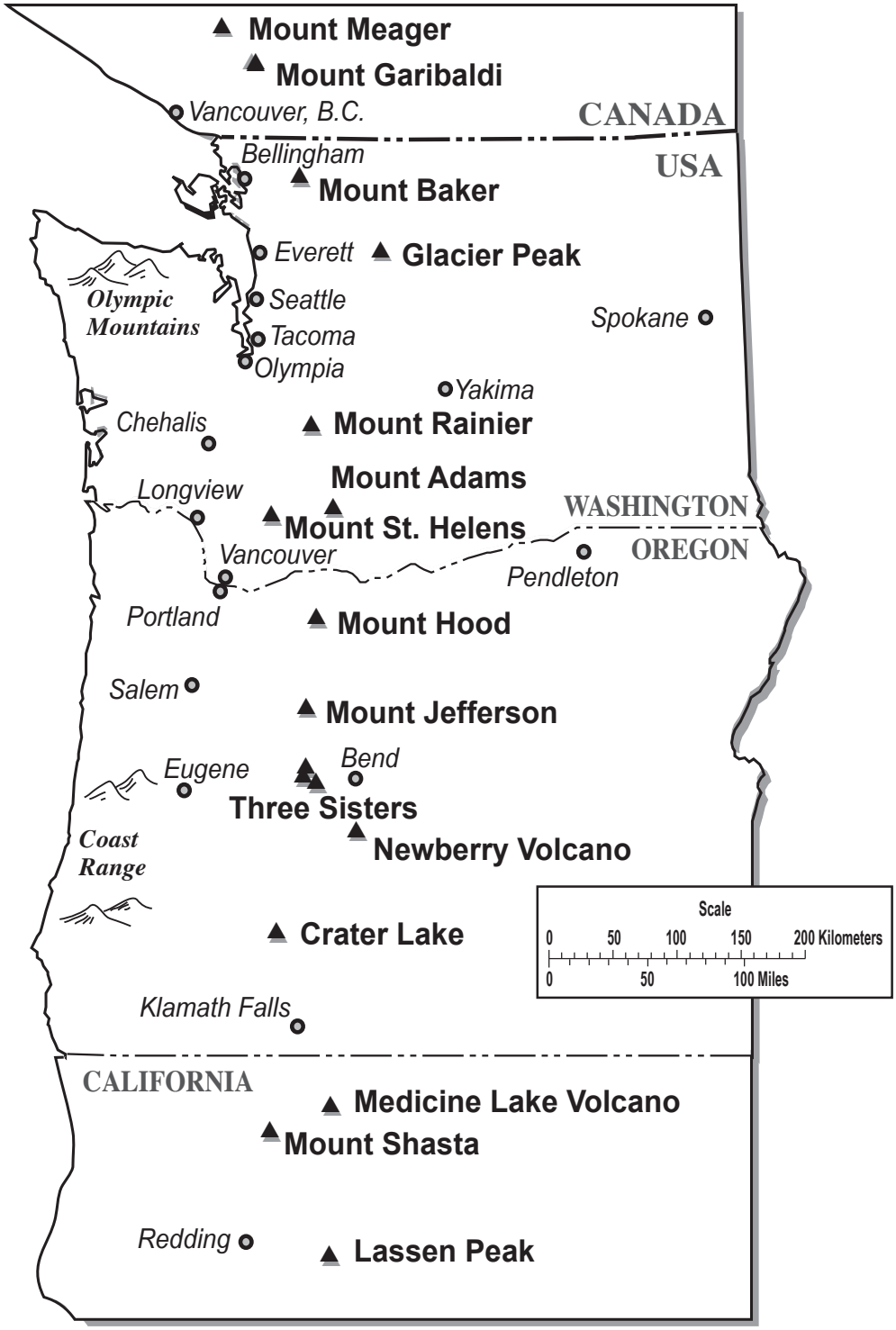
Source Volcano: ***Mount St. Helens***

Age: ***Approximately 500 years ago***

Description: Tephra layer W was erupted from Mount St. Helens around A.D. 1480 and transported towards the northeast by winds. On the slopes of Mount Rainier, 500 kilometers (310 miles) to the north, tephra layer W appears gray—white in color and has a coarse texture. This eruption also formed small lava flows and pyroclastic flows on the slopes of Mount St. Helens. Scientists know that this tephra is from Mount St. Helens and NOT Mount Adams, because they followed the tephra trail back to the slopes of Mount St. Helens.

Graphic Page

Map of Cascade Volcanoes



Shoebox Geologist

Grade Level: 6–10

Learner Objectives:

Students will:

- Learn about the types of deposits produced by volcanic processes
- Learn about the law of superposition
- Apply knowledge of geologic processes to create and interpret a model
- Measure and record data to create a stratigraphic column

Setting: Outdoors or in a tarped or uncarpeted classroom

Timeframe: 90 minutes (or two class sessions) plus 2 to 3 days drying time for models

Interpreting a Stratigraphic Column of Books and Papers—10 minutes

Modeling Earth Events in a Shoebox —40 minutes

Interpreting Earth Events in a Shoebox —40 minutes

USGS
science for a changing world

Living with a Volcano in Your Backyard-An Educator's Guide with Emphasis on Mount Rainier

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

Model depositional processes from volcanically active areas using sediments in a shoebox. Interpret geologic events from layers in a classmate's shoebox model and draw a stratigraphic column graphic.

Before

After

Activity last modified: September 5, 2014

Materials:

Introducing Rock and Sediment Layer Interpretation

- Class copies of ***"Shoebox Geologist Recipes"*** student page
- ***"Layers at Sunrise Ridge on Mount Rainier"*** graphic

Modeling Erosion and Deposition in a Shoebox

- 6 to 8 copies of ***"Shoebox Geologist Recipes"*** student page
- 6 to 8 copies of ***"Shoebox Geologist—Sequence of Events"*** student page
- 6 to 8 copies of ***"Shoebox Geologist—Interpretation of Events"*** student page
- 2 to 4 tarps (for indoor use only)
- Pea gravel
- Medium to coarse sand
- Sawdust
- Potting soil
- Dry cement powder or rock dust
- 4 or more varieties of colored sand
- Soil
- Fine white sand
- Twigs
- Human artifacts (bottle caps, match sticks, string, etc.)
- 6 to 8 shoeboxes
- 18 to 24 containers for mixing sediments (plastic bags, buckets or large beakers work well)
- Disposable gloves for students
- Spoons for scooping rock materials
- Spray bottles with water

Interpreting Volcanic Events from Layers in a Shoebox Model

- Copies of ***"Shoebox Geologist-Recipes"*** student page
- Copies of ***"Shoebox Geologist—Interpretation"*** student page
- 6 to 8 rulers
- 6 to 8 scissors

Vocabulary: Deposit, Law of Superposition, stratigraphic column

Skills: Measure, demonstrate, compare, interpret, observe, apply, analyze, conclude

Benchmarks:

See benchmarks in Introduction.

Teacher Background

Earth processes, such as volcanic events, floods, landslides and glaciers, frequently leave behind evidence of their passing in the form of layers known by geologists as ***deposits***. By studying deposits of recent Earth events, geologists are able to look at older deposits and identify the processes that caused them.

One of the fundamental principles of geology is the ***Law of Superposition***. This law states that layers that are younger will be deposited on top of layers that are older. This law is a guiding principle of studying rock and soil layers. The Law of Superposition helps geologists determine the relative ages of earth events.

Geologists often portray these deposits in a vertical drawing called a ***stratigraphic column***. Drawing a stratigraphic column can help students visualize a sequence of earth events.

Procedure

What to do before class begins:

1. See "Materials" and "Recipes" on page 12 for list of items to collect and description of what volcanic deposits they represent.

2. Assemble each type of rock material in a bucket, or in bags. Label your materials for easy access and identification by students—tephra, lahar, forest floor, etc. You might choose to place a selection of materials in one-gallon bags, and deliver them to each student group. If you are conducting the activity in a natural setting, ask the students to collect and label materials.

3. Instruct students to collect "human artifacts" (i.e., paper clips, buttons, etc.), and to bring a shoebox from home.

4. The shoebox layers will remain more cohesive if you add powdered quick-drying cement such as Plaster of Paris, at a ratio of approximately four parts rock material to one of quick-drying cement. A light misting of water should be added by students using a spray bottle just after they create each layer in their shoebox. Test this before class to determine how much water students should spray on with the material that you have given to them. Tamping or pressing firmly after each layer will also help the layers to solidify. As an alternative to use of the cementing ingredient, use simple layers of different coors of sand—layers that hold together well and can be identified easily.

Interpreting a Stratigraphic Column of Books and Papers

The Law of Superposition states that layers that are younger will be deposited on top of layers that are older. Illustrate this concept by having the class build a column of papers and books, followed by the drawing of a stratigraphic column on a projected transparency or board.

1. To illustrate the Law, create a stratigraphic column graphic as a class. Multiple students stack papers and books at one central location that is visible to all.

2. Afterwards, the class describes the events from first to last. Students verbally describe some characteristics of each book or paper layer. During this discussion draw and label the event sequence, from bottom to top, on an overhead transparency or board.

3. Instruct students to remove one or more books before the stratigraphic column graphic is finished. Ask if there is evidence that the event ever happened.

4. Discuss some of the geologic processes that might produce layers at Cascade volcanoes. Then, display the ***"Layers at Sunrise Ridge on Mount Rainier"*** graphic to show the class a true example of rock and sediment layers. Point out the different types of layers in the section. Refer students to the table on the ***"Shoebox Geologist Recipes"*** student page that describes the different layers produced by geologic processes.

5. Discuss gradual versus catastrophic processes and give examples: soils are formed by gradual processes; tephra desposits are deposited by a catastrophic process.

Modeling Earth Events in a Shoebox

Model the deposition and erosion of various geological processes using ingredients in a shoebox.

1. Conduct this activity outdoors or in a room free of carpets.

2. Place buckets or bags of materials and water on a resource table so that students can obtain them as needed.

3. Divide students into 4 to 5 person groups.

4. Each group requires a shoebox, containers for water (spray bottles) and for carrying materials to their work area, copies of "***Shoebox Geologist Recipes***" and "***Shoebox Geologist Sequence of Events***" student pages. Students write their group number on the "***Shoebox Geologist—Sequence of Events***" student page.

5. Students should work in groups to decide the type, order and thickness of layers that they wish to construct in their shoebox. Encourage and model discussion along the following lines: "***At the bottom of the box, I will make a stream bed. A thick lahar will flow over the top of the stream bed, followed by rocks from a pyroclastic flow, and a thin layer of volcanic ash. On top of that I will put a layer of rocks from a lahar, then two more layers of thick volcanic ash—each of different colors. Then, I will add rocks from another lahar, some human artifacts, another ash layer, and then forest floor on top.***"

6. Students list their chosen layers in sequence from oldest to youngest (bottom to top) on the "***Shoebox Geologist– Sequence of Events***" student page. On the "***Shoebox Geologist Recipes***" student page, students circle their necessary ingredients, and place numbers on the page margin to show the order in which ingredients are be added.

7. Place the "oldest" layer on the bottom of the shoebox and tamp or press firmly to solidify. Mist lightly with water to activate the Plaster of Paris. Continue layering the materials, pressing firmly, and lightly misting each layer according to the desired sequence of events. Be careful not to add too much water. The boxes should be damp but not dripping.

8. Allow shoeboxes to dry for 2 to 3 days.

Interpreting Volcanic Events from Layers in a Shoebox Model

Interpret the shoebox layers by drawing a graphical representation of the stratigraphic column.

1. After the shoebox models are dry, students exchange their model for that of another group.

2. Give each group a "***Shoebox Geologist—Interpretation of Events***" student page. Each group should also have at hand their "***Shoebox Geologist Recipes***" student page distributed previously.

3. Instruct students to cut open the sides of the boxes carefully, using scissors, making any notations about initial observation of geologic events on the back of the student page.

4. Measure the thickness of each layer with a ruler, and then record their observations on the "***Shoebox Geologist—Interpretation of Events***" student page. ***Note: If the model is too dry and crumbly, use water from a spray bottle to dampen it.***

5. Instruct students to use the table from the "***Shoebox Geologist Recipes***" student page to identify the layers. Students should interpret the order of geologic events using the stratigraphic columns and the "Law of Superposition."

6. Return the "***Shoebox Geologist—Sequence of Events***" student pages from the previous section to the appropriate groups. Direct students to compare their interpretations to the list of actual events from the group that constructed the model.

7. Discuss as a class why interpreting layers is important. What are some difficulties in interpreting layers? Which layers were gradually deposited and which were deposited catastrophically?

Photo Instructions:

1. Choose Ingredients:

Choose types of ingredients and order of layers. Include vegetation and human artifacts.

2. Add layers to the box:

Add ingredients in the order that your group has chosen.

3. Fill the box:

Add layers that are easily distinguishable.

4. Tamp down layers:

Tamping or pressing firmly after each layer will help them solidify.

5. Cutting the box:

After box has dried—cut a slit in the front of the box.

6. Peeling back:

Slowly and carefully peel off the front and sides to reveal the layers.

7. Observe the layers:

Measure and analyze origin of layers.

Adaptations

- Stratigraphic columns can be created in a graduated cylinder or beaker.

Extensions

- **Photograph Your Shoebox**
  Take photographs of each opened shoebox and instruct students to label each layer using a computer graphics program.

- **Kitchen Layers in a Jar**
  Make your own layered sequence out of kitchen ingredients. Use ingredients such as cornmeal, cinnamon, oatmeal, flour, decorative sprinkles, and different colors of sugar to represent volcanic deposits (lahars, tephra, lava) and glacial or stream deposits.

  1. Fill a graduated cylinder or tall jar with layers of different ingredients. Add each ingredient so that layers are of different thickness. Each layer should contain material that looks similar to the type of deposit it represents.

  2. Instruct students to write and apply labels of each layer with a piece of masking tape.

  3. Instruct students to write a story about the series of events that occurred to deposit these layers.

- **Stratigraphic Columns from Other Regions?**
  Use library or Internet research to find stratigraphic columns of other geologic regions. Discuss how they are alike or different from stratigraphic columns in volcanic landscapes.

- **Write a Geologic Story**
  Instruct students to write the geologic story of the events that happened at the site of their shoebox geology.

◆ **Luscious Layers—build an edible model of Mount Rainier using simple kitchen products.**

Conduct this activity as a teacher demonstration or in student groups. Prior to the class, bake three cake layers for your demonstration or for each student group. Assemble kitchen ingredients that represent a variety of eruptive products. For example, use cut and quartered cake layers as lava layers, crumbled cookies as loose rock layers deposited by pyroclastic flows, cocoa powder as tephra, canned whipped cream as glacier cover, and chocolate sauce as a lahar. Provide each group with a cookie tray, cake layers, and assembled kitchen ingredients, paper towels for cleanup, and plates and forks for eventual cake consumption. Build a stratovolcano by stacking ingredients into alternating layers. Take care to stack layers irregularly, as is typical of a stratovolcano. Remind students that most stratovolcanoes are not perfect cones. Pour chocolate sauce over the cake to illustrate a lahar. When the volcano cakes are completed, summarize the processes that build real stratovolcanoes, and review the Law of Superposition. Use a knife to carve out a section that exposes all layers, and then feed the cake to your volcano makers.

Simplify preparations by purchasing a frosted layer cake. Gently lift cake layers to add crumbled cookies and cocoa powder. Run the chocolate sauce lahar over it. Cut the cake open to expose the layers. As a cheaper alternative, stack pancakes instead of cake layers.

Assessment

For assessment, review the stratigraphic columns and look for evidence of student recognition that each layer represents a geologic event. Students should be able to interpret the order of events by noting that the oldest evidence exists at the bottom while products of younger events are found at the top. Assess application to real—world situations by assigning interpretation of an additional ready-to-interpret geology shoebox. For older students assign an interpretation of layers at a local roadcut or stream cut in your community.

References

Cas, R.A.F., and Wright, J.V., 1987, Volcanic successions modern and ancient—a geological approach to processes, products and successions: Allen and Unwin, London, 528 p.

Fisher, R.V., and Schmincke, H.U., Pyroclastic rocks: New York, N.Y., Springer–Verlag, 1984, 472 p.

Scott, K.M., Vallance, J.W., and Pringle, P.T., 1995, Sedimentology, behavior, and hazards of debris flows at Mount Rainier, Washington: U.S. Geological Survey Professional Paper 1547, 56 p., 1 pl.

Vallance, J.W., and Scott, K.M., 1997, The Osceola Mudflow from Mount Rainier: sedimentology and hazard implications of a huge clay-rich debris flow: Geological Society of America Bulletin, February, 1997, v. 109: no. 2, p. 143–163, 6 tables.

Zehfuss, P.H., Atwater, B.F., Vallance, J.W., Brenniman, H., and Brown, T.A., 2003, Holocene lahars and their by-products along the historical path of the White River between Mount Rainier and Seattle: *in* Swanson, T.W., ed, Western Cordillera and adjacent areas: Boulder, Colo., Geological Society of America Field Guide 4, p. 209–223.

Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

Photo Credits

1. Layers at Sunrise Ridge on Mount Rainier, Photo by Greg Burtchard, National Park Service.

Shoebox Geologist Recipes

Instructions: *Use this table to construct and interpret shoebox geologist models*

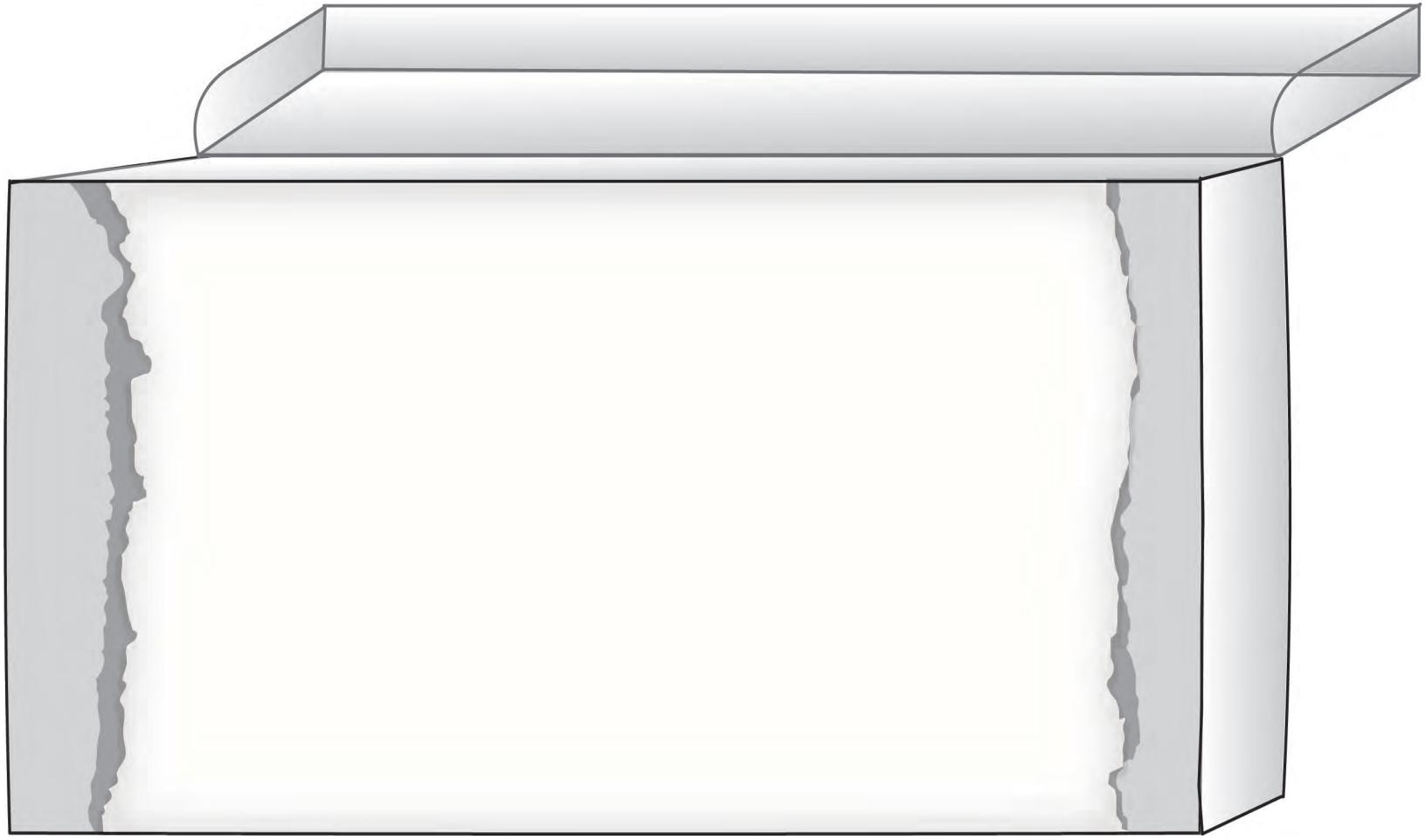
Layers	Mechanisms	Materials in actual deposit	Recipe for deposit in shoebox
TEPHRA (Volcanic ash is fine-grained tephra)	Tephra falls from eruption plume or cloud	Fragments of rock exploded out of the volcano (some bubbly) White, gray, yellow, orange, and brown in color	Colored sand, coarse natural sand, cement dust, sawdust, small gravel
LAHAR (Volcanic mudflow)	Eruptions melt snow and ice; meltwater mixes with loose rocks and flows down river valleys	Boulders and cobbles in a mixture of water, mud, clay, dirt and tree debris	Mixture of dirt and gravel or crushed rock. Add just enough water to make it flow
PYROCLASTIC FLOW	Avalanche of hot, dry rocks capped by a cloud of rock dust and gases	Coarse to fine-grained rock	Mixture of sand and gravel
STREAM GRAVEL	Overlapping layers of well-sorted and rounded stones, gravel, sand, silt deposited in water	Overlapping layers of well-sorted and rounded stones, gravel, sand, silt	Gravel of variable sizes
LAVA FLOW	Lava erupts from volcanic vent and flows across surface of a volcano	Solid rock and often broken into large blocks	Mixture of fist-sized and smaller rocks
LANDSLIDE or ROCKFALL	Rocks accumulate as a fan-like pile that is narrow at the source and broad down slope	Boulders or large chunks of rock and dirt that have been displaced down slope	Clods of dirt or cobbles to represent large boulders
FOREST FLOOR	Long-term accumulation of decomposed plant material mixed with rock fragments	Partially decomposed needles and leaves from trees and smaller plants; rock fragments	Twigs, bark needles and leaves, garden soil
HUMAN ARTIFACTS	Litter remains from human occupation; may be buried by more recent volcanic layers	Stone tools, litter piles, and other evidence of old dwellings and eating areas	Bottle caps, paper, string, match sticks, etc.

Student Page

Team Names _____

Shoebox Geologist—Sequence of Events

Instructions: *Record the series of geological events that you show in your model from oldest to youngest.*

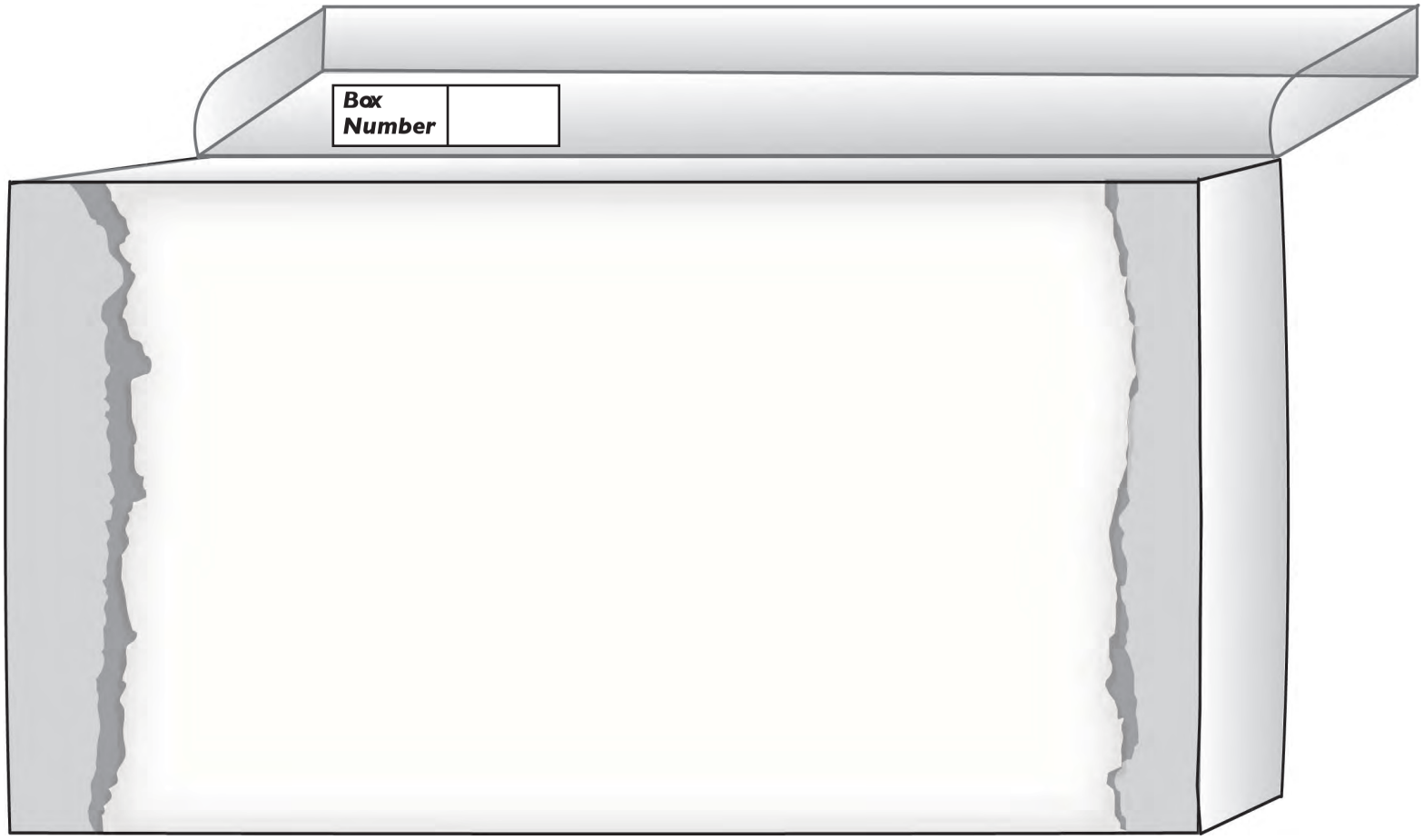


Student Page

Team Names _____

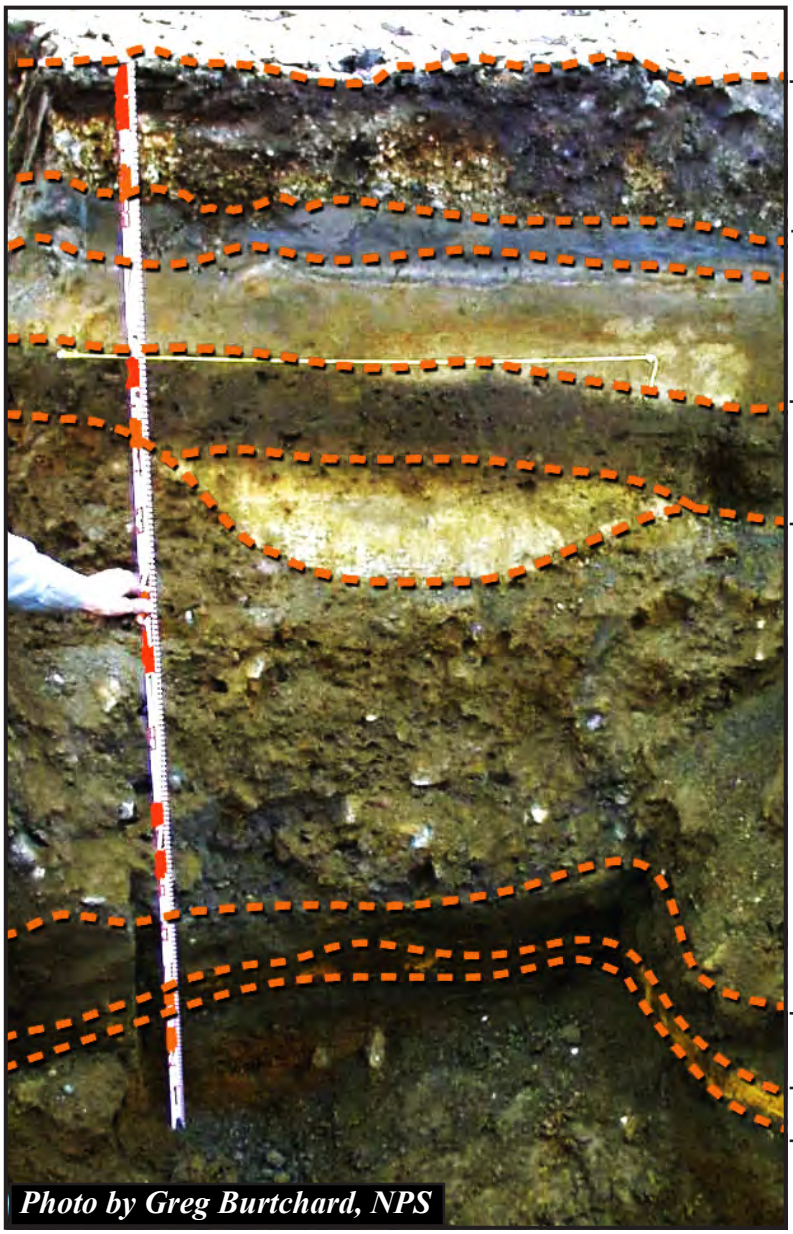
Shoebox Geologist—Interpretation of Events

Instructions: *Draw the layers from the model you were given to interpret. Be sure to measure the thickness of each layer and accurately draw the layers in the rectangle below. Use shading and patterns to represent the different deposits. Label all layers in your stratigraphic column. On the back of the paper, describe the order of events. Which team's shoebox are you interpreting?*



Graphic Page

Layers at Sunrise Ridge on Mount Rainier



Modern Ground Surface

Mount Rainier C-layer tephra
~2,200 years ago

Mount St. Helen's P-layer tephra
2,500 to 3,000 years ago

Mount St. Helen's Y-layer tephra
~3,300 to 3,700 years ago

Old Soil

Mount Rainier F-layer tephra
(in pocket), ~5,000 years ago

Possible Osceola Lahar
~5,700 years ago

Old Soil

Ancient Mount Mazama O-layer tephra
~7,700 years ago

Forest fire material in old soil
~7,700 years ago

Perilous Beauty Video

Grade Level: 5+

Learner Objectives:

Students will:

- Learn about the types of hazards common to Mount Rainier
- Understand the mechanisms that cause lahars
- Describe how to prepare for lahars from Mount Rainier

Setting: Classroom

Timeframe: 45 minutes (video is 29 minutes)

Materials:

- Video—*"Perilous Beauty: The Hidden Dangers of Mount Rainier"*
- VHS video cassette player
- Television monitor
- Copies of *"Perilous Beauty"* student page

USGS
science for a changing world

Living with a Volcano in Your Backyard-An Educator's Guide with Emphasis on Mount Rainier

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

The "***Perilous Beauty***" video introduces students to the volcanic hazards common to Mount Rainier, specifically mudflows (also known as lahars), and the types of mechanisms that produce them.

Vocabulary: Debris flow, Electron Mudflow, hazard, hydrothermal alteration, lahar, landslide, lava flows, monitor, mudflow, Osceola Mudflow, pyroclastic flow, risk

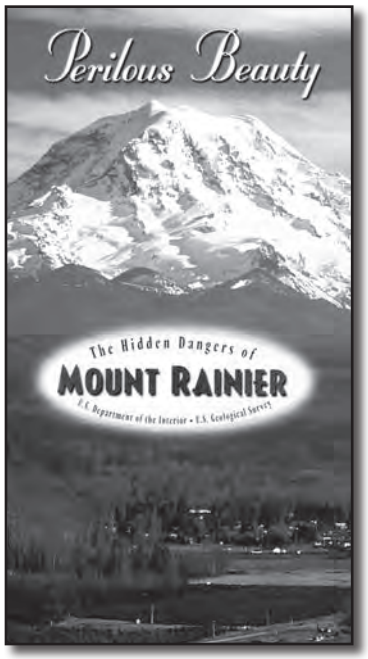
Skills: application, interpretation, listening

Benchmarks:

See benchmarks in Introduction.

Activity last modified: September 5, 2014

Teacher Background



The video, "***Perilous Beauty—The Hidden Dangers of Mount Rainier***," describes the types of volcanic activity common to eruptions at Mount Rainier, and places a focus on ***landslides*** and ***mudflows*** (also known as ***lahars***) that have dramatically modified the landscape. Understanding these natural processes is a key step in reducing the ***risk*** from future volcanic activity at Mount Rainier. This video uses computer animation, eruption footage, interviews with scientists, and photography to show how ***lahars*** can affect communities in western Washington. It ends with a recommendation of five actions for citizens to take that reduce volcanic risk in their communities.

Mudflows, as defined in the video, can be triggered by sudden landslides, meltwater produced in eruptions, and the sudden release of glacial water during severe rainfall or intense snow melt. Some of the largest mudflows at Mount Rainier began as landslides of weak, altered rock that, once mobilized, flowed as far as Puget Sound. The most common mudflows at Mount Rainier happen during eruptions and are the result of ***lava flows*** that break apart on steep slopes as avalanches of hot rock and gas called ***pyroclastic flows***. The pyroclastic flows melt snow and ice, and produce meltwater surges that transform into mudflows as they erode loose rock on the volcano's slopes.

The "Perilous Beauty" video focuses on two large mudflows that buried the terrain where at least 150,000 people live today. ***The Osceola Mudflow*** was the largest of the known lahar on Mount Rainier. About 5,600 years ago, magma intruded the volcano and destabilized its eastern flank. This forced a landslide into motion that filled the White River Valley with more than 180 meters (600 feet) of mud and rock debris. The landslide became a muddy river of rock, sand, and boulders that swept across the plain at Enumclaw and then settled into the inlets of Puget Sound. The ***Electron Mudflow*** on the volcano's western flank happened approximately 500 years ago. Repeated exposure to hot magma bodies and acidic groundwater (the process is known as ***hydrothermal alteration***) has weakened much of the rock on the volcano's western slopes.

Scientists and emergency managers use several techniques to ***monitor*** volcanoes for mudflows and inform people of impending danger. The most important way to reduce risk is preparation. You can prepare by determining if you live or work in a hazard zone, finding out what steps local officials have taken to prepare, developing emergency plans for your family and business, and by finding out how ***hazards*** might disrupt your daily routine.

Authors recommend that teachers preview the videos and determine appropriateness for the intended grade level. Students gain an understanding of terminology by watching Understanding Volcanic Hazards before viewing the video in the Perilous Beauty activity. An additional activity, Reducing Volcanic Risk, in Chapter 3 addresses pro-active community management of volcanic risk.

A NOTE ON TERMINOLOGY: ***The general term "mudflow" used in the video broadly describes both lahars and debris flows. At Mount Rainier, local scientists and public officials have defined the terms more specifically to reduce confusion between major and minor events. They define lahars as the large, far traveling slurries of rock, mud and water caused by landslides or eruptions, which threaten distant communities. They use the term debris flow for small events initiated by excess rain or glacial meltwater, which seldom move beyond park boundaries. Debris flows are common in river valleys at Cascade volcanoes and happen almost annually at Mount Rainier.***

Procedure

Understanding Mount Rainier

1. Explain to students that they will watch a video about some major volcanic events that happen infrequently, but can occur again at Mount Rainier.

2. View the video from beginning to end.

3. Initiate a discussion of the video using the questions that follow. End your discussion with conversation about what risk is faced by students in your school. See Chapter 3 for information about hazard zones and emergency preparations.

Adaptations

- Provide each student with a copy of the "Perilous Beauty Questions" student page.
- View the video and pause the video after each section on the answer sheet so that students can record their answers
- Following the video, allow students to work in small groups to answer the questions on the student page.

Assessment

Use the video questions to assess students' current knowledge of volcanic processes and hazards at Mount Rainier. You may wish to use the same questions at the end of your study of volcanoes as a post-assessment activity.

References

Driedger, C., and Scott, W., 2008, Mount Rainier—Living safely with a volcano in your backyard: U.S. Geological Survey Fact Sheet 2008–3062, 4 p.

Myers, B., Brantley, S.R., Stauffer, P.H., and Hendley, J.W., II, 1997, What are volcano hazards? (revised March 2008): U.S. Geological Survey Fact Sheet 002–97, 2 p.

Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

Student Page

Name _____

Perilous Beauty—Questions

Instructions: *View the video and answer the questions.*

Geologist Rocky Crandell's Surprising Discovery

1. When geologist Rocky Crandell began working around Mount Rainier, the surface of the lowlands near the volcano were thought to have been formed by glacial action. What did he find to show that the old ideas were incorrect?

2. What evidence convinced Crandell that the mudflow (lahar) came from Mount Rainier?

3. Describe the appearance, texture and sound produced by a mudflow (lahar and debris flows).

4. What is the name of the largest mudflow (lahar) from Mount Rainier?

5. Describe the effects the Osceola Mudflow had on Mount Rainier.

6. Explain what events occurred after this collapse that rebuilt the volcano.

The Electron Mudflow

7. Describe what process formed the Orting plain, and when this event occured.

Student Page

Name _____

Perilous Beauty—Questions -continued

Landslides

8. Name two events that can trigger landslides.

9. What does the video suggest is unique about the timing of the Electron Mudflow?

Unstable Rock at Mount Rainier

10. Describe how hydrothermal alteration changes the texture of rock.

11. Explain how hydrothermal alteration makes some slopes of Mount Rainier unstable.

12. What is the most far-reaching eruptive hazard for people in the valleys near Mount Rainier?

Pyroclastic Flows

13. Define pyroclastic flow.

14. Describe where past pyroclastic flow layers exist today at Mount Rainier.

Student Page

Name _____

Perilous Beauty—Questions
-continued

Pyroclastic Flows continued . . .

15. Describe how a pyroclastic flow transforms into a mudflow (lahar).

16. What evidence indicates that pyroclastic flows occur frequently during eruptions at Mount Rainier?

Small Mudflows

17. Explain what causes the small mudflows (debris flows) at Mount Rainier.

Comparisons with Nevado del Ruiz

18. Was there historical evidence that mudflows had occurred at Nevado del Ruiz?

19. Explain how the risks of living near Nevado del Ruiz are similar to those of living near Mount Rainier.

Student Page

Name _____

Perilous Beauty—Questions
-continued

Preparation

20. Describe some of the warning signs of a mudflow (lahar).

21. List five actions that citizens can do to reduce risk.

Teacher Page

Perilous Beauty—Answers

Geologist Rocky Crandell's Surprising Discovery

1. When geologist Rocky Crandell began working around Mount Rainier, the surface of the lowlands near the volcano were thought to have been formed by glacial action. What did he find to show that the old ideas were incorrect?

ANSWER: ***Rocky Crandell found a flat plain of Mount Rainier rocks on the valley floor that were moved there by a volcanic mudflow from Mount Rainier.***

2. What evidence convinced Crandell that the mudflow (lahar) came from Mount Rainier?

ANSWER: ***While studying the origin of valley floors, Rocky Crandell found rocks from Mount Rainier that had been moved there by a mudflow.***

3. Describe the appearance, texture and sound produced by a mudflow (lahars and debris flows).

ANSWER: ***A mudflow is a slurry of muddy, churning debris, that resembles a fast-flowing river of wet concrete. It is accompanied by intense roaring and shaking.***

4. What is the name of the largest mudflow (lahar) from Mount Rainier?

ANSWER: ***Osceola Mudflow***

5. Describe the effects the Osceola Mudflow had on Mount Rainier.

ANSWER: ***Summit rocks collapsed as a landslide and traveled from the mountain to the lowlands as a mudflow. The mudflow was more than 180 meters (600 feet) deep as it swept through the White River on the mountain's east side.***

6. Explain what events occurred after this collapse that rebuilt the volcano.

ANSWER: ***Lava erupted from the summit and rebuilt the summit cone.***

Perilous Beauty—Answers -continued

The Electron Mudflow

7. Describe what process formed the Orting plain, and when this event occured.

ANSWER: ***The Electron Mudflow (lahar) formed the Orting plain. The mudflow occurred about 500 years ago.***

Landslides

8. Name two events that can trigger landslides.

ANSWER: ***The video suggests earthquakes and rising magma. Additionally, slopes might fail for other reasons, including water saturation, loss of buttressing by glacier ice, and gradual weakening.***

9. What does the video suggest is unique about the timing of the Electron Mudflow?

ANSWER: ***Scientists have not found conclusive evidence of an eruption coincident with the Electron Mudflow. They are forced to conclude that the Electron Mudflow could have occurred during a period of volcanic quiescence, unheralded by volcanic activity. The video implies that future events could happen during periods of quiescence with little or no advance warning.***

Unstable Rock at Mount Rainier

10. Describe how hydrothermal alteration changes the texture of rock.

ANSWER: ***When warm sulfur-rich water combines chemically with minerals, the minerals transform into a clay-rich material.***

11. Explain how hydrothermal alteration makes some slopes of Mount Rainier unstable.

ANSWER: ***Hydrothermal alteration chemically changes lava layers from solid rock to a weak, loose, clay-bearing material that is susceptible to collapse. Currently the upper west flank contains the majority of such altered rock.***

Teacher Page

Perilous Beauty—Answers -continued

12. What is the most far-reaching eruptive hazard for people in the valleys near Mount Rainier?

ANSWER: ***Mudflows (lahars).***

Pyroclastic Flows

13. Define pyroclastic flow.

ANSWER: ***A flow of hot ash and gas.***

14. Describe where pyroclastic flow layers exist today at Mount Rainier.

ANSWER: ***Layers of loose rock from pyroclastic flows are now sandwiched between some layers of lava flows.***

15. Describe how a pyroclastic flow transforms into a mudflow (lahar).

ANSWER: ***These dense flows of hot rock and gases erode and melt ice and snow and mix with meltwater to form mudflows (lahars).***

16. What evidence indicates that pyroclastic flows occur frequently during eruptions at Mount Rainier?

ANSWER: ***Pyroclastic flows left behind many layers of loose rock rubble.***

Small Mudflows

17. Explain what causes the small mudflows (debris flows) at Mount Rainier.

ANSWER: ***Intense rain and rapid melting of snow and ice can overload hidden channels within the glacier and cause sudden expulsions of water that can mix with loose rock to make debris flows.***

Perilous Beauty—Answers
-continued

Comparisons with Nevado del Ruiz

18. Was there historical evidence that mudflows had occurred at Nevado del Ruiz?

ANSWER: Yes, historical records in Armero show that mudflows (lahars) covered the town site on several occasions before 1985.

19. Explain how the risks of living near Nevado del Ruiz are similar to those of living near Mount Rainier.

ANSWER: People have constructed communities on top of very young lahar deposits and now those communities are vulnerable to future lahars.

Preparation

20. Describe some of the warning signs of a mudflow (lahar).

ANSWER: Scientists watch for evidence of magma moving to shallow levels in the volcano, such as increases in earthquakes, changes in volcanic gases and changes in shape of the volcano's slopes.

21. List five actions that citizens can do to reduce risk.

ANSWER: Determine if you live or work in a hazard zone.

- *Find out what steps local officials have taken to prepare.*
- *Develop emergency plans for family and business.*
- *If you do not live in a hazard zone, find out how hazards might disrupt your daily routine.*
- *Contact your local Emergency Management agency or the U.S. Geological Survey for more information.*

Living with a volcano in your backyard—An educator's guide with emphasis on Mount Rainier
Coordinated by Carolyn Driedger, Anne Doherty, Cheryl Dixon, and Lisa Faust
U.S. Geological Survey General Information Product 19
http://pubs.usgs.gov/gip/19/

Chapter 3. Don't be Scared—Be Prepared!

Chapter 3 contains information about volcanic hazards and suggestions for preparedness. Several activities suggest how students can appreciate the benefits of living near a Cascade volcano, and can enjoy them, most often from their own communities. Activities are grouped under three themes—" Mapping Your Way to Mount Rainier," "Living with a Volcano in Your Backyard," and "Home and Community Preparedness Plans":

Overview

Mapping Your Way to Mount Rainier

- **Play-Dough Topo**—Students make a clay model volcano, complete with glacial and fluvial valleys, and then create a topographic map of their volcano.
- **Topographic Maps and Mount Rainier**—Students explore how lines on a topographic map represent the real landscape by comparing features on photographs and topographic maps. Later, students analyze and answer questions about a Mount Rainier National Park map.
- **Planning Your Trip to Mount Rainier National Park**—Students will plan a trip to Mount Rainier National Park using topographic, highway, and official park maps.

Living with a Volcano in Your Backyard

- **The Next Eruption of Mount Rainier**—Through a series of activities, students will examine the hazards associated with Mount Rainier by making a timeline of Mount Rainier events, interpreting hazard maps, investigating the potential effects of volcanic events on their community, and becoming acquainted with how scientists watch for signs of volcanic unrest.
- **Reducing Volcanic Risk video/DVD**—Familiarizes students with the steps they can take to reduce volcanic risk.

Home and Community Preparedness Plans

- **Don't be Scared—Be Prepared!**—Students learn simple steps to preparedness by conducting basic preparedness tasks with their class and family.
- **A Volcano Tussle—How Much Do We Risk?**—Students play the roles of persons with interest in maintaining visitation facilities at Mount Rainier National Park while faced with the prospect of geologic hazards. They write position papers and later defend them within a group.
- **Living Well with a Volcano in Your Backyard!—Prepare, Then Enjoy It!**—This activity provides a variety of options for students to explore and appreciate the many ways that volcanoes are beneficial to their community. It includes the Mount Rainier paper model. Students color, cut, fold, and paste a simple cone-shaped volcano and in the process become familiar with many geographic features within Mount Rainier National Park.

This page left intentionally blank

Don't Be Scared—Be Prepared
Overview—Chapter 3

The objective of Chapter 3 is to provide students with a realistic knowledge of potential hazards to their community and to encourage them to take part in mitigation efforts. Most students have a natural enthusiasm for volcanoes. Encourage this interest and promote an understanding that living near a volcano is an uncommon opportunity and, indeed, can be a benefit to their community. Urge students to view volcanoes as sources for recreation, inspiration, and learning. Inspire them to visit local volcanoes.

Activities in Chapter 3 promote exploration of and appreciation for volcanoes. They encourage personal and community preparedness. The chapter begins with **Play-Dough Topo**, **Topographic Maps of Mount Rainier**, and **Planning Your Trip to Mount Rainier**, in which students construct and read topographic maps and plan a real or virtual trip to Mount Rainier National Park. **The Next Eruption of Mount Rainier** addresses the onset of volcanic unrest and how communities can be affected by increased volcanic activity. Students will learn to read hazards maps, investigate the hazards in their community, and examine preparations already underway. They are challenged to participate in preparedness efforts in their community.

The **Reducing Volcanic Risk Video/DVD** and activity illustrate how some communities around the world prepare for volcanic unrest. It elaborates on the three steps for preparedness: identification of hazard areas, observations of the volcano, and assembly and testing of emergency plans. **Perilous Beauty Video** in Chapter 2 addresses the volcanic hazards of Mount Rainier. Students role-play the parts of people interested in the outcome of volcano hazards planning in **A Volcano Tussle**.

Chapter 3 ends with two activities that invite discussion about living with volcanos. **Don't Be Scared—Be Prepared** teaches simple steps for preparedness at school and home. For example, with a single homework assignment, students will develop a Family Emergency Preparedness Plan. According to emergency managers, this is one of the single most important steps a family can make together toward preparedness.

Choose one or more options from **Living Well With a Volcano in Your Backyard**. As postassessment tools, encourage students to draw a picture or write a story about a visit to a Cascade volcano. Have them write a story about a future eruption of Mount Rainier, then compare it with the story they wrote as a pre-assessment tool in the Chapter 1 activity **Eruption!**.

Last modified: September 5, 2014

Our occasional experiences with volcanic eruptions, whether directly or through news and movies, can both fascinate and scare us. As your class progresses through these activities, be watchful of your students' reactions. When discussing the potential for volcanic activity, don't exaggerate the hazards, but don't minimize them either. Remind students that volcanic activity can range from very small, barely noticeable phenomena that occur relatively frequently, to the larger scale, more devastating events that we are more likely to hear about in the news. Although we can't prevent volcanic eruptions, we can prepare to live with them. The knowledge of volcanoes that you promote will not only help students academically, but it will also help them learn ways they can contribute to creating more disaster-resistant communities.

In summary, here are some steps that you and your students can take to mitigate risks from volcanic hazards:

Learn: Learn whether you live, work, or go to school in a volcano hazard zone.
Inquire: Ask public officials how they advise you to respond if there is a volcanic event.
Plan: Plan for how you and your family can be prepared for any natural hazard event.
Participate: Participate in helping your community be prepared!

Make your message clear:

When people become knowledgeable about volcanoes, they can prepare for hazards and then live with greater safety and comfort in their communities.

Play-Dough Topo

Grade Level: 5–12

Learner Objectives:

Students will:

- Visualize how a 2-dimensional topographic map represents 3-dimensional landscape
- Understand contour lines and contour interval
- Increase their spatial visualization skills

Setting: Classroom

Timeframe: 50 to 90 minutes, depending on the complexity of the model volcanoes

Materials:

- Copies of *"Play-Dough Topo"* student page
- Copy of *"Play-Dough Topo"* teacher discussion questions
- Soft modeling clay (pottery clay also works well but can be messy) You can substitute with homemade Play Dough made from flour and salt. See recipe below.
- Fishing line or clay cutting wire

USGS
science for a changing world

Living with a Volcano in Your Backyard-An Educator's Guide with Emphasis on Mount Rainier

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

Students make a clay model volcano, and then create a topographic map of it.

Teacher Background

Mapmakers have devised an ingenious way to show three–dimensional ***topography*** on a two dimensional flat surface with the use of a ***topographic map.*** On these maps ***contour lines*** illustrate the variations in ***elevation*** of surface terrain. A contour line is defined as a line of equal elevation. If you were to walk on a contour line painted on the ground around the side of a hill you would neither go up nor down, but remain level. The elevation difference between adjacent contour lines, called the ***contour interval***, is selected to best show the pattern of the landscape. Relatively flat landscapes often are illustrated with a small contour interval of 10 feet or less. Maps in mountainous areas, however, often have a larger contour interval of 40 feet or more. The contour interval is usually printed under the scale at the bottom of topographic maps. Topographic maps can present a major challenge in the classroom, but practice in interpreting them is an excellent way to develop spatial relations skills and is a useful tool in its own right. This activity is designed to develop an understanding of what the contour lines on the map represent, as well as introduce the term "contour interval."

Activity last modified: September 5, 2014

- 1/4 inch dowel or a pencil
- Blank paper (1 sheet per group)
- Spoon
- Pointed wooden tool or butter knife
- Pencil

Vocabulary: Contour, contour interval, contour line, elevation, map scale, topographic map, topography,

Skills: Model, interpret, compare, demonstrate, visualize

Benchmarks:

See benchmarks in Introduction.

Students should already be familiar with the basic concept of a map and ***map scale***. You may want to create a map of your classroom or the playground using paces as measurement to help your students prepare. Students may use local street maps to chart the route they travel to come to school as preparation for this activity.

Before class begins, obtain modeling clay or Play Dough for this activity. Play Dough can be made with the recipe that follows.

A simpler no-mess topographic model can be assembled by following the instructions in the Extensions section.

Play-Dough Recipe

4 cups flour
1 cup salt
4 cups water
4 tablespoons oil
1/2 cup cream of tartar

Mix all ingredients in a saucepan. Cook and stir over low/medium heat until play dough is completely formed and no longer sticky. Allow to cool slightly before storing in an air tight container or zip lock bag. Just before class, separate the clay into equal amounts, approximately 450 grams (1 pound) for each group. In volume, this is equivalent to the amount contained within two adult hands clasped together.

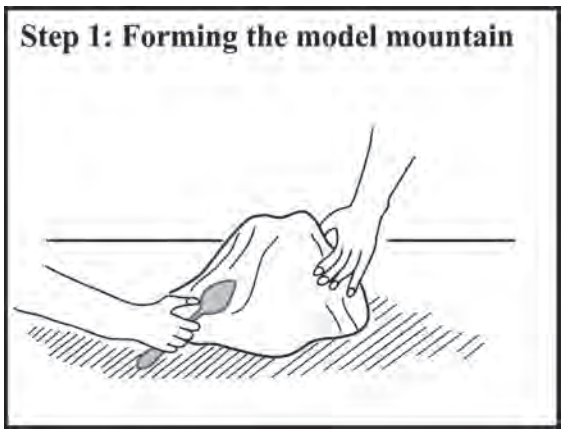
During the activity, steps 1 through 4 can be displayed by projector, or printed as hard copy and distributed to student groups.

NOTE: This recipe makes 3 one pound lumps of play dough with a bit extra.

Procedure

1. **Shape a volcano:**

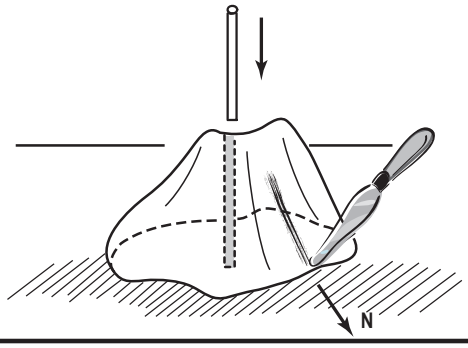
   Distribute 450 grams (1 pound) lumps of clay to each student or group. Each student (or pair or small group) places the the clay on a piece of scrap paper. They will shape the mound into a cone—pointy side up—roughly the shape of a stratovolcano like Mount Rainier. For more advanced classes, encourage students to make realistically shaped volcanoes, approximating the shape of Mount Rainier. Remind students that each side of the volcano may have a different slope, or steepness. Consider making U-shaped glacial valleys running down the sides of the model using the back of a spoon, and then putting in some smaller V-shaped valleys, representing those carved by rivers and streams, using a pointed wooden tool or a butter knife.



2a. Make a vertical hole for alignment of parts later in the activity:

Next, for all students, use the 1/4-inch wooden dowel (or a pencil) to make a vertical hole from the summit of the volcano, all the way down to the work surface. Remove the pencil and mark this spot on your paper. This mark will allow students to align the pieces of their model on the paper as they make a topographic map, so they should be able to see through it.

Step 2: Making the vertical hole and alignment notch.



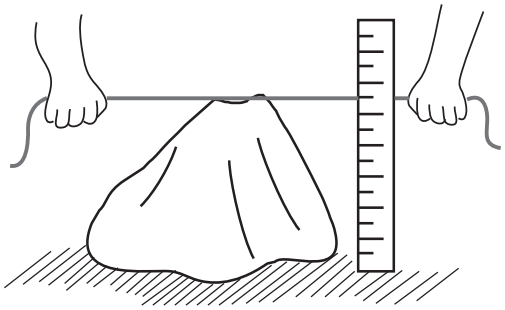
2b. Choose north:

Choose a direction for north, such as the front of the classroom, and then make a straight groove down the outside of the model facing north. You will need to know where north is on your clay pieces, so, make the groove obvious.

3. Measure and record elevation:

Measure the elevation of the volcano and record it at question 1 on the student page. To make this measurement, stretch the wire across the top of the volcano to a vertical ruler (see graphic). Each student or group should divide their answer by 4 or 5 to determine their contour interval, that is, the distance between each contour line to be drawn in Step 4. Rounding is permitted.Write answer on student page at question number 2.

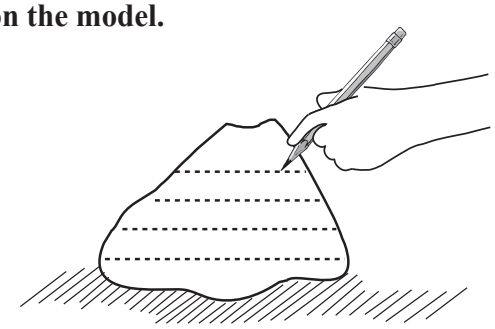
Step 3: Measuring the summit elevation.



4. **Mark dots to show elevation on the model:**

Then, holding a pencil horizontal, ask students (or help them) to punch holes at each calculated contour interval, completely around their model. For younger children or with soft clay, use increments of 1 inch. For more advanced classes and with Play Dough, you may be able to make thinner slices, and so should use increments of 1 centimeter (approximately 0.39 inch).

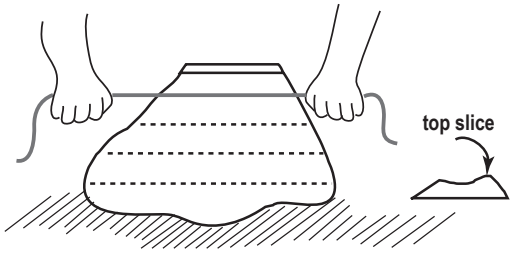
Step 4: Mark dots to show elevation on the model.



5. **Slice the model to create contour lines:**

Next, using the wire tool or a length of fishing line wrapped securely around your hands, cut the model parallel to the work surface horizontally at the elevations marked by the dots. Tell students to try to keep their hands steady (or you if you are doing the slicing for younger classes) and to attempt to keep all slices parallel and of even thickness. Start with horizontal slices near the top. These slices, cutting through the model at one elevation, will make a slice that outlines the volcano at that elevation. Since the cut is all at the same elevation, the outline is a contour line. The distance from one cut to the next is the contour interval. Discuss these concepts with your class as the horizontal slicing continues.

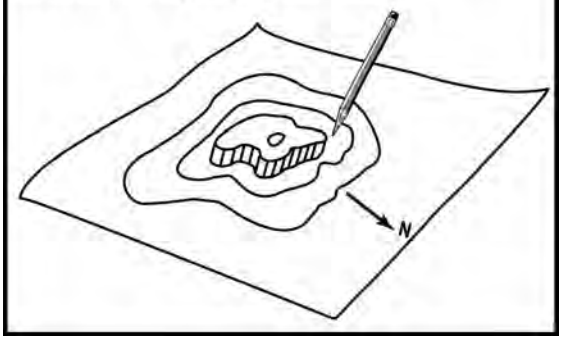
Step 5: Slice the model to create contour lines.



6. **Trace the outline of each slice on paper to make a contour map of the Play-Dough volcano model:**

Distribute a piece of blank paper to each group of students. This will be made into a paper map of each volcano. Starting with the bottom-most, largest slice, center it on the paper, with the "North" groove facing the top of the page, and mark the position of the groove with a tic-mark. Use a pencil to make a distinct dot on the paper in the center of the dowel-hole. This dot will be used for centering all of the other pieces. Finally, carefully trace the outline of the slice, paying attention to indentations and the shapes made by any valleys you may have carved. Remove the slab and center the next piece of your model over the "dowel-dot," lining up the "North-groove" with the direction of the tic-mark, towards the top of the page. Carefully trace the shape. Repeat until all of the slices have been centered and traced. You have just created a topographic map of your volcano!

Step 6: Tracing the shapes onto paper, creating a topographic map.



7. **Reassemble the volcano for comparison with the topographic map:**

Reassemble your volcano and compare the three-dimensional model to your topographic map. Without smoothing the lines made by the cuts (your contour intervals), look down on both from above—they should match. Consider using the questions below to guide older students' inquiry. On their map, students should name their volcano, then list the contour interval, label the elevation of the summit, draw a north arrow, and state the name of the mapmaker. Consider drawing some hypothetical rivers as discussed in question 4. Color and border the map.

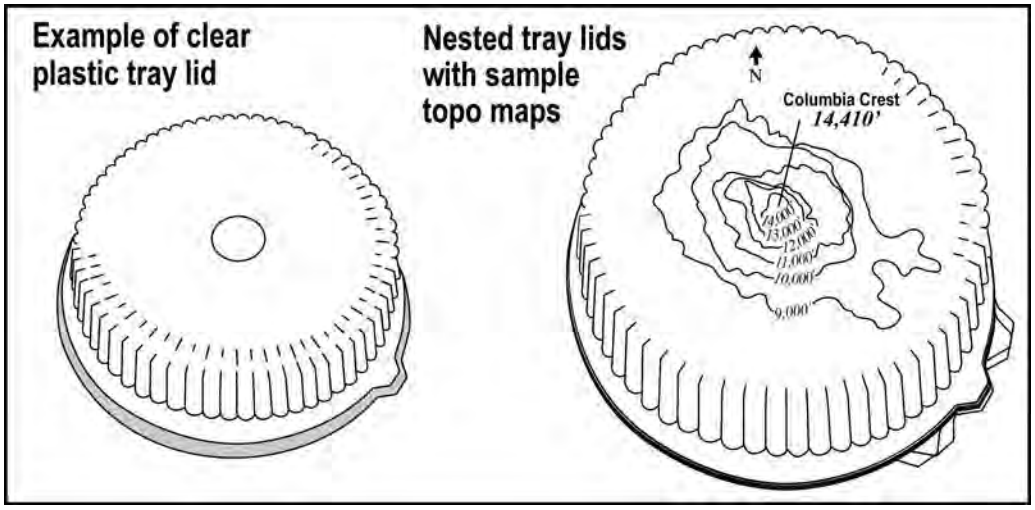
Adaptations

- Make a paper mache or clay model of a cone-shaped Cascade volcano. To illustrate how contour lines represent equal elevation, paint contour lines on your volcano.

Extensions

- ***Make a See-Through 3D salad-tray model of a topographic map***

  From a delicatessen, bakery, or grocery store, obtain approximately 8 clear plastic disposable tray lids that can be nested, for each student group. Obtain a topographic map of a volcano. Use a photocopier to adjust the size of the volcano's cone so that it is almost as large as the flat bottom of the tray lids. Use a marker to outline principal contours on the reduced-size map (1,000 foot contours on Mount Rainier). Use scissors to trim the map so that it fits snugly inside the first tray lid. Temporarily tape the map in place. Use a permanent marker to trace one contour line onto each tray lid. Add contour elevations and a North arrow to each tray lid. Admire your 3D representation of a topographic map!



Assessments

Use questions on the "***Play-Dough Topo***" student page to assess students' ability to apply the concept of contours to a physical model. Look for students' grasp of contour lines, and of how the lines represent real landform features. Note how students' understanding of contour lines has progressed throughout the activity. For example, at the beginning of the activity, students may have a rudimentary understanding of how contours represent the landscape. Later, students can describe the landscape based on their reading of the contours, can produce their simple contour map based on the model, and can answer questions about it successfully.

References

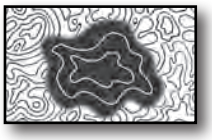
U.S. Geological Survey, 1971, Mt. Rainier National Park, Wash.,: U.S. Geological Survey Topographic Map, scale 1:50,000.

Steger, T.D., 1990, Topographic maps: U.S. Geological Survey, 27 p.

Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

Student Page

Name _____



Play-Dough Topo

Instructions: *Answer the questions below using your new knowledge of topographic maps.*

1. Find the elevation of your volcano in centimeters and inches. (1 inch equals 2.54 centimeters)

2. Make four or five contour lines on your volcano. List the elevation of the contour lines on your volcano.

3. What is the contour interval of your topographic map?

4. Notice how the glacial and river valleys are represented on the topographic map. Do the two types of valleys look the same? Draw the rivers on your map using a dashed-and-dotted line and give each river a name.

5. How might you distinguish a valley from a ridge on a topographic map?

6. Notice how all of your lines form irregular circles or ovals. Imagine what would happen if you left the front door of your house and could only walk at one elevation, never traveling up or down—could you get back home? Do all contour lines in the world eventually have to connect back to themselves? Why or why not?

Teacher Page

Play-Dough Topo—Answers

1. Find the elevation of your volcano in both centimeters and inches.
Students' answers should make sense and have correct unit labels.

2. Make 4 or 5 contour lines on your volcano. List the elevation of the contour lines on your volcano.

3. What is the contour interval of your topographic map?

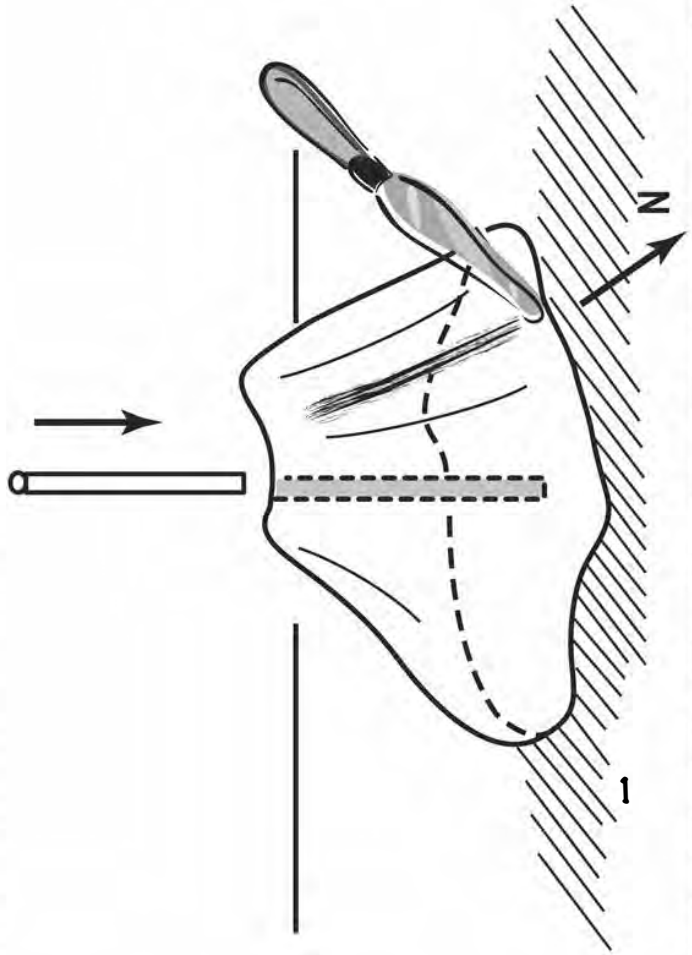
4. Notice how the glacial and river valleys are represented on the topographic map. Do the two types of valleys look the same? Draw the rivers on your map using a dashed-and-dotted line and give each river a name.
Glacial valleys should have a U shape pointing upstream while river valleys should have a V shape also pointing upstream. River marks should be drawn in on the diagram vertically underneath where they appear on the model.

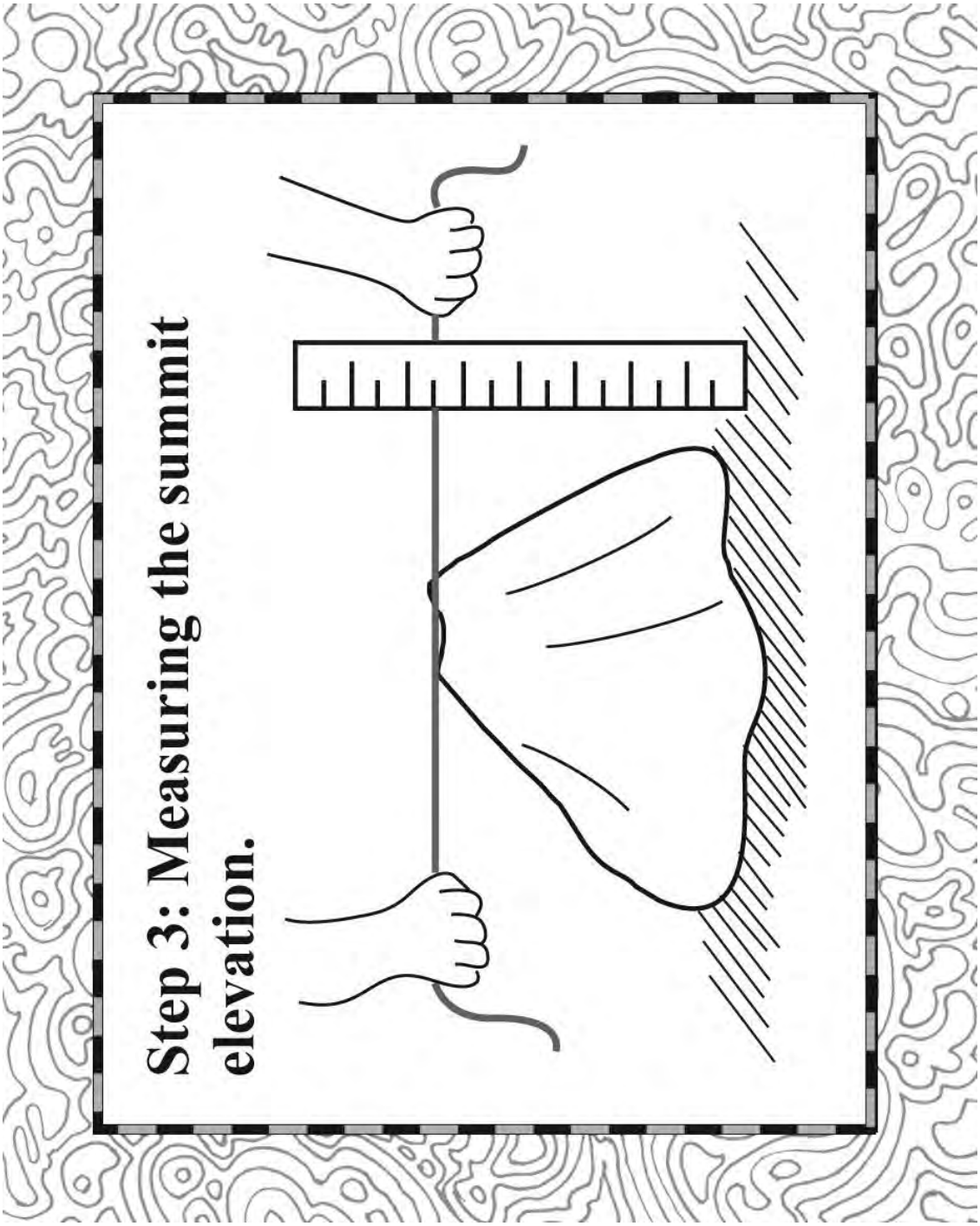
5. How might you distinguish a valley from a ridge on a topographic map?
Valley "V"s point upstream; ridge "V"s point downstream. Also, rivers do not flow on ridge tops, but in valley bottoms.

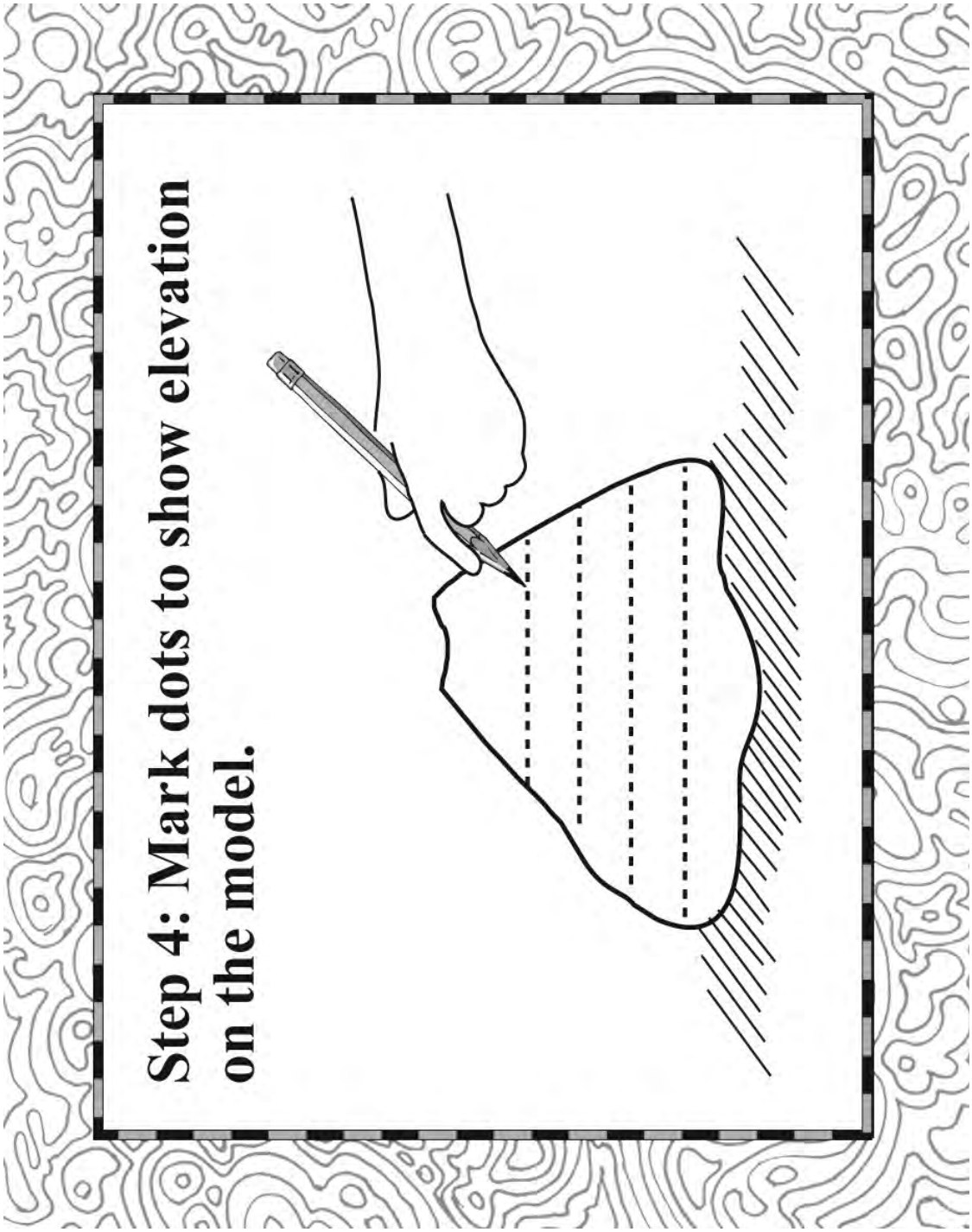
6. Notice how all of your lines form irregular circles or ovals. Imagine what would happen if you left the front door of your house and could only walk at one elevation, never traveling up or down—could you get back home? Do all contour lines in the world eventually have to connect back to themselves? Why or why not?
You would eventually return—all contour lines necessarily form complete polygons Think of the slices of your model volcano. If a contour line seemed to stop, at a cliff for example, does it actually stop? The elevation still exists; it just may run along a vertical wall for a while. There is no way that the line can stop until it runs back into its own tail. If students are having a hard time with this, consider making a contour map of your classroom, including the desks, to demonstrate how contour lines sometimes stack up, but always eventually close themselves.

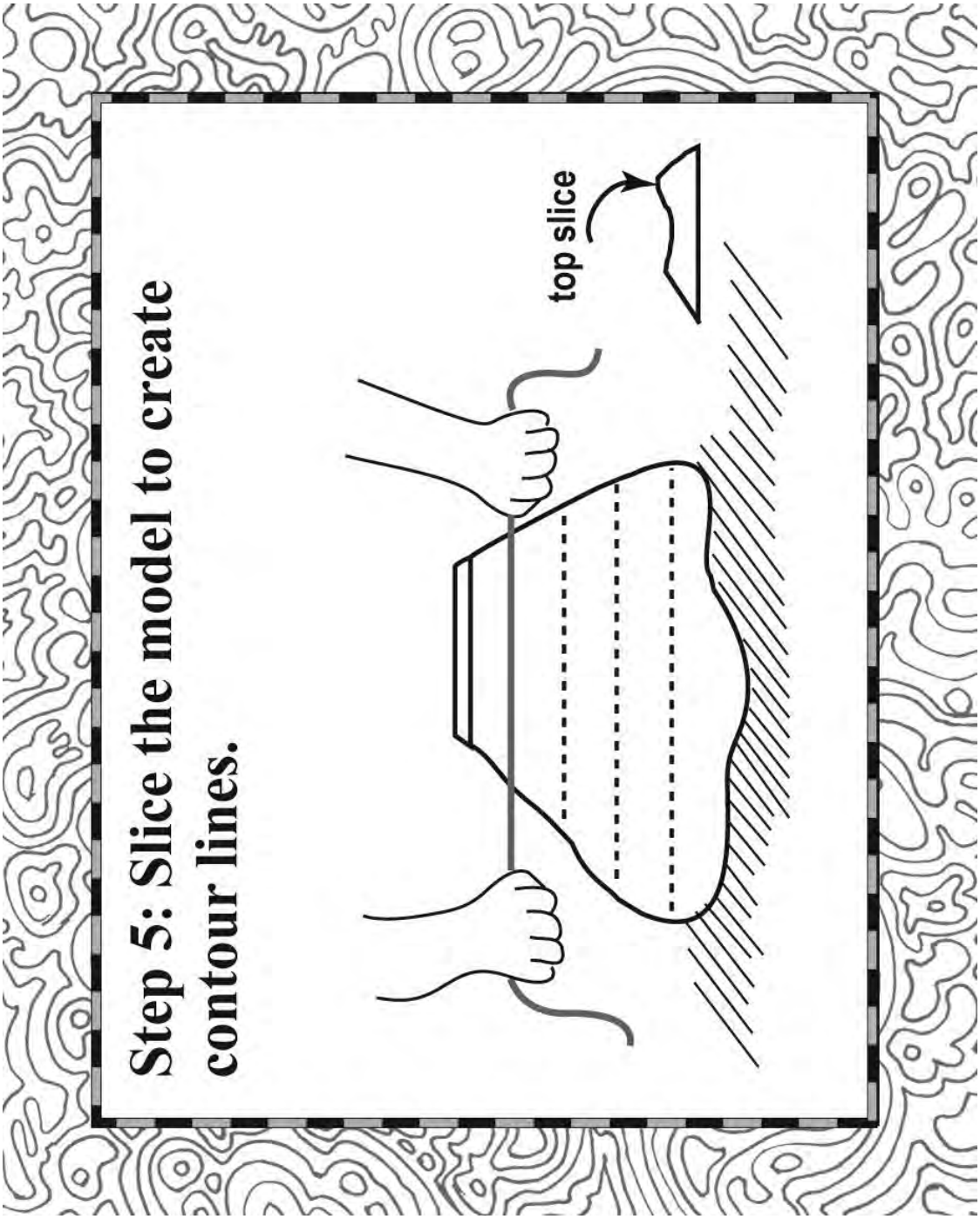
Step 1: Forming the model mountain

Step 2: Making the vertical hole and alignment notch.

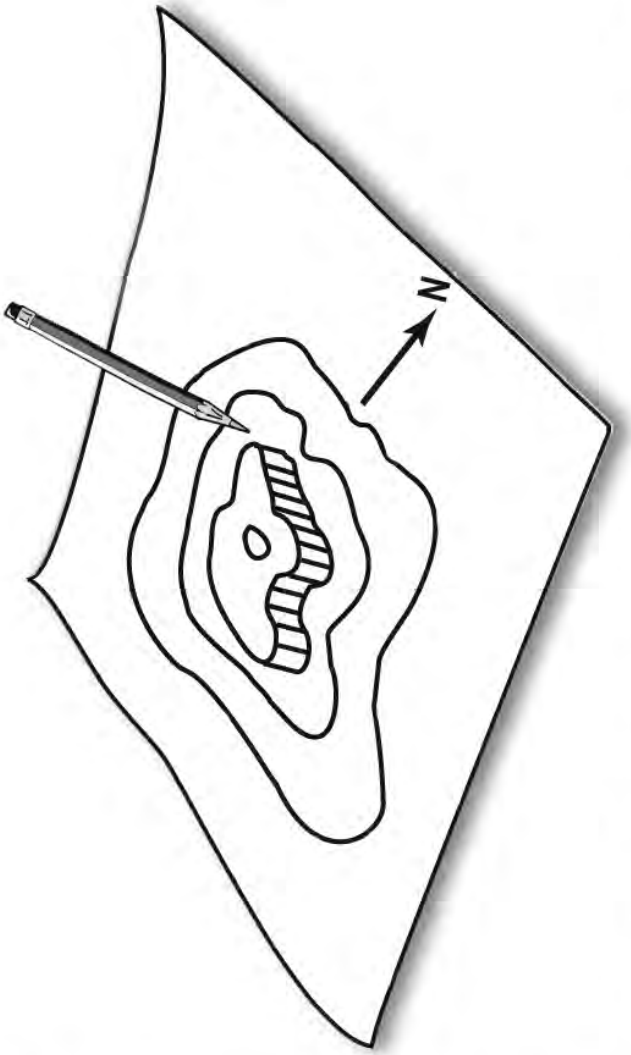



Step 3: Measuring the summit elevation.

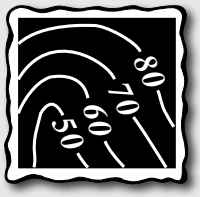

Step 4: Mark dots to show elevation on the model.


Step 5: Slice the model to create contour lines.
top slice

Step 6: Tracing the shapes onto paper, creating a topographic map.



Topographic Maps and Mount Rainier



Grade Level: 5–12

Learner Objectives:

Students will:

- Read and understand map explanations, including the name, date and origin of the map, scale and contour intervals
- Understand contour lines and contour interval
- Recognize that contour lines on topographic maps represent the shapes of landscape features

Setting: Classroom

Timeframe: Two 50-minute, or one 90-minute period

Visualizing Topography—50 minutes

Topo Map Scavenger Hunt—50 minutes

Materials:

Visualizing Topography

- Adobe Acrobat program capability
- Computer projector or student computers

USGS science for a changing world

NATIONAL PARK SERVICE

Living with a Volcano in Your Backyard-An Educator's Guide with Emphasis on Mount Rainier

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

Students explore how lines on a topographic map represent the real landscape by comparing features on photographs and topographic maps. Later, students analyze and answer questions about a Mount Rainier National Park map.

- Copies of "*Visualizing Topography*" student pages
- Adobe Acrobat file "*Visualizing Topography Show*"

Topo Map Scavenger Hunt

- Topographic maps entitled "Mt. Rainier National Park, Wash." for each student group.
- Copy of *"Topographic Map Symbols"* for each student group or displayed overhead
- Copies of "*Topo Map Scavenger Hunt*" student page
- Rulers
- String
- Either the USGS pamphlet on map symbols or the Web site.

Vocabulary: Benchmark, contour interval, contour line, elevation, map scale, topographic map, topography

Skills: Measuring, inferring

Activity last modified: November 22, 2014

Benchmarks:

See benchmarks in Introduction.

Teacher Background

Map scale

Every map has a map scale that identifies the number of units of length in the real world that are represented by one unit of length on the map. A scale of 1:1 would be the same size as the real feature. The smaller the scale (in other words, the bigger the second number) the more area you can show on a map, although in less detail. The map entitled "Mt. Rainier National Park, Wash.," has a scale of 1:50,000, meaning one inch on this map translates to 50,000 inches on the ground, or less than one mile. If you measure one centimeter on the same map, it equals 50,000 centimeters on the ground, and if you measure one foot on the map it equals 50,000 feet on the ground. You can find distance on the bar scale at the bottom of a topographic map. Marked points of precisely measured elevation, called benchmarks, are shown on topographic maps as "BM," followed by the elevation in feet.

Contour review

A ***contour line*** is defined as a line of equal ***elevation*** on the map. If you were to walk on a contour line painted on the ground around the side of a hill you would neither go up nor down, but remain level throughout. The difference between contours, known as the ***contour interval***, is selected by the mapmaker. For any given topographic map, the contour interval remains the same. On topographic maps, every fifth contour line, regardless of map scale, is shown in bold, and has an elevation value of even hundreds. See more information about contour lines in the activity **Play-Dough Topo**.

This activity is divided into two parts; both enable students to analyze topographic maps. In *"**Visualizing Topography**,"* students work in small groups at a computer to examine and compare a topographic map with corresponding photographs of landforms at Mount Rainier National Park. An arrow on each topographic map indicates the direction from which the photograph was taken. This activity helps students to visualize what is represented on a topographic map and to recognize the value of map scale. The second part, *"**Topo Map Scavenger Hunt**,"* provides a series of questions about the topographic map that students will answer in groups. The questions point out some features common to all topographic maps. Students will also examine map scale and map symbols using some simple math questions. Understanding how to read maps will then help students prepare for planning their trip to the park.

Teacher Tips

This lesson can follow Play-Dough Topo, as it elaborates the subject of topographic maps, using contour lines to illustrate the variations in shape of the landforms. The questions have been selected to emphasize features common to all topographic maps. This activity will provide students with a good introduction to the value of topographic maps, and will help to prepare them for visits to Mount Rainier National Park. We recommend that the teacher show the photos and maps in the Acrobat presentation provided. This may take some setup time prior to each class. Information about map explanations can be found at the Topographic maps Web pages of the USGS Web site (See Internet Resources Page).

Procedure

Visualizing Topography

Students view *"Visualizing Topography Show"* at computers. They compare photographs of real landform features with map features. As an alternative, display *"Visualizing Topography Show"* for the entire class on a computer projection system.

1. Decide whether to conduct the activity as a class, with the display of *"Visualizing Topography Show"* on a computer projector, or whether you will divide class into small student groups and have them work at computers. In either case, distribute paper copies of the *"Visualizing Topography"* student page. ***Photos and maps should be viewed on a computer screen or classroom projection system.***

2. Review topographic map concepts with students, such as how three dimensions are represented in two dimensions through the use of contour lines, and the definition of a contour interval.

3. Explain that each photograph from the topographic map corresponds to a real location on or near Mount Rainier. Each topographic map contains an arrow, which represents the photographer's location and the tip pointing in the direction the photo was taken.

4. Students should look at both pictures and then answer the questions on the *"Visualizing Topography"* student page.

Topo Map Scavenger Hunt

Introduce students to a topographic map of Mount Rainier with the use of a paper copy of the map entitled "Mt. Rainier National Park, Wash." map and the student page *"**Topo Map Scavenger Hunt**."*

1. Regroup students (if necessary) into groups of three or four and give each group a map, *"**Topographic Map Symbols**"* and student page entitled *"**Topo Map Scavenger Hunt**."* Distribute string or ruler for use in comparing distances on the map and scale bar.

2. Each student group can work at its own pace, or the activity can be conducted as a true scavenger hunt where the first group with all the correct answers wins. The only problem with the latter scenario is that groups thinking ahead will subdivide the tasks, so everyone will not complete every task.

Hint: Your maps will last for years if you laminate and roll them instead of folding them.

Adaptations

- For *"**Topo Map Scavenger Hunt**,"* adjust number of questions assigned, based on student needs.

Extensions

- Conduct a Mount Rainier field trip. Instruct students to take photographs and find or mark their locations on the topographic map.

- Students find or are given topographic maps of other areas that show different kinds of landforms such as plains, broad river valleys, the topography of your community, and then answer questions assigned by the teacher.

- Instruct students to make a cross section or profile of a landscape feature from a topographic map.

Assessement

Use questions on the *"**Topo Map Scavenger Hunt**"* student pages to assess students' ability to apply the concept of contours to an actual map-reading activity. Look for their grasp of map purpose and of how contours represent real landforms. Note how students' understanding of map reading has progressed from part 1 to part 2. Instruct students to make a cross section or profile or a landscape feature from a topographic map.

References

National Geographic Society, 2003, Trails Illustrated—Mount Rainier National Park, Washington: National Geographical Society, Washington D.C., scale 1:55,000 and 1:27,500, 26 x 38 in., two sides, one plate.

National Geographic, Topo! state series—Washington CD-ROMS: National Geographic Society, Washington D.C., set of 7 CD-ROMS, PC format only.

Northwest Interpretive Association, 1999, Mount Rainier National Park—centennial edition map: Northwest Interpretive Association, Seattle, Wash., scale 1:30,000, 56 x 40 in., one plate.

U.S. Geological Survey, 1971, Mt. Rainier National Park, Wash.,: U.S. Geological Survey, scale 1:50,000, one plate.

Resources

Maps and publications can be obtained at park stores and via the Internet from the Northwest Interpretive Association, National Geographic, and the U.S. Geological Survey.

Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

Photo Credits

All slide show photographs by Mike Roylance, National Park Service.

Student Page

Name _____

Visualizing Topography

Instructions: *Observe each map and photograph pair as provided by your teacher and follow instructions for each question.* ***Note: The small photographs and maps on the student page are for reference purposes only****.*

PHOTO AND MAP 1a

1. Examine photo and map 1a, Rampart Ridge as viewed from the southeast at Longmire. Note the exposed cliff of andesite. Describe how the map contour lines illustrate a cliff.

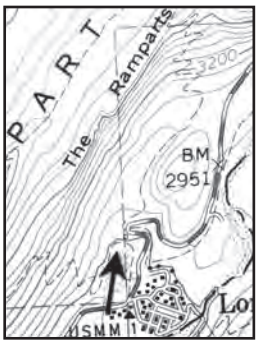
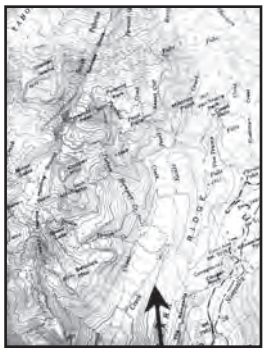


PHOTO AND MAP 1b

2. Now compare photos 1a and 1b. Observe the terrain immediately above the arrow on 1a. Describe how the north and south surface slopes of Rampart Ridge differ. Which side of Rampart Ridge would you find easier to ascend—the area shown in 1a, or 1b?



Student Page

Name _____

Visualizing Topography-continued

PHOTO AND MAP 2

3. The Nisqually River Valley, viewed in Map 2, is recently deglaciated. Photo 2 shows the view down valley from the highway bridge that crosses the Nisqually River. On the map, find the contour line immediately to the left of the arrow. In the space below, draw the contour line from the "Y" in Canyon Rim View Point to Christine Falls.

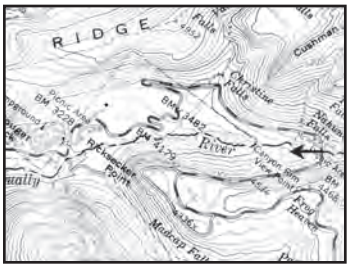
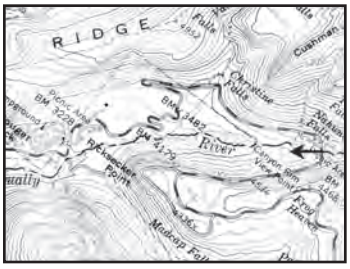


PHOTO AND MAP 2

4. Examine the cliffs near Benchmark (BM) 4179 on Map 2. Find the name of the high point on the left side of the photo and write its name below.



Student Page

Name _____

Visualizing Topography-continued

PHOTO AND MAP 3

5. This view is taken from the highway above Chinook Creek, looking downstream. Erosion at Chinook Creek and its tributaries has been dominated by stream activity. Draw the 3,600 foot contour where it crosses Dewey Creek.

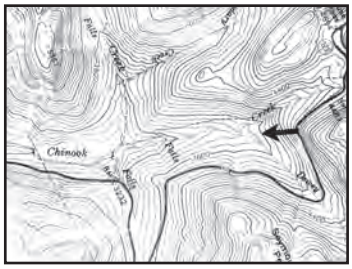
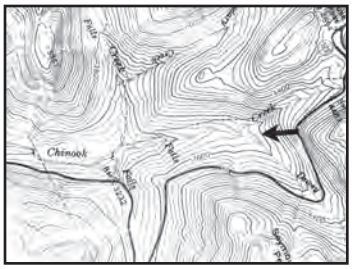


PHOTO AND MAP 3

6. Describe the difference between the shape of the contour lines across the Nisqually River and Chinook Creek. Which letters of the alphabet do each contour resemble?



Student Page

Name _____

Visualizing Topography-continued

PHOTO AND MAP 2 AND 3

7. Examine and compare Photos 2 and 3. Make some additional observations about the size and shape of the streambeds. How are the differences represented on the corresponding maps?

PHOTO AND MAP 4

8. This picture shows the Nisqually River, looking downstream from the former Sunshine Point Campground. On the map, what does the red line represent? Explain why many buildings exist left of the line and not to its right.

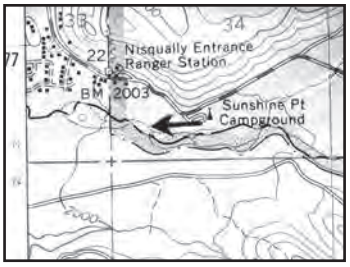


PHOTO AND MAP 5

9. List the name and elevation of the highest feature you see on the map.

Student Page

Name _____

Visualizing Topography-continued

PHOTO AND MAP 6

10. What hydrologic (water) feature exists between Pinnacle Peak and The Castle? Explain how Pinnacle Peak might have influenced formation of this feature.

PHOTO AND MAP 6

11. On the photo, examine the cliffs below Unicorn Peak. Describe what additional information the map provides that might help you climb Unicorn Peak easily and safely.

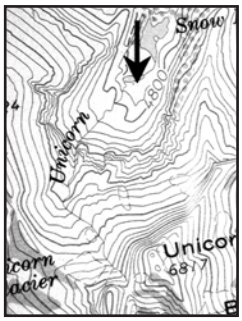
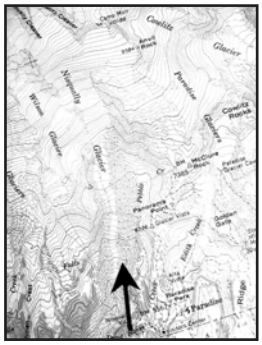


PHOTO AND MAP 7

12. Examine map 7 that shows Nisqually Glacier. Now examine photo 7. Name one difference between your perceptions of Nisqually Glacier when viewed on the photo and the map.



Teacher Page

Visualizing Topography—Answers

PHOTO AND MAP 1a

1. Examine photo and map 1a, Rampart Ridge as viewed from the southeast at Longmire. Note the exposed cliff of andesite. Describe how the map contour lines illustrate a cliff.
   Maps show cliffs through closely spaced contour lines. The more closely-spaced the contours, the steeper the cliff!

PHOTO AND MAP 1b

2. Now compare photos 1a and 1b. Observe the terrain immediately above the arrow. Describe how the south and north surface slopes of Rampart Ridge differ. Which side of Rampart Ridge would you find easier to ascend—that shown in 1a, or 1b?
Contours are closely spaced at the cliff shown on photo and map 1a. The north-facing side of Rampart Ridge seen in photo 1b, is a fairly gentle slope, compared to the cliff on the southeast side, as seen on 1a. The north-facing side would be easiest to ascend.

PHOTO AND MAP 2

3. The Nisqually River Valley, viewed in Map 2, is recently deglaciated. Photo 2 shows the view down valley from the highway bridge that crosses the Nisqually River. On the map, find the contour line immediately to the left of the arrow. In the space below, draw the contour line from the "Y" in Canyon Rim View Point to Christine Falls.
Students should draw a "shaky" U.

PHOTO AND MAP 2

4. Examine the cliffs near Benchmark (BM) 4179 on Map 2. Find the name of the high point on the left side of the photo and write its name below.
The cliffs in the photo will be those at Ricksecker Point.

PHOTO AND MAP 3

5. This view is taken from the highway above Chinook Creek, looking downstream. Erosion at Chinook Creek and its tributaries has been dominated by stream activity. Draw the 3,600 foot contour where it crosses Dewey Creek.
Students should draw a V.

Teacher Page

Visualizing Topography—Answers -continued

PHOTO AND MAP 3

6. Describe the difference between the shape of the contour lines across the Nisqually River and Chinook Creek. Which letters of the alphabet do each contour resemble?

The Nisqually Valley has a much broader channel than Dewey Creek and is glacially eroded and partially filled with glacial sediment; hence it has a "U" shape rather than the "V" shape.

PHOTO AND MAP 2 AND 3

7. Examine and compare Photos 2 and 3. Make some additional observations about the size and shape of the streambeds. How are the differences represented on the corresponding maps?

As above, the streambed is much broader in the Nisqually, and the maps show the same thing. The Nisqually Valley is less vegetated.

PHOTO AND MAP 4

8. This picture shows the Nisqually River, looking downstream from the former Sunshine Point Campground. On the map, what does the red line represent? Explain why many buildings exist left of the line and not to its right.

The red line indicates the park boundary. Residential buildings are allowed on private land, but not within park boundaries. The dotted stipples represent sand, mud and gravel. The river is eroding forested land upstream.

PHOTO AND MAP 5

9. List the name and elevation of the highest feature you see on the map.

Pinnacle Peak should be described as a pyramid or horn. Pinnacle Peak; elevation 6,562 feet.

PHOTO AND MAP 6

10. What hydrologic (water) feature exists between Pinnacle Peak and The Castle? Explain how Pinnacle Peak might have influenced formation of this feature.

Snow from avalanches accumulated at the north-facing base of Pinnacle Peak. Shadows cast by Pinnacle Peak preserved the snow. The snow transformed to glacier ice.

Teacher Page

Visualizing Topography—Answers -continued

PHOTO AND MAP 6

11. On the photo, examine the cliffs below Unicorn Peak. Describe what additional information the map provides that might help you climb Unicorn Peak easily and safely.

The cliffs in view on the north side are too steep to climb. Slopes on the south side are less steep.

PHOTO AND MAP 7

12. Examine Map 7 that shows Nisqually Glacier. Now examine Photo 7. Name one difference between your perceptions of Nisqually Glacier when viewed on the photo and the map.

The area covered by Nisqually Glacier's surface is difficult to ascertain in the photo because the glacier is in large part rock covered. The glacier is shown in blue and within dashed lines on map. The glacier's debris cover is shown as stippled dots.

Student Page

Name _____

Topo Map Scavenger Hunt

Instructions: *Using the map provided by your teacher, answer the questions below as completely as you can. If math is involved, be sure to show your work. Credit will not be given for just the answer!*

1. Record the name, date and agency that made this map.

2. Record the map scale. Explain the meaning of map scale.

3. Record the contour interval of the map as noted in the map explanation.

4. The contour interval on a map can also be calculated by looking at the elevation numbers on the contour line. Do this by taking any two adjacent bold contour lines and finding the elevation numbers on each. Subtract the elevation numbers to find the difference and divide by the number of intervals (spaces) you would have to cross to go from one bold contour to the other (remember the last bold line that you will have to cross). Show your work.

5. Look at the edges of the map. You will notice that the contour lines end there. Does the landscape actually end at the edge of the map? Explain your answer.

6. Describe the appearance of map contour lines at a stream valley and a glacial valley.

Student Page

Name _____

Topo Map Scavenger Hunt-continued

7. Describe what the green represents on the map.

8. In the southern part of the map you will note about a dozen white angular shapes. Roads join these areas. Explain what these white angular areas represent.

9. How many kilometers (miles) would you drive from the Nisqually Entrance to Box Canyon? At the average park speed of 50 kilometers per hour (35 miles per hour), how long would it take you to travel this distance?

10. Explain why the glaciers are shown in blue. Do these contours remain the same from year to year? Explain your answer.

11. Explain the meaning of the term "BM 5,557" on the map.

12. Find the name of the highest mountain in the Tatoosh Range and record its elevation.

13. Describe how the mapmaker represents the boundary of Mount Rainier National Park.

14. What is the color of water features on the map?

Student Page

Name _____

Topo Map Scavenger Hunt-continued

15. The map displays numbered red squares. How big is each square?

16. Which glacier has the greatest length? What is its length?

17. Measure the round trip distance and vertical elevation gain of your hike to Pinnacle Peak. Assuming that a steep climb such as this would take you an average of 45 minutes per 1.6 kilometer (1 mile), what would be the duration of your hike?

Teacher Page

Topo Map Scavenger Hunt—Answers

1. Record the name, date, and agency that made the map.
Mt. Rainier National Park, Wash.; 1971; U.S. Department of Interior, U.S. Geological Survey (USGS).

2. Record the map scale. Explain the meaning of map scale.
(1:50,000); one inch (or centimeter, etc) on the map equals 50,000 inches (or centimeters) on the ground.

3. Record the contour interval of the map as noted in the map explanation.
Students should draw a "shaky" U.

4. The contour interval on a map can also be calculated by looking at the elevation numbers on the contour line. Do this by taking any two adjacent bold contour lines and finding the elevation numbers on each. Subtract the elevation numbers to find the difference and divide by the number of intervals (spaces) you would have to cross to go from one bold contour to the other (remember the last bold line that you will have to cross). Show your work below.
Example: 4000-3600 = 400 There are 5 intervals to cross, so 400/5 = 80

5. Look at the edges of the map. You will notice that the contour lines end there. Do they really just stop there? Why or why not?
No, they continue at that elevation on features shown on the adjacent map.

6. Describe the appearance of map contour lines at a stream valley and a glacial valley.
Contours in a stream valley are V-shaped at the valley bottom; contours in a glacial valley display a flattened U-shape.

7. Describe what the green represents on the map.
Vegetation

8. In the southern part of the map you will note about a dozen white angular shapes. Roads join these areas. Explain what these white angular areas represent.
These are areas that were clear cut at the time the map was made, therefore they do not have the normal vegetation pattern.

Teacher Page

Topo Map Scavenger Hunt—Answers -continued

9. How many kilometers (miles) would you drive from the Nisqually Entrance to Box Canyon,? At the average park speed of 50 kilometers per hour (35 miles per hour), how long would it take you?
Distance is approximately 23 miles. The trip would require about 40 minutes or .7 hours.

10. Explain why the glaciers are shown in blue. Do these contours remain the same from year to year? Explain your answers.
The glaciers consist of water, and thus are considered water features. No, contours do not remain the same from year to year, because the glacier's size is dependent on changeable climatic conditions.

11. Explain the meaning of the term "BM 5,557" on the map.
It tells us the elevation at that point is exactly 5,557 feet above sea level. Incidentally, BM stands for benchmark. If you go to Paradise, you can find this marker easily, since it sits on top of a foot high pole.

12. Find the name of the highest mountain in the Tatoosh Range and record its elevation.
Unicorn Peak at 6,817 feet is the tallest.

13. Describe how the mapmaker represents the boundary of Mount Rainier National Park.
By a thick red line.

14. What is the color of water features on the map?
Blue

15. The map displays numbered red squares. How big is each square?
They are one-mile squares.

16. Which glacier has the greatest length? What is the length of it?
It seems to be a toss-up between Carbon and Winthrop Glaciers at about 5.2 miles.

17. Measure the round trip distance and vertical elevation gain of your hike to Pinnacle Peak. Assuming that a steep climb such as this would take you an average of 45 minutes per mile (1.6 kilometers), what would be the duration of your hike?
The trail is about 3 miles round trip (give credit for 2 miles, since there are a lot of switch-backs) and gains about 1,120 feet (6,000–4,880). This trail would require two and one quarter hours to hike.

Graphic Page

Official USGS Topographic Map Symbols—Page 1

BATHYMETRIC FEATURES

- Area exposed at mean low tide; sounding datum line***
- Channel***
- Sunken rock***

BOUNDARIES

- National
- State or territorial
- County or equivalent
- Civil township or equivalent
- Incorporated city or equivalent
- Federally administered park, reservation, or monument (external)
- Federally administered park, reservation, or monument (internal)
- State forest, park, reservation, or monument and large county park
- Forest Service administrative area*
- Forest Service ranger district*
- National Forest System land status, Forest Service lands*
- National Forest System land status, non-Forest Service lands*
- Small park (county or city)

BUILDINGS AND RELATED FEATURES

- Building
- School; house of worship
- Athletic field
- Built-up area
- Forest headquarters*
- Ranger district office*
- Guard station or work center*
- Racetrack or raceway
- Airport, paved landing strip, runway, taxiway, or apron
- Unpaved landing strip
- Well (other than water), windmill or wind generator
- Tanks
- Covered reservoir
- Gaging station
- Located or landmark object (feature as labeled)
- Boat ramp or boat access*
- Roadside park or rest area
- Picnic area
- Campground
- Winter recreation area*
- Cemetery (Cem)

COASTAL FEATURES

- Foreshore flat (Mud)
- Coral or rock reef (Reef)
- Rock, bare or awash; dangerous to navigation
- Group of rocks, bare or awash
- Exposed wreck
- Depth curve; sounding (18, 23)
- Breakwater, pier, jetty, or wharf
- Seawall
- Oil or gas well; platform

CONTOURS

Topographic

- Index (6000)
- Approximate or indefinite
- Intermediate
- Approximate or indefinite
- Supplementary
- Depression
- Cut
- Fill
- Continental divide

Bathymetric

- Index***
- Intermediate***
- Index primary***
- Primary***
- Supplementary***

CONTROL DATA AND MONUMENTS

- Principal point** (3-20)
- U.S. mineral or location monument (USMM 438)
- River mileage marker (Mile 69)

Boundary monument

- Third-order or better elevation, with tablet (BM 9134; BM 277)
- Third-order or better elevation, recoverable mark, no tablet (5628)
- With number and elevation (67 4567)

Horizontal control

- Third-order or better, permanent mark (Neace; Neace)
- With third-order or better elevation (BM 52; Pike BM393)
- With checked spot elevation (1012)
- Coincident with found section corner (Cactus; Cactus)
- Unmonumented**

Official USGS Topographic Map Symbols—Page 2

CONTROL DATA AND MONUMENTS – *continued*

Vertical control

- Third-order or better elevation, with tablet — BM × 5280
- Third-order or better elevation, recoverable mark, no tablet — × 528
- Bench mark coincident with found section corner — BM 5280
- Spot elevation — × 7523

GLACIERS AND PERMANENT SNOWFIELDS

- Contours and limits
- Formlines
- Glacial advance
- Glacial retreat

LAND SURVEYS

Public land survey system

- Range or Township line
  - Location approximate
  - Location doubtful
  - Protracted
  - Protracted (AK 1:63,360-scale)
  - Range or Township labels — R1E T2N R3W T4S
- Section line
  - Location approximate
  - Location doubtful
  - Protracted
  - Protracted (AK 1:63,360-scale)
  - Section numbers — 1 - 36 1 - 36
- Found section corner
- Found closing corner
- Witness corner — WC
- Meander corner — MC
- Weak corner*

Other land surveys

- Range or Township line
- Section line
- Land grant, mining claim, donation land claim, or tract
- Land grant, homestead, mineral, or other special survey monument
- Fence or field lines

MARINE SHORELINES

- Shoreline
- Apparent (edge of vegetation)***
- Indefinite or unsurveyed

MINES AND CAVES

- Quarry or open pit mine
- Gravel, sand, clay, or borrow pit
- Mine tunnel or cave entrance
- Mine shaft
- Prospect — x
- Tailings — Tailings
- Mine dump
- Former disposal site or mine

PROJECTION AND GRIDS

- Neatline — 39°15′ 90°37′30″
- Graticule tick — 55′
- Graticule intersection
- Datum shift tick

State plane coordinate systems

- Primary zone tick — 640 000 FEET
- Secondary zone tick — 247 500 METERS
- Tertiary zone tick — 260 000 FEET
- Quaternary zone tick — 98 500 METERS
- Quintary zone tick — 320 000 FEET

Universal transverse metcator grid

- UTM grid (full grid) — 273
- UTM grid ticks* — 269

RAILROADS AND RELATED FEATURES

- Standard guage railroad, single track
- Standard guage railroad, multiple track
- Narrow guage railroad, single track
- Narrow guage railroad, multiple track
- Railroad siding
- Railroad in highway
- Railroad in road
- Railroad in light duty road*
- Railroad underpass; overpass
- Railroad bridge; drawbridge
- Railroad tunnel
- Railroad yard
- Railroad turntable; roundhouse

RIVERS, LAKES, AND CANALS

- Perennial stream
- Perennial river
- Intermittent stream
- Intermittent river
- Disappearing stream
- Falls, small
- Falls, large
- Rapids, small
- Rapids, large
- Masonry dam
- Dam with lock
- Dam carrying road

Official USGS Topographic Map Symbols—Page 3

RIVERS, LAKES, AND CANALS – *continued*

- Perennial lake/pond
- Intermittent lake/pond
- Dry lake/pond (Dry Lake)
- Narrow wash
- Wide wash (Wash)
- Canal, flume, or aqueduct with lock
- Elevated aqueduct, flume, or conduit
- Aqueduct tunnel
- Water well, geyser, fumarole, or mud pot
- Spring or seep

ROADS AND RELATED FEATURES

Please note: Roads on Provisional-edition maps are not classified as primary, secondary, or light duty. These roads are all classified as improved roads and are symbolized the same as light duty roads.

- Primary highway
- Secondary highway
- Light duty road
- Light duty road, paved*
- Light duty road, gravel*
- Light duty road, dirt*
- Light duty road, unspecified*
- Unimproved road
- Unimproved road*
- 4WD road
- 4WD road*
- Trail
- Highway or road with median strip
- Highway or road under construction (Under Const)
- Highway or road underpass; overpass
- Highway or road bridge; drawbridge
- Highway or road tunnel
- Road block, berm, or barrier*
- Gate on road*
- Trailhead*

SUBMERGED AREAS AND BOGS

- Marsh or swamp
- Submerged marsh or swamp
- Wooded marsh or swamp
- Submerged wooded marsh or swamp
- Land subject to inundation (Max Pool 4.3)

SURFACE FEATURES

- Levee (Levee)
- Sand or mud (Sand)
- Disturbed surface
- Gravel beach or glacial moraine (Gravel)
- Tailings pond (Tailings Pond)

TRANSMISSION LINES AND PIPELINES

- Power transmission line; pole; tower
- Telephone line (Telephone)
- Aboveground pipeline
- Underground pipeline (Pipeline)

VEGETATION

- Woodland
- Shrubland
- Orchard
- Vineyard
- Mangrove (Mangrove)

* USGS-USDA Forest Service Single-Edition Quadrangle maps only.
In August 1993, the U.S. Geological Survey and the U.S. Department of Agriculture's Forest Service signed an Interagency Agreement to begin a single-edition joint mapping program. This agreement established the coordination for producing and maintaining single-edition primary series topographic maps for quadrangles containing National Forest System lands. The joint mapping program eliminates duplication of effort by the agencies and results in a more frequent revision cycle for quadrangles containing National Forests. Maps are revised on the basis of jointly developed standards and contain normal features mapped by the USGS, as well as additional features required for efficient management of National Forest System lands. Single-edition maps look slightly different but meet the content, accuracy, and quality criteria of other USGS products.

** Provisional-Edition maps only.
Provisional-edition maps were established to expedite completion of the remaining large-scale topographic quadrangles of the conterminous United States. They contain essentially the same level of information as the standard series maps. This series can be easily recognized by the title "Provisional Edition" in the lower right-hand corner.

*** Topographic Bathymetric maps only.

Topographic Map Information

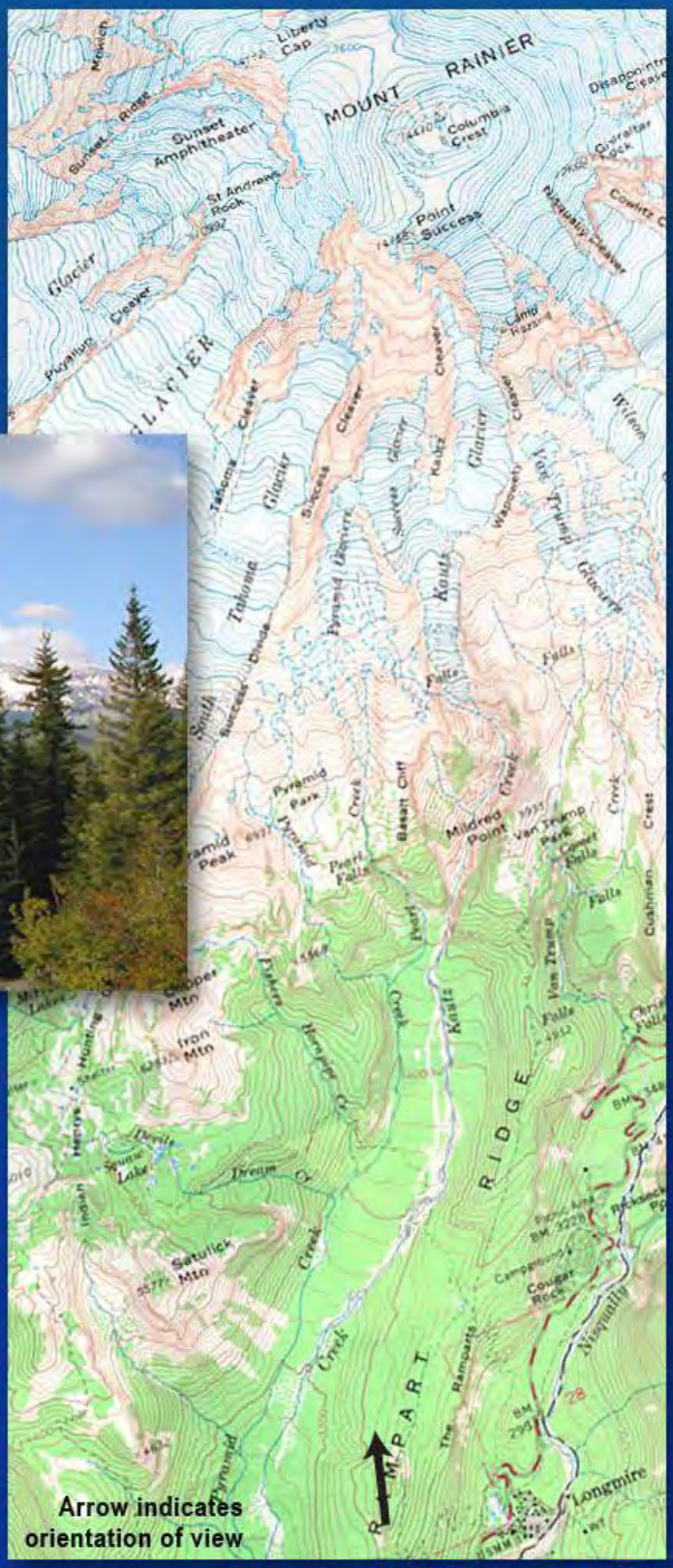
For more information about topographic maps produced by the USGS, please call: 1-888-ASK-USGS or visit us at http://ask.usgs.gov/

ISBN 0-607-96942-3
9 780607 969429

Printed on recycled paper

USGS
science for a changing world

Visualizing Topography Show



U.S. Department of the Interior
U.S. Geological Survey

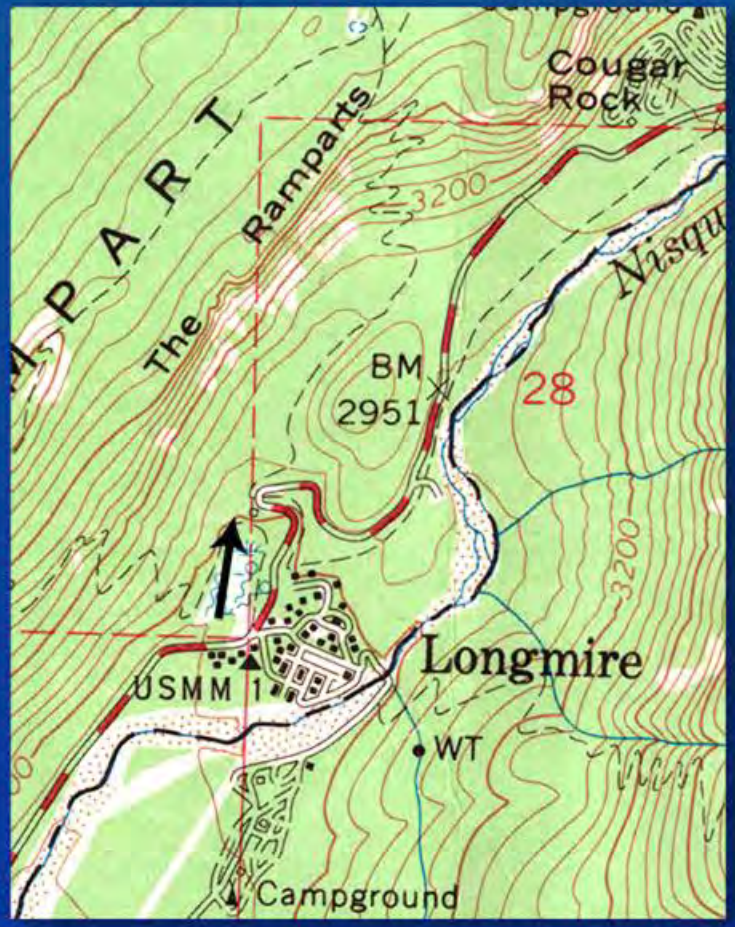
Last Modified: January, 2014

1a - Rampart Ridge

Rampart Ridge southeast side, view from Longmire

Photo 1a

Map 1a



Arrow indicates orientation of view

USGS
science for a changing world

1b - Mount Rainier

View from Rampart Ridge north side

Photo 1b

Map 1b

Arrow indicates orientation of view

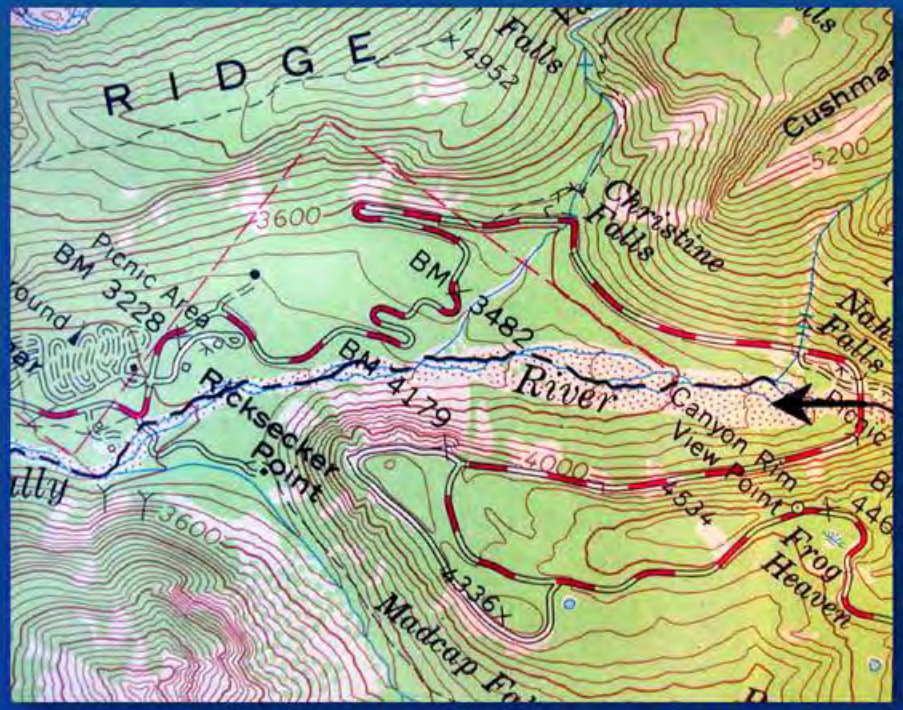
USGS
science for a changing world

2 - Nisqually River

View from highway bridge looking down valley

Photo 2

Map 2



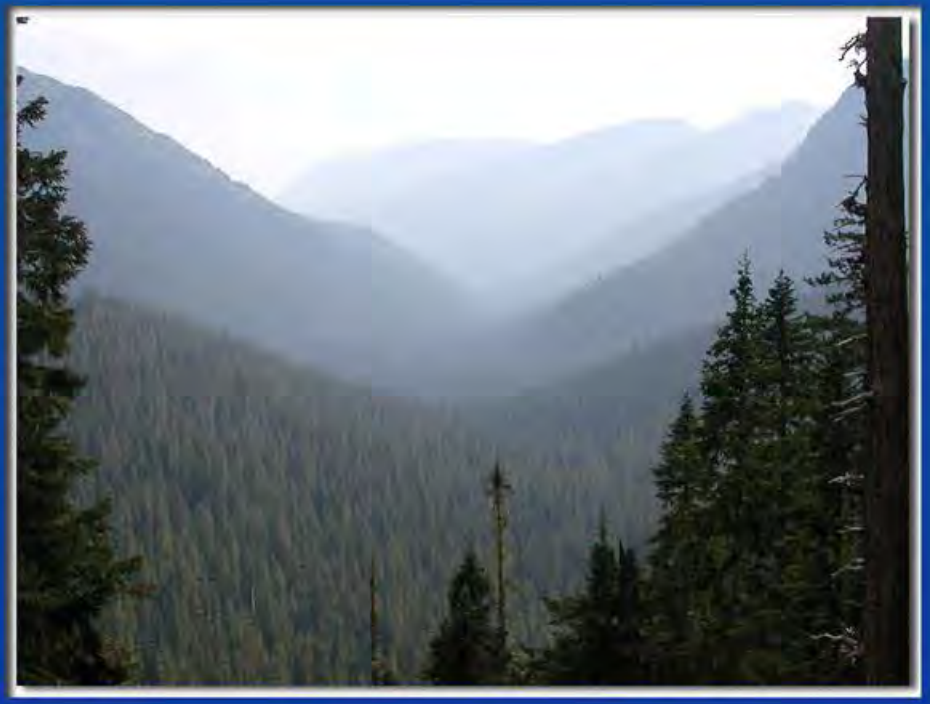
Arrow indicates orientation of view

USGS
science for a changing world

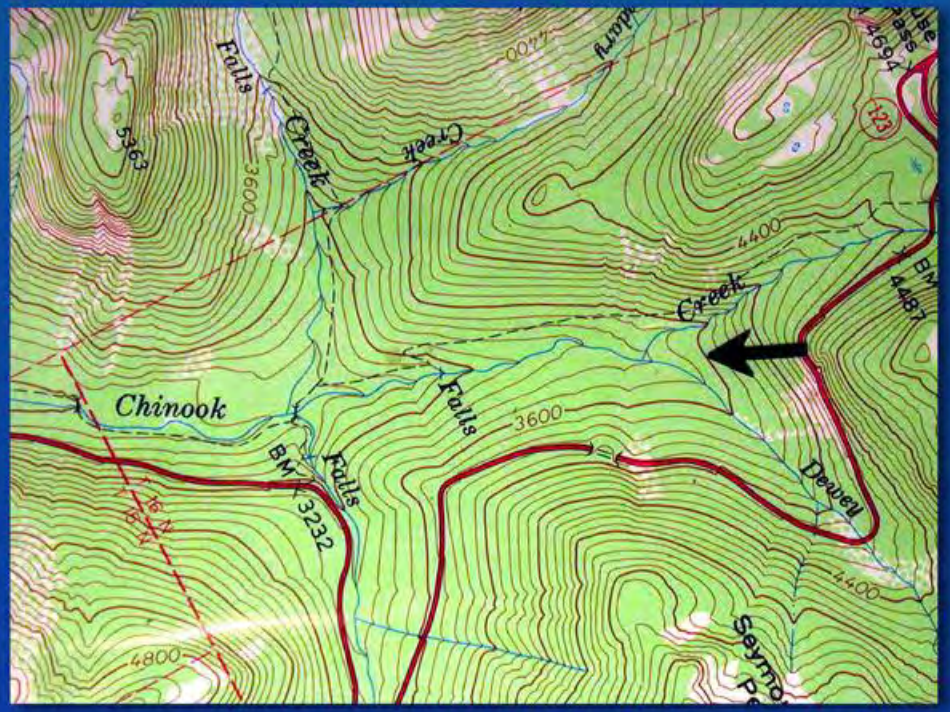
3 - Chinook Creek

View from 2km (1.2m) upvalley of highway 123 tunnel

Photo 3



Map 3



Arrow indicates orientation of view

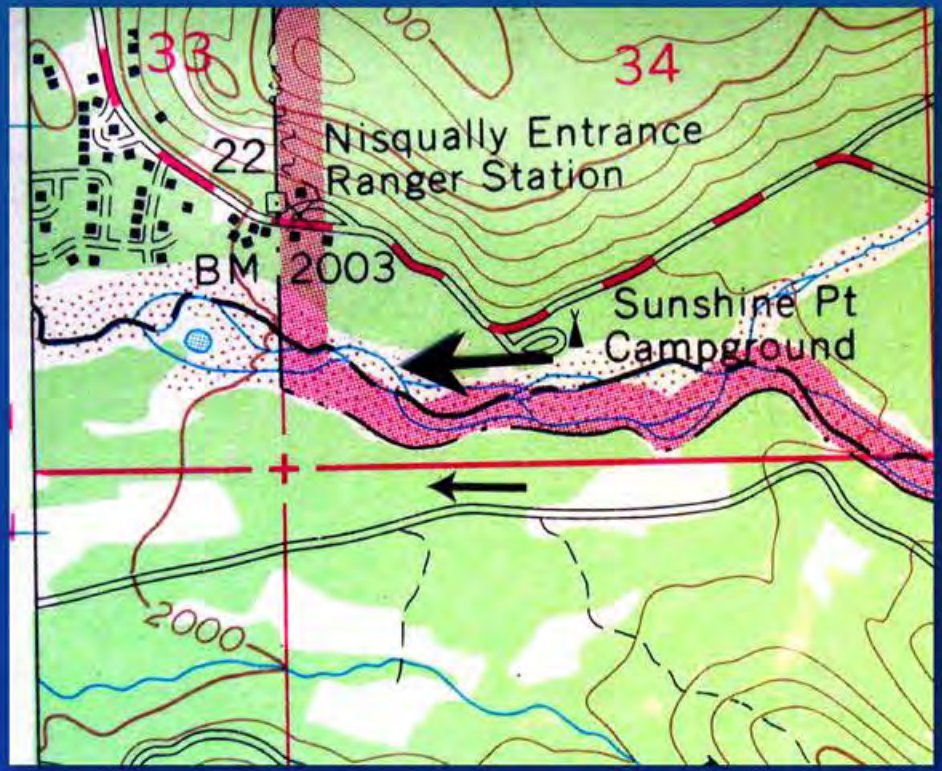
USGS
science for a changing world

4 - Nisqually River (near SW Park Boundary)

View adjacent to the former Sunshine Point Campground Restrooms

Photo 4

Map 4



Arrow indicates orientation of view

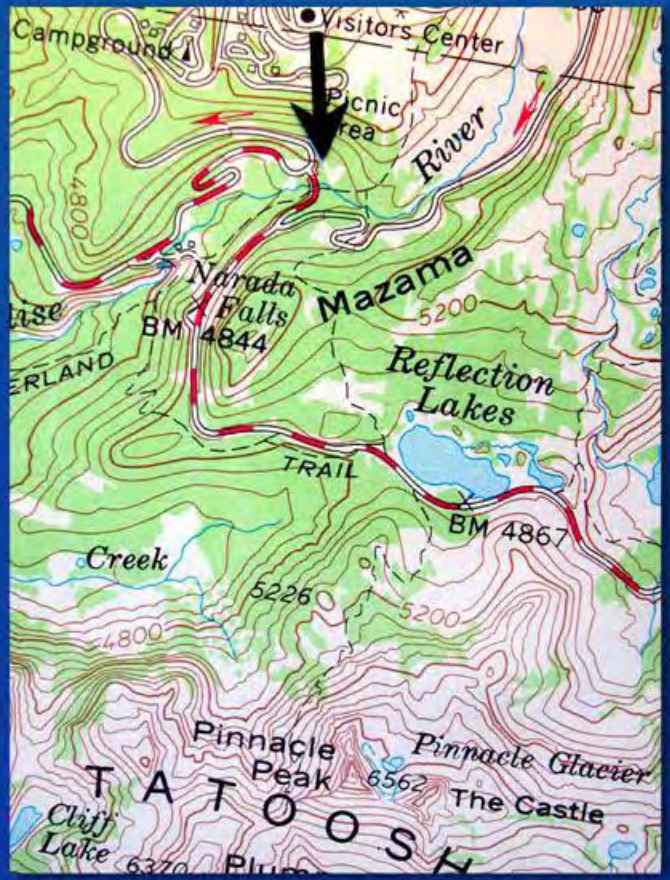
USGS
science for a changing world

5 - Pinnacle Peak

View from the south side of Jackson Visitor Center

Photo 5

Map 5



Arrow indicates orientation of view

USGS
science for a changing world

6 - Snow Lake and Unicorn Peak

View from Snow Lake Campground

Photo 6

Map 6

Arrow indicates orientation of view

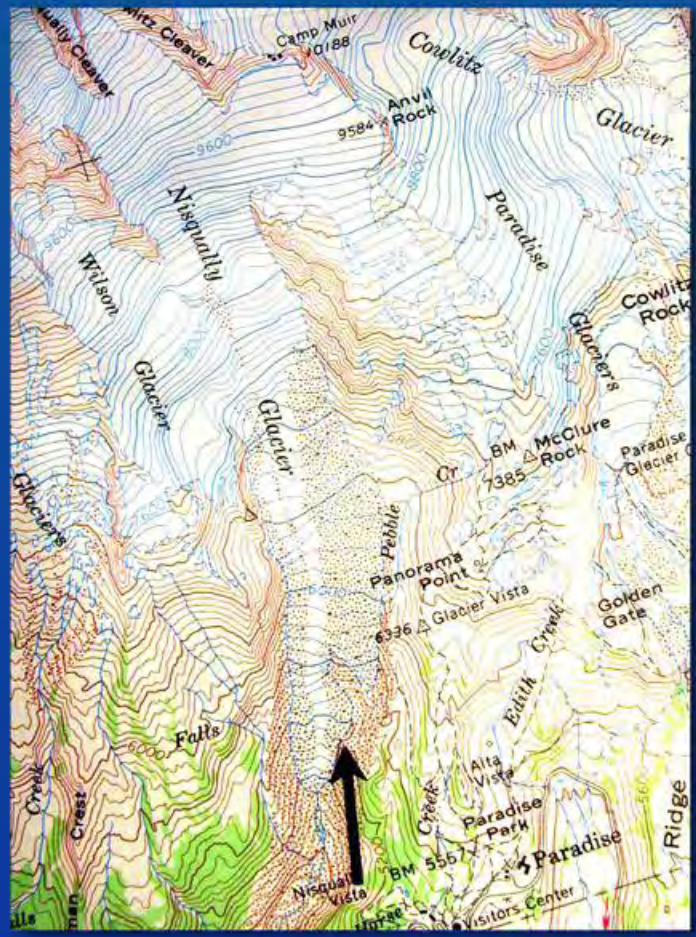
USGS
science for a changing world

7 - Nisqually Glacier

View from Nisqually Vista trail viewpoint

Photo 7

Map 7

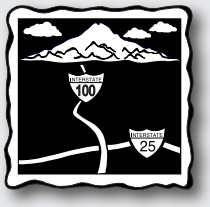


Arrow indicates orientation of view

USGS
science for a changing world

Planning Your Trip
to Mount Rainier National Park!

Living with a VOLCANO in Your Backyard
MOUNT RAINIER



Grade Level: 5–12+

Learner Objectives:

Students will:

- Recognize how to interpret maps and guidebooks
- Recognize some interesting places to visit at Mount Rainier National Park
- Understand safety considerations when visiting a natural setting

Setting: Classroom

Timeframe: 1 to 2 hours plus homework time

Materials:

- Copies of *"My Trip to Mount Rainier National Park"* student pages
- Washington State highway map
- Mt. Rainier National Park, Wash., topographic map
- Books and brochures about Mount Rainier
- Internet resources (optional)
- Bookbinding materials (stapler, thread, spiral binder machine, etc.)

USGS
science for a changing world

NATIONAL PARK SERVICE

Living with a Volcano in Your Backyard–An Educator's Guide with Emphasis on Mount Rainier

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

Students plan a virtual or actual trip to Mount Rainier National Park using maps, books, brochures, and Internet resources.

Teacher Background

This activity builds upon students' familiarity with topographic, highway, and general information maps. ***Topographic maps*** can present a major teaching challenge in the classroom. However, maps are a useful tool and their interpretation provides excellent practice for building spatial relation skills.

A preparation analogy

Students take specific items with them when they leave for school in the morning: their books, homework, lunch, etc. They bring different items when going to the beach: a swimsuit, towel, sunscreen, etc. All these items could be put into a bag, just like school gear. Ask students what would happen if they grabbed the wrong bag and arrived at school with beach gear; or what a bummer it would be if they found it was snowing when they arrived at the beach. What if they were unable to find the beach at all? The point is that it is important to be prepared for the specific trip one is planning to take. That means they must do some research to find out what they will need for their visit to an unfamiliar place. It is also important that they check the weather for outdoor destinations and know how to get around once they have arrived.

Activity last modified: September 5, 2014

Vocabulary: Elevation, glaciers, lava flows, topographic map, volcano

Skills: Measure, organize, identify, interpret

Benchmarks:

See benchmarks in Introduction.

Before beginning this activity, students should be familiar with the basic concept of a map. The activities Play-Dough Topo ***and*** Topographic Maps and Mount Rainier ***can help prepare your students for the optional use of topographic maps in this activity.***

Prepare for this activity by assembling maps, books and brochures that can help students plan a visit to Mount Rainier National Park. Include several map types such as a Washington State highway map, a topographic map of Mount Rainier, and a Mount Rainier National Park Service Park Map. Students can assemble these supplies from home, library and Internet resources, and can request some maps in a letter to the National Park Service. Visit the National Park Web site as noted on the Internet Resources Page. ***Note that there is no Teacher Page with answers for this open-ended activity.***

Procedure

1. Assemble books, maps, brochures, and Web site resources. The National Park Service's Web site for Mount Rainier National Park contains up-to-date information and maps. Park maps found on the Web site should be enlarged one-and-a half to two times for legibility.

2. Read or summarize the analogy for the class from the *"**Teacher Background**."*

3. Students work in groups to answer all or selected questions; or they can do the research at home in preparation for a real or virtual one-day, weekend, or weeklong trip to Mount Rainier!

4. Students create a drawing or collage on the book cover.

5. Students record and archive their trip plans and then "bind them" as a book using staples, thread or spiral binding machine.

6. Students can write trip notes and collect photographs or create drawings of their real or virtual trip to Mount Rainier.

Adaptations

- Pick and choose questions or modify them to suit students' age group. Adjust expectations for the map, book, and brochure resources you have available.

Assessment

Use answers to assess the students' ability to interpret Mount Rainier information resources and to apply them to their trip itinerary.

Resources

Decker, R., and Decker, B., 1996, Road guide to Mount Rainier National Park: Mariposa, Calif., Double Decker Press, 48 p. [online version: *http://www.dartmouth.edu/~volcano/texts/DekRainier.html,* accessed October 25, 2005]

Driedger, C., and Scott, K., 2002, Mount Rainier—Learning to live with volcanic risk: U.S. Geological Survey Fact Sheet 034–02, 4 p.

Field, N., and Machlis, S., 1992, Discovering Mount Rainier: Middleton, Wisc., Dog-Eared Publications, 32 p.

Gauthier, M., 2005, Mount Rainier: A climbing guide: Seattle, Wash., The Mountaineers Books, 245 p.

Harlin, J., and Martin, J., 2001, Mount Rainier: Views and adventures: Seattle, Wash., Sasquatch Books, 128 p.

Harris, S.L., 2005, Fire mountains of the west—The Cascade and Mono Lake volcanoes: Missoula, Mont., Mountain Press Publishing Company, 390 p.

Hoblitt, R.P., Walder, J.S., Driedger, C.L., Scott, K.M., Pringle, P.T., and Vallance, J.W., 1998, Volcano hazards from Mount Rainier, Washington—1998 volcano-hazards assessment report: U.S. Geological Survey, Open–File Report 98–428, 11 p.

Judd, R., 2002, Day hike! Mount Rainier: The best trails you can hike in a day: Seattle, Wash., Northwest Interpretive Association Press, 200 p.

Kirk, R., 1999, Sunrise to Paradise: The story of Mount Rainier National Park: Seattle, Wash., Northwest Interpretive Association Press, 152 p.

Northwest Interpretive Association, 1999, Rainier the mountain (DVD) (re–recorded 2005): Seattle, Wash., Northwest Interpretive Association Press, 60 minutes.

Northwest Interpretive Association, 1999, Mt. Rainier National Park—Centennial Edition Map: scale: 1:30,000.

Pierce County Department of Emergency Management, 1999, Mount Rainier volcano hazards response plan: Pierce County Department of Emergency Services, 103 p. [online version: *http://www.co.pierce.wa.us/DocumentCenter/view/3499,* accessed October 25, 2005]

Prager, E.J., and Woodman, N., 2001, Volcano!: Washington, D.C., National Geographic Society, 32 p.

Schneider, H., and Skjelset, M., 1999, Hiking Mount Rainier National Park: Helena, Mont., Falcon Press, 246 p.

U.S. Geological Survey, 1971, Mt. Rainier National Park, Wash: U.S. Geological Survey Topographic Map, scale 1:50,000.

Wuerthner, G., and Moore, D.W., 2002, Mount Rainier: A visitor's companion: Northwest Interpretative Association, 230 p.

Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

My Trip To
Mount Rainier National Park

Authored by: _____

Trip Preparations

1. The first thing you need to know is how to get to and when to go to Mount Rainier! What type of reference material will help you find a route to Mount Rainier? What roads would you take to get to the park? Use maps or Internet resources to determine how far you need to travel to reach Mount Rainier National Park. Calculate estimated travel time required to reach the park. Keep in mind that some roads are closed during winter.

2. There are several entrances to Mount Rainier National Park. Identify the name of the entrance that is closest to your community.

3. Mount Rainier is a ***volcano***. What evidence can you find on the maps of Mount Rainier National Park that supports this fact?

4. There are several different types of visitor facilities in the park. Record the names of the visitor centers and note where they are located. What is the purpose of a visitor center? What kinds of services do visitor centers provide? Which visitor facilities are open all year around?

5. Are there campgrounds in the park? Count the number of drive-in campgrounds. Do they require reservations? Are there any services offered in the campgrounds that you might like to use? Where can you obtain this information? Where can you obtain food? Discuss what kinds of supplies you might need to pack for a campout at the park.

6. Use a map to examine the park trail system. You will notice that some campgrounds are located beside trails far from roads. How could you get to these campgrounds? What kind of reservation or permit would you need to camp there? What kinds of extra supplies or equipment would you need for an overnight stay at these campsites?

7. Is there any place within the park where you could stay overnight and have meals?

8. Mount Rainier has an extensive trail system. Find the name of the trail that encircles the mountain? How long is this trail?

9. Look for trails close to the park entrance nearest to your school. What are some of the trails that you might choose for a hike or are appropriate for a snowshoe walk? Choose one trail. Determine the trail length, and ***elevation*** change from the trailhead to a destination. How long do you think it would take you to reach it?

10. When you go for a hike or snowshoe walk, it is important to be prepared for unfavorable weather and travel conditions. What items should you have with you when you set out for your hike? List at least ten things you should take along, and explain why each one is important. Use park brochures and other resources to assemble your list.

11. More than 88 square kilometers (34 square miles) of ***glaciers*** cover Mount Rainier. When you look at Mount Rainier from any direction, one or more glaciers are in view. Which glaciers might you be able to see from the high points on the trails near your park entrance?

12. Find the name and elevation of the highest point on Mount Rainier. Find the elevation of your school. Determine how much higher the summit of Mount Rainier is above the visitor center at Paradise, and above your school. Calculate how many steps would be needed to reach the summit from Paradise and from your school, assuming that a stair step is six inches high. Use park literature and Web site information to determine the best season of the year for summit climbs. Research what types of additional preparations you might make if you wanted to climb to the top of Mount Rainier.

13. Now that you know something about the layout of Mount Rainier National Park, you should decide what attractions you would most like to visit, and discover the best places to view them. Take into account how much hiking you would like to do, how much time you have, and look for places that fit your own personal preferences. For each of the natural or man-made features listed below, find at least one place in the park where you could visit or see this sight. Use the maps and any guides or reference books about Mount Rainier to help you find the answers. Remember that some activities vary with the season.

- Rivers
- Glaciers
- Historic monuments
- Old-growth forests
- Fire lookouts
- Waterfalls
- Alpine meadows and flowers
- Great views of Mount Rainier
- Wildlife
- Lava flows

To your list, add any other sites that interest you, and include where to find them!

14. The last thing you will have to do when planning your trip is one of the most important, because it affects what you will bring and what you will most enjoy on your visit. Check the season, snow pack, and weather forecast specifically for Mount Rainier before you go.

15. Plan an itinerary for a three-day visit to Mount Rainier National Park. Include information about your route to the park. Estimate how long it would take you to hike and drive around the park. When would you start? What attractions would you visit? What items must you pack to be fully prepared for your trip? Write your answers on the page entitled *My Trip Itinerary.*

My Trip Itinerary

Getting to Mount Rainier National Park:

Food and Lodging:

Activities at the park:

Return Home:

You are now ready to visit one of the country's first National Parks!

LEARN ALL YOU CAN, BE SAFE, AND HAVE FUN!

Trip Notes

Trip Photo Scrapbook

The Next Eruption of Mount Rainier

Grade Level: 6–12

Learner Objectives:

Students will:

- Identify how volcano hazards differ from other natural hazards in timing, duration, and style
- Expect future eruptions at many Cascade volcanoes, including Mount Rainier
- Become familiar with methods used by scientists to watch for indications of renewed volcanic unrest and for lahars
- Understand that scientists make hazard maps to identify areas that could be affected during future volcanic eruptions
- Recognize some of the ways that volcanoes can impact a society's infrastructure and methods for mitigation
- Recognize that volcanic eruptions are survivable, especially with proper precautions
- Recognize that they can play an important role by bringing an understanding of volcanic risk to their family, school, and community, now and in the future

USGS
science for a changing world

Living with a Volcano in Your Backyard-An Educator's Guide with Emphasis on Mount Rainier

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

In this activity, students use Mount Rainier as an example, while they explore a variety of themes associated with future volcanic activity. Students make a timeline of Mount Rainier volcanic events, interpret hazard maps, investigate potential effects on people and infrastructure, learn how scientists watch for signs of volcanic unrest, and create a warning statement. All products created during this activity can be included in a "school volcano museum" for students and parents to view.

Teacher Background

What are the volcano hazards?

Scientists recognize that Mount Rainier will erupt again. They consider it an active volcano because of four factors:

- Location on an active ***subduction zone***
- Presence of ***earthquakes*** beneath the volcano
- Active hydrothermal system within the volcano
- Recentness of volcanic ***eruptions*** in ***geologic time*** (on multiple occasions during the 19th century)

Last modified: September 5, 2014

Setting: Classroom and homework

Timeframe:

Mount Rainier Timeline: 50 minutes

Reading Hazard Maps: 50 minutes

Eyes and Ears on Mount Rainier: 50 minutes

The Volcano and Your Community: homework and 30 minutes for class discussion

Eyes and Ears on Mount Rainier: 50 minutes

Volcano Evacuation Route Sign: 30 minutes

Educating Future Generations—The Granatello Epigraph: 50 minutes

Materials:

Mount Rainier Timeline

- Graphic *"Summary of Notable Events at Mount Rainier, 10,000 Years Ago to Present"*
- Adding machine tape

Reading Hazard Maps

- Graphic *"Lava and Pyroclastic Flow Hazard Zones on Mount Rainier"*
- Graphic *"Lahar Hazard Zones from Mount Rainier"*
- Graphic *"Lahar Hazard Map Extensions"*
- Graphic *"Effects of Volcanic Processes"*
- Graphic *"Prepare for Volcanic Unrest"*

The Volcano and Your Community

- Facilities for library or Internet research
- Graphic *"Volcano Evacuation Route Sign"*

Volcanic eruptions are unique among natural events

Volcanic ***eruptions*** are unique among natural events because they present multiple uncertainties about when eruptive activity will begin, how long it will last, and who will be affected. Unlike floods and earthquakes, volcanic eruptions are seldom singular events. ***Volcanic unrest***, when a volcano shows signs of reawakening, is often prolonged over a period of months to years with no predictable end. Sometimes it results in an eruption, and sometimes it does not. Even without an eruption, the uncertainty associated with volcanic unrest can cause repeated or long-term evacuations and psychological stresses and thus have major impacts on populations at ***risk***.

Volcanic processes—Nuisances or disasters

Volcanic activity occurs in a variety of sizes, patterns, durations, and styles. Volcanic processes can be simply a nuisance or cause disaster, depending on their nearness to communities. Fortunately, symptoms of rising ***magma*** can be identified and measured, and people at risk generally have some time to invoke response plans and evacuate to safer terrain. However, people at risk must be advised *beforehand* about how ***volcanic hazards*** might affect their area so that they know how to prepare and can make risk-wise decisions before the onset of volcanic unrest. People at risk should become aware of strategies for ***mitigation*** that have been established by officials in their community.

Eyes and Ears on Mount Rainier

- Graphic *"Volcano Monitoring Techniques"*
- Graphic *"The USGS Alert-Notification System for Volcanic Activity"*
- Facilities for library or Internet research
- Volcano Evacuation Route Sign
- Graphic *"Volcano Evacuation Route Sign"*

Educating Future Generations—The Granatello Epigraph

- Graphic *"Text of Granatello Epigraph, Portici, Italy"*
- Poster paper
- Art materials

Vocabulary: **Active volcano, ashfall, bombs, blocks, conduit, earthquake, emergency plan, epigraph, eruption, explosion, gas, family emergency preparedness plan, geologic time, geothermal, hazard, hazard map, hydrothermally altered rock, infrastructure, lahar, lava flows, magma, magmatic eruption, monitor, mitigation, pyroclastic flows, risk, subduction, tephra, vent, volcano, volcanic ash, volcanic gases, volcanic hazards, volcanic unrest**

Skills: **Apply, interpret, participate, explain, research, debate, clarify, draw conclusions**

Benchmarks:

See benchmarks in Introduction.

Recent eruptions at Mount Rainier

Small eruptions were reported in local newspapers during the nineteenth century (see **Nineteenth-Century Newspaper Accounts of an Eruption at Mount Rainier**). The last eruptions to cause significant change to the shape of Mount Rainier happened approximately 1,000 years ago. Some of these most recent eruptions built the two summit craters visible today and spewed small ***lava flows*** onto the northeast flank of the volcano. Perhaps thousands of local inhabitants witnessed this eruption. The next eruption of Mount Rainier could be witnessed by millions of people.

A likely scenario for the next magmatic eruption of Mount Rainier

Scientists believe that future eruptions will likely resemble events that occurred repeatedly during Mount Rainier's past. Volcanic unrest at Mount Rainier might begin with an increase in earthquake activity, accompanied by increases in the release of carbon dioxide, sulfur dioxide, and other ***volcanic gases*** from a ***vent***, and a visible, persistent steam plume. This precursory activity could continue for weeks, month, or longer and lead to a variety of outcomes. The unrest could subside and the volcano could return to sleep. Or, increased ***geothermal*** heating might cause small steam ***explosions*** at the summit but no eruption of fresh magma. Less commonly, magma from deep within the Earth could rise into the volcano and cause a ***magmatic eruption***. It might begin with a blast of ***tephra*** and hot volcanic gases. Large pieces of tephra would drop onto the volcano's slopes, while finer-grained ***volcanic ash*** would be blown by the wind and fall to the ground many kilometers (or miles) from Mount Rainier. Volcanic ***bombs*** and ***blocks*** might bombard the surface of the volcano. A lava lake might rise within the crater and spill over the rim to form lava flows. On a steep-sided volcano such as Mount Rainier, lava

flows would break apart and descend the slopes as avalanches of hot rock and gas known as ***pyroclastic flows***, which could melt snow and ice and produce ***lahars*** (volcanic mudflows). Large lahars could rush down valley as far as 120 kilometers (70 miles) from the volcano. Landslides of wet ***hydrothermally altered rock*** could be shaken loose from the flanks of the volcano and thunder down the valleys as lahars.

Eruption hazards can affect people near and far

In the past, lava and pyroclastic flows have not traveled beyond the cone of Mount Rainier and at present there is no reason to assume that they will do so in the future. However, lahars produced by melting ice and snow have been found as far as 100 kilometers (60 miles) from the volcano. Lahars are the principal hazard at Mount Rainier because they travel far from the volcano to areas that are now densely populated. At least 80,000 people now live, work, and go to school in lahar hazard zones. We can expect that volcanic ash will fall in the largest quantities near the volcano and in progressively smaller amounts farther away. The severity of volcanic ***ash fall*** will depend on the amount erupted, wind speed, and direction.

Volcanic eruptions are survivable when people take proper precautions

Over the millennia, millions of people have experienced the fear and splendor of volcanic eruptions and learned that volcanic eruptions are survivable when safety precautions are taken. Societies respond best when their citizens understand the hazards, when they can identify areas at risk, and are knowledgeable about how to respond during volcanic unrest.

Plan now to maintain infrastructure during volcanic eruptions

The term ***infrastructure*** refers to all services and facilities that support functioning of a community, such as electrical power, water, sewer, transportation and communication systems, schools, police and fire departments, hospitals, and prisons. Managers of these services and systems should coordinate their emergency planning efforts now so that services remain uninterrupted or are quickly restored after a disaster. A society can reduce the risk to people by limiting dense settlement in the paths of lahars, by educating entire populations about proper response measures, preparing ***emergency plans***, and planning and practicing evacuations.

Preparing for the next eruption

Working with a long record of hazardous natural events and recognition of effects on humans, the American Red Cross and emergency management agencies assembled a variety of materials that serve as guides for preparations during an emergency. Some examples of preparations are community education and development of evacuation plans, ***family emergency preparedness plans***, and preparedness kits. These materials provide a basis for discussion and planning efforts in families, schools, and communities. When people become knowledgeable about volcanic processes, they can prepare for volcanic events and then live with greater safety, comfort, and enjoyment in their communities.

One example of a community planning effort—Mount Rainier

During the 1990s, emergency managers, educators, park and other public officials, community leaders and scientists established the Mount Rainier Volcano Hazards Work Group, which is dedicated to mitigating the effects of future volcanic activity at Mount Rainier. The group developed a volcano response plan, which defines the roles of agencies during volcanic crisis. This group practices its emergency plan, trains emergency responders, and supports public educational efforts, including installation of evacuation route signs. Pierce County Department of Emergency Management maintains a lahar-detection and notification system that warns of approaching lahars.

How prepared is your community?

As of this writing, scientists and land and emergency managers have written a volcano response plan for each of the Cascade volcanoes in Washington and Oregon. Find emergency response plans at Web sites listed on the **Internet Resources Page**.

Reading volcano hazard maps

Scientists developed hazard maps for most of the major Cascade volcanoes and for many hazardous volcanoes around the world to help emergency and land-use managers, community leaders, scientists, and citizens develop preparedness plans. Although no one can predict precisely how large the next eruption or lahar will be, scientists who have examined the extent of deposits formed during previous volcanic eruptions make best estimates of localities that might be affected in the future. We repeat for emphasis—*these maps are best approximations of areas that might be directly affected* by the volcanic processes noted below.

- **Graphic *"Lava and Pyroclastic Flow Hazards at Mount Rainier"***
  In the past, lava and pyroclastic flows have not traveled beyond the cone of Mount Rainier, and at present there is no reason to assume that they will do so. Scientists based their hazards map on this assumption, with the recognition that future events can be larger or smaller than the hazard zones displayed on the map.

- **Graphic *"Lahar Hazard Zones from Mount Rainier"***
  The lahar hazard map is based on the extent of previous geologic events. To develop hazard zonation for lahars, scientists measured the extent of the Election Mudflow of about A.D. 1500 and used this information as a guide to which areas might be covered by the next lahar. Debris flows, small versions of lahars that are formed by intense rainfall and sudden glacial outbursts floods, are *seldom large enough to travel beyond the boundaries of Mount Rainier National Park*. See the activity **Lahar in a Jar** for more information about previous lahars at Mount Rainier.

- ***Prediction of volcanic ash fall***
  The size of an ash cloud and location of ashfall depends on the size of the eruption and wind speed and direction. Atmospheric data provides the basis for prediction about which up-to-the-hour analysis, indicating the most likely location of ashf all. See the activity **Volcano Fan Club** and **Internet Resources Page** for instructions about computer-generated programs that track the most likely destination of volcanic ash, based on current wind speed and direction.

Eyes and ears on Mount Rainier

When it comes to keeping track of activity at volcanoes, volcanologists are a bit like professional athletes. The athlete tries to figure out an opponent's next move by examining past records and by keeping a close watch on them during a game. In the same way, volcanologists must study a volcano's past activity and keep a close watch on a volcano's current conditions. These actions allow volcanologists to know, in a general way, what styles of eruption could happen and to spot any signs of rising magma that might lead to an eruption. Until magma shows some evidence of ascent toward the surface, scientists have no way to forecast when a volcano will reawaken.

The first evidence of a potential eruption is usually earthquake activity caused by rising magma, which cracks and breaks brittle rock. These earthquakes are often accompanied by deformation of the landscape, whereby some segments of the landscape rise and others subside. These changes in ground surface help scientists calculate the amount of magma in the ***conduit***, its position relative to Earth's surface, and how soon a volcano will erupt. The fracturing and breaking of rocks permits the release of gases from the rising magma. There is no set formula for forecasting volcanic eruptions because volcanoes do not always follow a well-defined, predetermined sequence of events preceding volcanic activity. Scientists use a combination of data analysis and scientific judgments to assess the likelihood of an eruption.

Although the onset of a period of volcanic unrest remains unpredictable, some generalized forecasting about the timing and potential style of an eruption is possible, but only after volcanic unrest has been detected. Once signs of rising magma are observed, scientists can analyze the patterns of earthquakes, gas release, and ground deformation, and judge the likelihood of an eruption. When a volcano shows signs of unrest, or if it is erupting, scientists visit the volcano as often as possible to make observations and to install additional monitoring instruments that enable them to track the volcano's activity 24 hours a day.

Consult the **Internet Resources Page**, or use your Internet browser to locate information about emergency preparations, volcano response plans, evacuation plans, and educational efforts in your community.

Before you Begin:

Choose any or all of these activities for your students. After completion of the procedures, display students' products in a "school volcano museum" for viewing by other students and by their families. Your museum can include emergency preparedness information and student projects from other activities, such as **Cascade Volcano Timeline**, **Play-Dough Topo**, **Planning your Trip to Mount Rainier National Park!**, and **Living Well with a Volcano in your Backyard**.

Procedure:

A. Mount Rainier Timeline
B. Reading Hazard Maps
C. The Volcano and Your Community
D. Eyes and Ears on Mount Rainier
E. Volcano Evacuation Route Sign
F. Educating Future Generations—The Granatello Epigraph

A. Mount Rainier Timeline

Summary: Students use information in the table "***Summary of Notable Events at Mount Rainier, 10,000 Years Ago to Present***," to make a timeline, then use it to examine the likelihood that volcanic events will occur within a human lifetime.

Instructions:

1. Divide the class into groups of two to four students.

2. Provide the table "***Summary of Notable Events at Mount Rainier, 10,000 Years Ago to Present***," either projected or as a handout to student groups.

3. Give each group a strip of cash register or adding machine paper or other paper taped together that is 3 meters (10 feet) long.

4. Have the students determine a timescale, and then write the events and dates on the paper.

5. Students write events and dates on the timeline.

6. Students fold a piece of notebook longwise into halves, twice, so that it resembles a ruler. This ruler represents an average human lifespan of 80 years. Students place it on the timeline to find the length of 80 years on the ruler and mark it.

7. Engage students in a discussion about results. Students answer the questions below.

How many generations go by without any volcanic activity or lahars at Mount Rainier? Are there some generations during which more than one event occurs? Discuss with students the likelihood that most recent events are better documented, leading to the appearance that the volcano was more active in recent centuries.

B. Do you Live in a Volcano Hazards Zone?

Summary: Teacher leads students in discussion about areas likely to be affected by volcanic hazards associated with Mount Rainier. Show application to volcanoes globally by supplying students with Internet access to volcano images and maps.

Instructions:

1. Provide the graphics "***Mount Rainier Volcanic Hazard Zones***," "***Lahar Hazard Map Extensions***," and "***Lava flow and Pyroclastic Flow Hazards at Mount Rainier***," projected or as a handout to student groups. Or, choose hazard maps for other volcanoes, available through the USGS Volcano Hazards Program Web site, and other resources (See **Internet Resources Page**). Explain that the lahar hazard map was developed by scientists who used maps of volcanic deposits from past eruptions as a guide to identifying areas at risk. Introduce maps to students. Remind students that all hazard zones are best approximations based on evidence from previous events and on scientists' best judgments.

2. Find your community (or other chosen community) on a volcano hazard map. Is it in a lahar hazard zone? Is this community at direct risk from lava and pyroclastic flows? Note that lahars travel in river valleys. Instruct students to develop advice for people to escape a lahar (get to high ground). Discuss why scientists cannot predict with precision how far lahars will travel. Ask students to explain how lava flows and pyroclastic flows can affect communities distant from a volcano (lahar generation by snow and ice melt). For more process-related discussions on these topics, refer to the activities **Lahar in a Jar**, **Lava Building Blocks**, and **Volcanic Processes**.

3. Remind students that the location and thickness of volcanic ash fall depends on eruption size and wind speed and direction during and after the eruption. Note that in the Pacific Northwest, the wind blows towards the east, northeast, or southeast 85 percent of the time, so areas east of Cascade volcanoes are more likely to receive ash fall. Ask students if their community is at risk, and engage them in discussion about the risk to communities across your State. Optionally, and for a more process-related discussion on this topic, refer students to Web sites with computer-generated programs that can track the most likely destination of volcanic ash, based on current wind speed and direction. See **Internet Resources Page**. Students can use the graphic "***Effects of Volcanic Processes***" and the student page "***Prepare for Volcanic Unrest***" to organize their thoughts.

4. If you have Internet access in your classroom, use Web-based images and maps of planet Earth to analyze areas at risk from volcanoes. Use computer graphics tools to quantify the area at risk and to measure distances from the volcano. Look for volcanoes and nearby cities. Students should make some quick analyses about the volcanic hazards that these population centers might face.

5. Instruct students to write one-page reports about volcanic hazards and useful risk reduction measures that could benefit their community. Students share the information with their family.

C. The Volcano and Your Community

Summary: Students play the roles of town officials who must prepare for the possibility that an eruption will affect their community's infrastructure. Students list potential hazards and facilities at risk, develop strategies for protection, and then stage a "town meeting" to report back to the town's citizens—the teacher and class members.

Instructions:

1. Begin with a class discussion about the volcanic hazards that place a community at risk. List these hazards. Display the graphic "***Effects of Volcanic Processes***," or have students provide the information. Make the list of effects visible so that students can use them in instruction 2 below.

   Explain the definition of infrastructure. Note that infrastructure includes all the services and facilities that support day-to-day activity, such as electrical power, water, sewer, transportation (roads, bridges, trains, trucks, cars, airplanes, port facilities), communication systems, schools, police and fire departments, hospitals, and prisons. Discuss the dependencies that each has on the other. For example, consider the difficulties of repairing water-well facilities when the road system is inaccessible. Challenge students to list short-term and long-term effects to the local and regional economy. Encourage students to list specific populations at risk in high hazard zones, such as residents and tourists in valleys near the volcano. Within the resident population, discuss special needs populations, such as people under the age of 5 years and those more than 65 years old, people who don't speak English as a primary language, renter-occupied houses, and economically-disadvantaged people. Consider dependent populations who need special assistance with evacuation. Some examples are people with disabilities, as well as those in hospitals, jails, senior-citizen homes, and daycares.

2. Divide the class into groups of two or three students. Assign one part of community infrastructure (or a specific population group) to each student group. Students use information on the graphic to develop strategies for community protection. Instruct at least one group to develop strategies for community education and methods for informing communities about volcanic hazards. Students can use findings on the "***Prepare for Volcanic Unrest***" student page. They should visit Web sites listed on the **Internet Resources Page** to determine what actions are being taken to mitigate volcanic hazards, then prepare a video, oral or computer-projected presentation or written summary about protective strategies. Students stage a "town meeting" and present their results.

3. Optional—Use the community preparedness addresses in the **Internet Resources Page** to obtain a volcano hazards response plan that addresses volcanic hazards in a community. Encourage class discussion about how the components of the plan can help save life and property during a volcanic event.

D. Eyes and Ears on Mount Rainier

Summary: Students answer guiding questions to learn about the components of volcano monitoring. They write summary reports about their research, produce a video or computer-projected presentation, or talk about their results.

Instructions:

1. Begin your discussion of volcano monitoring by asking guiding questions that lead students to develop monitoring strategies. Tell students that they should muster all their critical thinking skills so that they can think like a physician who watches the "health" of a patient by making examinations and looking for clues of an illness. Then, ask students what symptoms of rising magma would be detectable from Earth's surface (most typical symptoms are earthquake swarms, swelling or subsidence of the land surface, ***gas*** measurements, temperature changes). How could scientists detect magma rising beneath a volcano [recording the shaking of earthquakes, measuring land surface changes, and making measurements of ground temperatures and gases]?

   Data collected by volcano-monitoring networks makes possible the early detection of volcanic unrest usually days to months or more before an eruption. The most effective monitoring is achieved by using a combination of techniques that detect changes in earthquake activity, gas release, ground surface, and hydrological conditions, as listed on the graphic "***Volcano Monitoring Techniques***." Begin your discussion by asking what types of tools scientists could use. For example, seismographs and similar recorders measure ground shaking; Global Positioning System (GPS) units, cameras, tiltmeters, satellite-based distance measuring techniques (Interferometric Synthetic Aperture Radar, also known as InSAR), and surveying instruments measure land movement; ground and airborne thermal and gas sensors measure heat sources and gas release.

2. Display the graphic "***Volcano Monitoring Techniques***." Tell students that the data collected from volcano monitoring networks make the early detection of volcanic unrest possible and are crucial for interpreting volcanic processes, forecasting eruptions, and predicting likely impacts of eruptions. How many types of monitoring do they see on the graphic [nine]? Ask the students about some of the challenges that scientists might encounter as they monitor a volcano (steep terrain, bad weather, volcano unrest threatening, equipment failures). Tell students that a volcano is a hazardous place for people and equipment. Can scientists obtain data without visiting a volcano? How so [earthquake data, ground deformation measurements, and automated camera

shots commonly are sent by radio from the volcano to the scientists at their observatory]? Volcano visits are required for setup and maintenance of equipment, for use of some instruments, and for visual observations. Ask students how scientists can know when conditions on the volcano have changed from normal. Encourage discussion on the importance of making measurements at volcanoes before, during and after volcanic eruptions.

3. Instruct students to conduct research from books and Web sites, such as that of the U.S. Geological Survey's Volcano Hazards Program, to determine the most up-to-date techniques for monitoring volcanoes. Students should write summary reports about their research or produce a video or computer-projected presentation. Encourage students to find current news reports about ongoing volcanic activity and the techniques that scientists use to watch hazardous volcanoes. Show the graphic "***The USGS Alert-Notification System for Volcanic Activity***," and encourage students to become familiar with it. See resources on the **Internet Resources Page**.

E. Volcano Evacuation Route Sign

Summary: Students answer questions about the evacuation route sign and about hazards in their community. They use the "***Prepare for Volcanic Unrest***" student page and the "***Effects of Volcanic Processes***" graphic to make decisions about whether it is better to remain in their community or evacuate during a volcanic eruption.

Instructions:

1. Begin a discussion about the "***Volcano Evacuation Route Sign***" graphic. Display the graphic and ask students if they have seen this sign in their community. Do they know what it means? Lead a discussion about the value of the signs. Be certain that students understand that the signs indicate routes to high ground, away from potential lahar paths. Be sure that students know that during other hazards, such as from volcanic ashfall, staying inside may be the best action.

2. Instruct students to complete the information on the bottom of the Student Page then take it home and display it for the safety of their family. Ask the students for suggestions about how to increase the effectiveness of the evacuation route signs.

3. Assign library and Internet research that examines the need to remain in or evacuate their community during volcanic eruptions. From library or Internet searches they learn appropriate procedures. Light ash fall requires them to remain indoors; lava eruptions that can produce lahars might require them to evacuate from a lahar hazard zone.

F. Educating Future Generations—The Granatello Epigraph

Summary: The December 1631 eruption of Mount Vesuvius, near Naples, Italy, was one of the most violent and destructive in the volcano's history. During this 3-day event, pyroclastic flows swept over the densely populated slopes of the volcano, killing approximately 6,000 people. The city of Portici, just 5 kilometers (3 miles) from the crater, was hit particularly hard. As a warning to future generations, Viceroy Emmanuel Fonseca commissioned the construction of an inscribed stone monument, known as an ***epigraph***. The inscription was intended to warn future generations about the destructive power of the volcano. Dense urban development now surrounds the Granatello Epigraph, a reminder of how quickly a disaster can be forgotten, and about the importance of continual education and planning for future volcanic eruptions.

Instructions:

1. Keep the issue in perspective. Inform students (or have students do research) about the differences in hazardous phenomena at Mount Vesuvius, and at Cascade volcanoes. [Pyroclastic flows and dense tephra fall place people at risk at Vesuvius, whereas lahars are the principal hazard to population centers near the Cascade volcanoes. Large populations live on the slopes and at the base of Vesuvius, whereas population centers exist farther from volcanic vents of most Cascade volcanoes.] Read or visually project the text of the epigraph on the "***Granatello Epigraph***" graphic. Discuss its meaning with the class. You might introduce the concepts of "hazard"—any physical process that can cause damage, harm, or adverse effects—and "risk," the chance or probability that people or property will be harmed or experience an adverse effect if the event were to happen.

2. Instruct students to recall what they have witnessed or heard about a volcanic event or other natural hazard that took place within their lifetime. Students should create a list of warning statements for future generations, in a manner similar to those written on the Granatello Epigraph.

3. Provide materials for students to make their own warning sign for future generations. Materials might take the form of a poster, story board, a time capsule to their children, or a clay model.

Adaptations

- Use modeling clay on a relief map to simulate large glaciers from the Ice Age. Lift the modeling clay and examine the shapes on the underside. Students note that the clay glaciers are thicker in valleys between the ridges.

- Students fold a piece of paper into six equal parts. They draw pictures in sequence of six volcanic processes that occur before, during, and after an eruption at Cascade volcanoes such as Mount Rainier. Students illustrate earthquake motion, escape of gases, tephra eruption, lava flows, pyroclastic flows, and lahars.

- Use Internet browsers to find satellite images of volcanoes and population centers that are at risk. Challenge students to find evidence of volcanic activity and areas that might be at risk.

- Instruct students to read the Granatello Epigraph, individually or in small groups, and write what it means in their own words. Discuss the writings as a class.

- In some volcanic regions, groups of public officials, community leaders, educators, and other concerned citizens have established volcano work groups to develop strategies for reducing volcanic risk. A response or coordination plan defines the problems and the roles of official groups to address during a crisis. Instruct students to conduct an Internet search for these plans. In Washington State, they are found at the Emergency Management Division Web site.

Extensions

- Instruct students to do a library or Internet search for methods used to mitigate volcanic hazards around the world.
- Obtain a map of volcano evacuation routes. Trace the routes to high ground for neighborhoods in your area.
- Visit the Web site of the U.S. Geological Survey's Volcano Hazards Program (see **Internet Resources Page**) and view the page entitled "Predict an Eruption." This presentation provides a very simplified synopsis of changing conditions before a volcanic eruption.

Assessment

Assess students' ability to apply their learning about volcanoes to a real-world situation. Students who are just beginning a study of volcanoes might not recognize the presence of volcanoes near their own community. They might not comprehend the nature and scale of volcanic processes that threaten their community. At the end of their study, students should be aware of the localities of nearby volcanoes and able to identify the hazards to their community. Instruct students to work in groups as they develop, in their own words, a written assessment of volcanic hazards at a volcano of their choice. They should make a plan for how to determine the economic impact on their community, develop some ideas for risk reduction, and discuss how to educate citizens about the hazards. Look for evidence of real-world understanding of the hazards and the social aspects. Students can present their information in a poster or report or as a computer projection or oral presentation.

References

Find hazards assessments and volcano fact sheets for many volcanoes within the United States and its territories on the Web pages of the U.S. Geological Survey. Response plans for some volcanoes are posted at emergency management Web sites. Some products, primarily focused on Mount Rainier, are listed on the **Internet Resources Page**.

Dent-Cleveland, L., 2003, The beautiful mountain in the sky—How to be safe if a lahar flows down the mountain: Washington Military Department, Emergency Management Division, Elementary Edition K-6 Booklet, 24 p.

Driedger, C., and Scott, W., 2008, Mount Rainier—Living safely with a volcano in your backyard: U.S. Geological Survey Fact Sheet 2008–3062, 4 p.

Dzurisin, D., Stauffer, P.H., and Hendley, J.W., II, 2003, Living with volcanic risk in the Cascades [revised March, 2008]: U.S. Geological Survey Fact Sheet 165–97, 2 p.

Hoblitt, R.P., Walder, J.S., Driedger, C.L., Scott, K.M., Pringle, P.T., and Vallance, J.W., 1998, Volcano hazards from Mount Rainier, Washington, Revised 1998: U.S. Geological Survey, Open-File Report 98–428, 11 p.

Mount Rainier Volcano Hazards Work Group, 2008, Mount Rainier volcano hazards response plan: Pierce County Department of Emergency Services, 93 p. [available at emergency management Web sites listed on **Internet Resources Page**.]

Sisson, T.W., 1995, History and hazards of Mount Rainier, Washington: U.S. Geological Survey Fact Sheet 95–642, 2 p.

Sisson, T.W., Vallance, J.W., and Pringle, P.T., 2001, Progress made in understanding Mount Rainier's hazards: EOS, Transactions of the American Geophysical Union, v. 82, p. 116–120.

Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

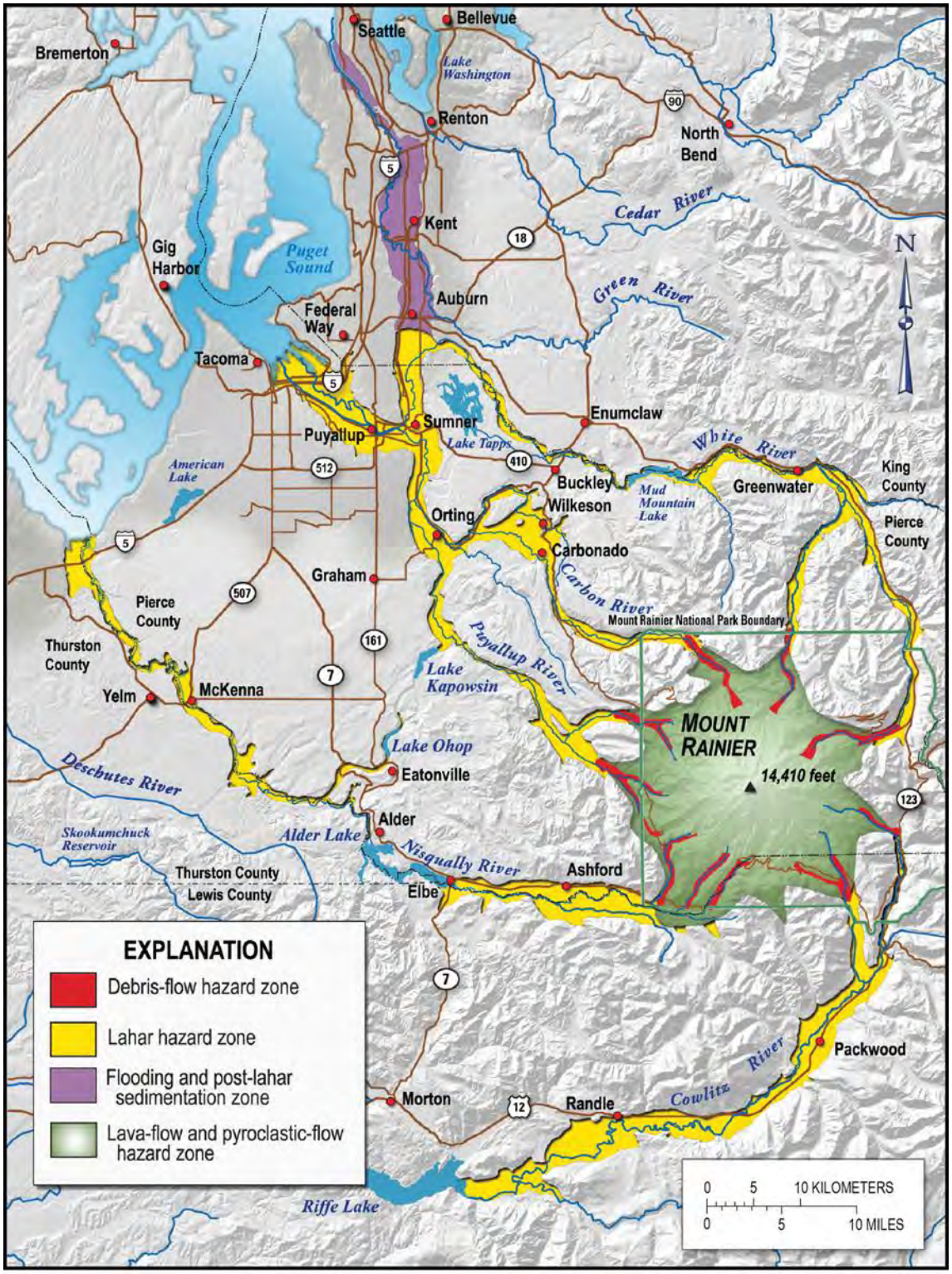
Graphic Page

Summary of Notable Events at Mount Rainier, 10,000 years ago to Present

Eruptive Period	Age or Date	Event	
Historic activity	A.D. 1980s to present	Several dozen debris flows in river valleys that head on Mount Rainier	
	A.D. 1963	Rock fall avalanche from Little Tahoma Peak	
	A.D. 1947	Debris flow and runout flow of glacial-outburst origin in Kautz Creek	
	A.D. 1930s to 1950s	Multiple debris flows in Nisqually River Valley	
	A.D. 1910 to 1927	Rock avalanche on Tahoma Glacier	
	A.D. 1894 to 1895	Reports of small steam and ash eruptions at summit	
	500 years ago	Rock avalanche-induced Electron Mudflow in Puyallup/Nisqually River Valleys; no documented association with volcanic eruptions	National Lahar in Nisqually River Valley sometime between 2,200 and 500 years ago
Fryingpan Creek eruptive episode	1,100 to 1,000 years ago	Lahar down Puyallup River at least as far as its confluence with Mowich River	
		Tephra and lahars in White River Valley as far as Kautz Creek	
Twin Creeks eruptive episode (Deadman Flats)	1,500 years ago	Tephras and lahars in valleys of the White River and Kautz Creek	
Summerland eruptive period	2,000 years ago	Lava flows formed summit cone, Columbia Crest	
	2,200 years ago	Eruption of Layer C tephra	
	2,200 to 2,600 years ago	Lahar in Nisqually River Valley deposits sandy layers	
	2,400 to 2,500 years ago	Eruption of block-and-ash flow in Puyallup River Valley; Eruption of tephra layers	
	2,600 years ago	Lahar-Round Pass mudflow descended Puyallup valley to Puget Sound lowland. Part of it descended Tahoma Creek and the Nisqually River	
	2,200 to 2,700 years ago	Multiple lahars in White River Valley	
Osceola eruptive period	4,500 years ago	Eruption of tephra layer B	
	4,700 years ago	Eruption of tephra layer H	
	5,600 years ago	Lahar-Osceola Mudflow in White River's main branch and West Fork extended to Puget Sound lowland. Eruption of tephra layer F; Paradise Lahar (part of the Osceola Mudflow) in Nisqually River Valley, extended as far as the community of National	
	>5,600 years ago	Eruption of tephra layer S	
Cowlitz eruptive period	6,700 years ago	Eruption of tephra layers N and D	
	7,400 to 7,200 years ago	Eruption of volcanic bomb-bearing rocks and lahars in White River Valley	
	7,400 to 7,200 years ago	Rock avalanche-induced lahar down the Nisqually River and at Reflection Lakes	
	7,400 to 7,200 years ago	Eruption of tephra layers L and A	
Sunrise eruptive period	11,000 years ago	Eruption of tephra layers L and R	

Graphic Page

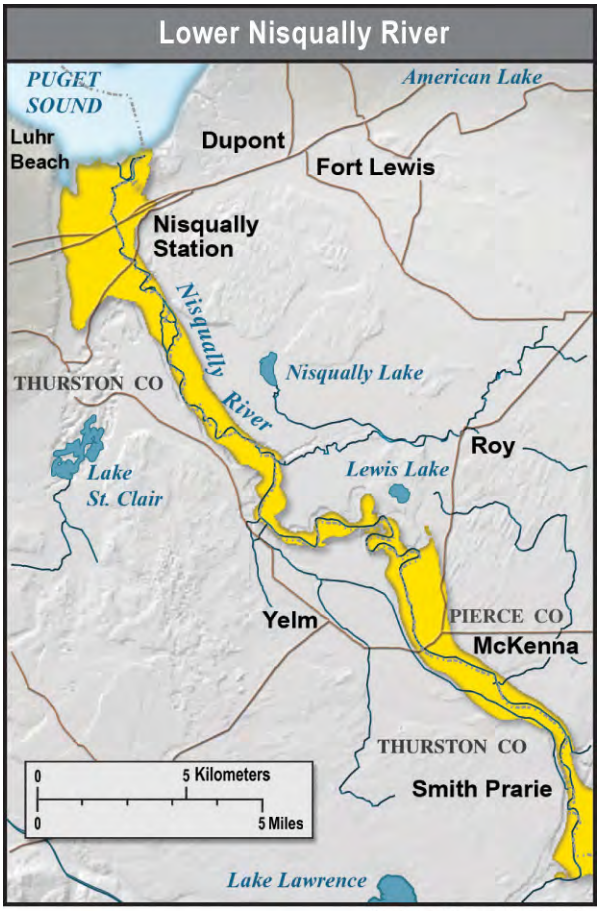
Mount Rainier Volcanic Hazard Zones



Revised September 5, 2014

Graphic Page

Lahar Hazard Map Extensions



Revised December, 2009

Revised December, 2009

EXPLANATION

- Debris-flow hazard zone
- Lahar hazard zone
- Flooding and post-lahar sedimentation zone
- Lava-flow and pyroclastic-flow hazard zone

Graphic Page

Effects of Volcanic Processes

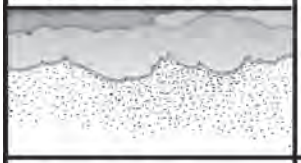
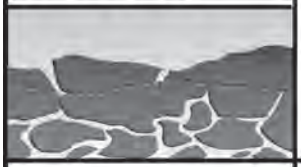
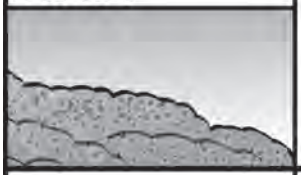
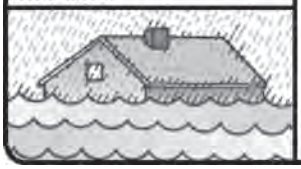
Volcanic Process	Effects
Ash fall	Affects people distant from the volcano Makes breathing difficult
	Irritates eys
	Reduces visibility
	Abrades machinery, equipment, and computer systems
	Damages jet engines and can cause aircraft equipment failures
	Clogs filters
	Causes electrical shorts
	Strips leaves from crops and trees
	Collapses buildings when wet and in excess of 10 centimeters (4 inches)
Lahars	Destroys or buries all in their path by impast or by burial
	Can travel at speeds that exceed 60 kilometers per hour (40 miles per hour)
	Can fill river channels and cause long-term flooding
Lava Flows and Pyroclastic Flows	Destroy all in their paths by burning, burial, or asphyxiation
	Can melt ice and snow and cause lahars
Volcanic Gases	Generally hazardous only when people come in contact with gases in confined spaces

Student Page

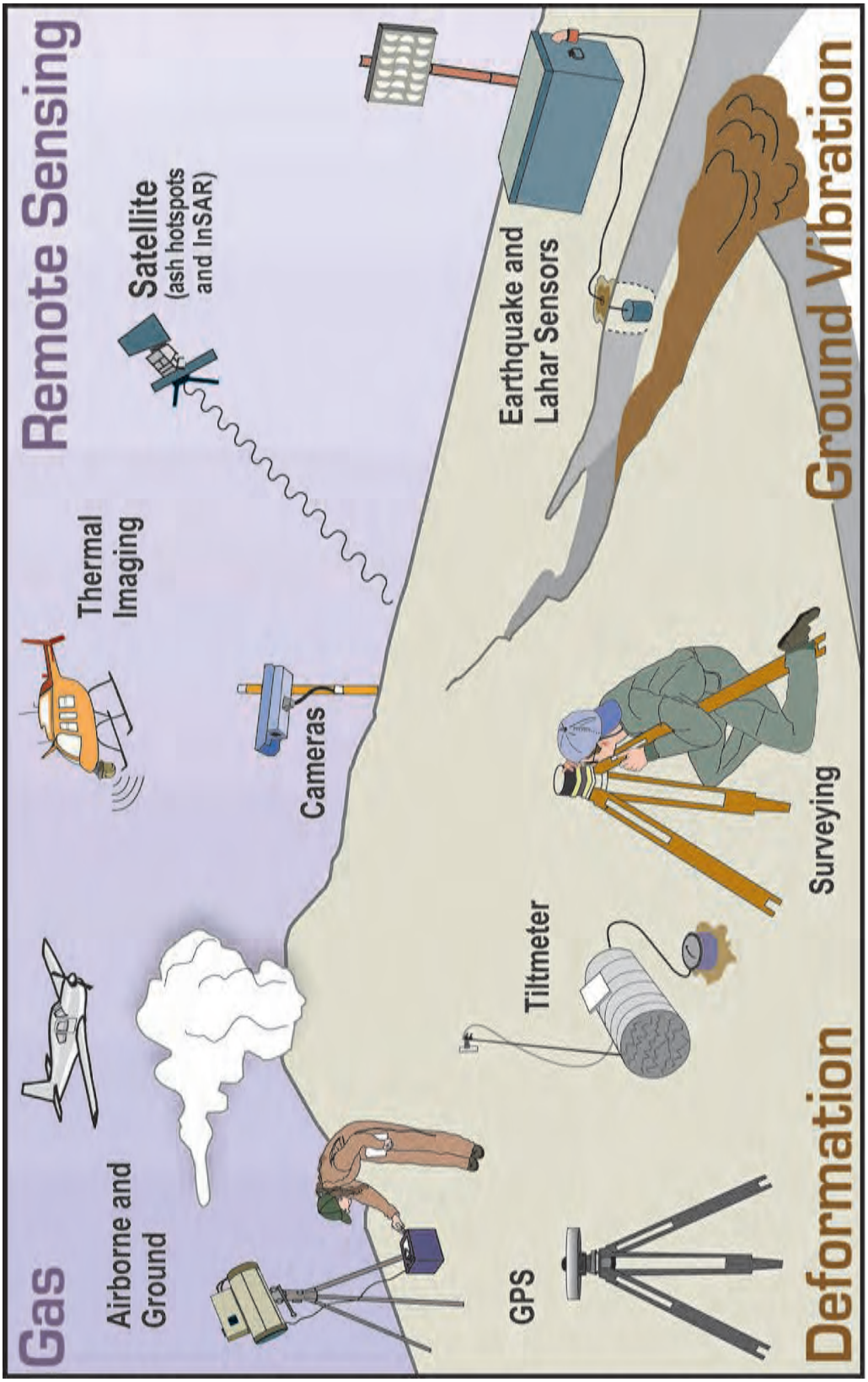
LIBRARY WEB

Prepare for Volcanic Unrest

Instructions: *Conduct an Internet or library search for materials that advise you about how to prepare for each of the following volcanic processes.*

Type of Hazard	What are the Hazards?	How Could the Hazard Affect Your Community-Directly or Indirectly?	How Will You and Your Family or School Group Become Prepared?
Volcanic Ashfall 			
Lava Flows 			
Pyroclastic Flows			
Lahars 			
Floods 			

Volcano Monitoring Techniques



Graphic Page

The USGS Alert-Notification System for Volcanic Activity

Volcano Alert Levels Used by U.S. Volcano Observatories

Alert levels are intended to inform peopel on the ground about a volcano's status and are issued in conjunction with the Aviation Color Code. Notifications are issued for both increasing and decreasing volcanic activity and are accompanied by text with details (as known) about the nature of the unrest or eruption and about potential or current hazards and likely outcomes.

Term	Description
NORMAL	Volcano is in typical background, noneruptive state or, *after a change from a higher level,* volcanic activity has ceased and volcano has returned to noneruptive background state.
ADVISORY	Volcano is exhibiting signs of elevated unrest above known background level or, *after a change from a higher level* volcanic activity has decreased signicantly but continues to be closely monitored for possible renewed increase.
WATCH	Used in two different situations: Volcano is exhibiting heightened or escalating unrest with increased potential of eruption, timeframe uncertain, **OR** eruption is underway but poses limited hazards.
WARNING	Hazardous eruption is imminent, underway, or suspected.

Aviation Color Code Used by U.S. Volcano Observatories

Color codes,which are in accordance with recommended International Civil Aviation Organization (ICAO) procedures, are intended to inform the aviation sector about a volcano's status and are issued in conjuction with and Alert Level. Notificiations are issued for both increasing and decreasing volcanic activity and are accompanied by text with details (as known) about the nature of the unrest or eruption, especially in regard to ash-plume information and likely outcomes.

Color	Description
GREEN	Volcano is in typical background, noneruptive state or, *after a change from a higher level,* volcanic activity has ceased; and volcano has returned to noneruptive background state.
YELLOW	Volcano is exhibiting signs of elevated unrest above known background level or, *after a change from a higher level,* volcanic activity has decreased signicantly but continues to be closely monitored for possible renewed increase.
ORANGE	Volcano is exhibiting heightened or escalating unrest with increased potential of eruption, timeframe uncertain, **OR** eruption is underway with no or minor ash emission height specied, if possible].
RED	Eruption is imminent with signicant emission of ash into the atmosphere likely **OR** eruption is underway or suspected with signicant emission of ash into the atmosphere [ash-plume height specied, if possible] .

Student Page

Volcano Evacuation Route Sign

Our Community's Beautiful Backyard Volcano

Volcano nearest to my community:_____

Most recent eruption:_____

Hazards from volcano:_____

Specific steps for my family before and during a volcanic event:_____

_____

Learn: *Learn whether you live, work, or go to school in a volcano hazard zone.*

Inquire: *Ask public officials how they advise you to respond.*

Plan: *Plan for how you and your family can be prepared for emergencies.*

Participate: *Participate in helping your community be prepared!*

Graphic Page

Granatello Epigraph

Descendents, descendents, it is about you!
Today illuminates tomorrow with its light. Listen!
Twenty times since the sun rose, if history does not tell stories,
the Vesuvius burst into flames,
always with huge extermination of those who hesitated.
I warn you so that it does not find you undecided.
This mountain has its womb heavy with pitch, alum, iron, sulphur,
gold, silver, saltpeter, and sources of water.
Sooner or later it catches fire and with the aid of the sea it delivers.
But before delivering, it shakes itself and shakes the ground.
It smokes, reddens, flares up. It ravages horribly the air.
It howls, roars, thunders, and chases the inhabitants of the
neighboring areas away.

Run away when you are still on time!

Here it is flashing, exploding, vomiting liquid
matter mixed with fire, which flows headlong,
cutting defaulters' way off.

If it reaches for you it is over. You are dead.

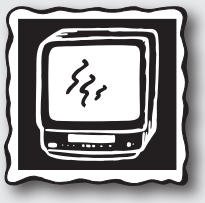
It punishes incautious and greedy people who
care more for their houses and furnishings
than for their life.

If you are wise listen to the voice of this stone.

Do not care about your home;
do not worry about packs.
Run away without delay!

Year 1632, 16 January
in the reign of Philip IV Emmanuel
Fonseca y Zunica,
count of Monterey viceroy

Reducing Volcanic Risk Video/DVD



Grade Level: 6–12+

Learner Objectives:

Students will:

- Recognize the steps required to reduce volcanic risk
- Identify factors that usually precede an eruption—increased volcanic unrest (seismicity, ground deformation, gas emission)
- Recognize that scientists cannot predict the exact time and size of an eruption, but can estimate the likelihood of an eruption by monitoring volcanic unrest
- Identify some volcanic hazard mitigation methods for consideration at Cascade volcanoes

Setting: Classroom

Timeframe: 45 minutes (video is 22 minutes)

Materials:

- *"Reducing Volcanic Risk"* Video or DVD
- DVD or VHS player

USGS
science for a changing world

Living with a Volcano in Your Backyard–An Educator's Guide with Emphasis on Mount Rainier

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

The ***"Reducing Volcanic Risk"*** video familiarizes students with steps that can be taken to reduce volcanic risk. Steps include: identification of hazardous areas, watching for signs of increased volcanic activity, and assembling and testing emergency plans.

- Television monitor
- Copies of *"Reducing Volcanic Risk Questions"* student page

Vocabulary: Ash flow, debris flows, emergency plan, hazard, lahar, lava flow, mitigation, monitor, pyroclastic flow, risk, volcanic ash, volcanic mudflows, volcano hazard map

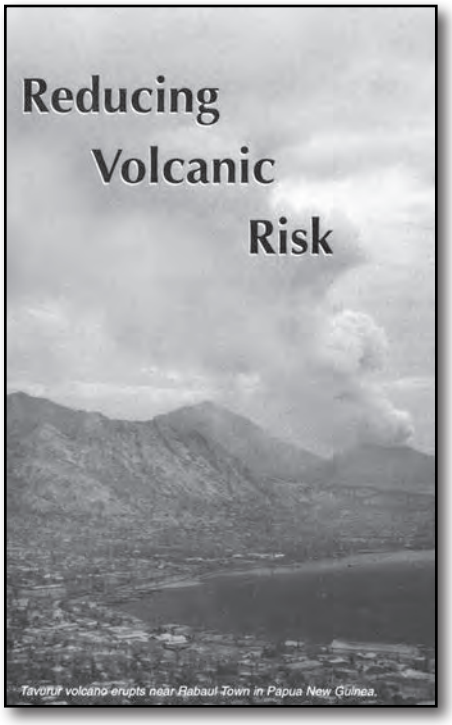
Skills: Application, interpretation, listening

Benchmarks:

See benchmarks in Introduction.

Activity last modified: September 5, 2014

Teacher Background



This video contains dramatic footage of eruptions from around the world that demonstrate how communities have responded to volcanic risk. ***Risk*** is defined as the loss (human, material, economic) that would result from a disaster, while ***hazard*** refers is the source of danger and the possibility of incurring loss or misfortune. Emergency managers use the word ***mitigation*** to classify any task intended to make risk less severe, intense, or painful. Following the simple steps described in the video can save lives.

- **Step 1—**Scientists use historical information and observations of older volcanic rock to identify hazardous areas on a ***volcano hazard map***.

- **Step 2—**Scientists ***monitor*** the volcano for signs of increased volcanic unrest. Monitoring is defined as the act of observing, recording, and detecting conditions with instruments and visual observations. Most volcanoes shake, swell, and expel increased quantities of gases during the days, weeks or months prior to an eruption. These factors indicate volcanic unrest.

- **Step 3—**Emergency managers and scientists develop an ***emergency plan*** because people should know what they must do before the onset of a volcanic eruption. The plan should include the roles of governmental agencies, and procedures for how to inform the population about a volcano's current behavior. A public warning system and evacuation plan can be developed based on the volcano hazard map. The emergency plan should be tested and practiced. Every person at risk from a volcanic activity should know what to do before, during, and after a volcanic eruption. They should be familiar with the terms ***ash flow (pyroclastic flow)***, ***lava flow, volcanic mudflow (lahar)***, and ***volcanic ashfall***.

View the video for appropriateness before deciding whether to show it to your students.

Procedure

Learning About Volcanic Risk

1. Explain to students that they will watch a video that shows steps some communities throughout the world take in order to reduce volcanic risk.

2. Ask students to define "risk."

3. Provide each student with a copy of the "***Reducing Volcanic Risk Questions***" student page.

4. Instruct students to answer questions during or after viewing the video.

5. View the video.

6. Review answers to the questions on the student page as a class. How can students use the steps outlined in the video to reduce risk in the Cascades? Ask students to give specific answers.

Adaptations

- As an alternative to showing the video, conduct a brainstorming session in which students develop logical steps to address the risk from volcanic hazards in their community.

Extensions

- Find out what steps have been taken to reduce volcanic risk in your community or in communities around the world.

Assessment

Use students' responses to questions as an assessment of their ability to recognize steps that reduce risk and to apply information learned from this lesson to a real-world situation.

References

Blong, R.J., 1984, Volcanic hazards–A sourcebook on the effects of eruptions: New South Wales, Academic Press, 424 p.

Driedger, C., and Scott, K., 2002, Mount Rainier—Learning to live with volcanic risk: U.S. Geological Survey Fact Sheet 034–02, 4 p.

Dzurisin, D., Stauffer, P.H., and Hendley J.W., II, 1997, Living with volcanic risk in the Cascades: U.S. Geological Survey Fact Sheet 165–97 (revised March 2003), 2 p.

Hoblitt, R.P., Walder, J.S., Driedger, C.L., Scott, K.M., Pringle, P.T., and Vallance, J.W., 1998, Volcano hazards from Mount Rainier, Washington—1998 volcano-hazards assessment report: U.S. Geological Survey, Open-File Report 98–428, 11 p.

IAVCEI, 1997, Reducing volcanic risk: International Association of Volcanology and Chemistry of Earth's Interior and United Nations Educational Scientific and Cultural Organization, video, 24 minutes.

IAVCEI, 1997, Understanding volcanic hazards: produced by Maurice Kraft for United Nations Educational Scientific and Cultural Organization and International Association of Volcanology and Chemistry of Earth's Interior, video, 26 minutes.

Kennedi, C.A., Brantley, S.R., Hendley J.W., II, Stauffer, P.H., 2000, Volcanic ash fall—A "hard rain" of abrasive particles: U.S. Geological Survey Fact-Sheet 027–00 (revised April 2002), 2 p.

Myers, B., Brantley, S.R., Stauffer, P.H., and Hendley J.W., II, 1998, What are volcano hazards? (revised April 2002): U.S. Geological Survey Fact Sheet 002–97, 2 p.

Mount Rainier Volcano Hazards Work Group, 1999, Mount Rainier volcano hazards response plan: Pierce County Department of Emergency Services, 103 p.

Scarpa, R., and Tilling, R.I., 1996, eds., Monitoring and mitigation of volcano hazards: New York, Springer-Verlag Walter de Gruyter & Co., 841 p.

Sheets, P.D., and Grayson, D.K., eds., 1979, Volcanic activity and human ecology: New York, N.Y., Academic Press, Inc., 642 p.

Simkin, T., and Siebert, L., 1994, Smithsonian Institution volcanoes of the world, 2nd edition—A regional directory, gazetteer, and chronology of volcanism during the last 10,000 years: Geoscience Press, Inc., Tuscon, Ariz., 349 p. *(For most recent edition or information, see the Smithsonian Global Volcanism Web site)*

Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

Student Page

Name _____

Reducing Volcanic Risk—Questions

Instructions: *Watch the video and answer the following questions.*

1. List the three recommended steps to reduce volcanic risk.

Identifying Hazardous Areas

2. List at least three strategies that scientists use to determine what to expect during eruption.

3. Describe how hazard maps are useful in preparations for responding to volcanic activity.

Monitoring Volcanoes

4. Changes at volcanoes commonly provide warning of possible future eruptions. True or False?

5. List at least three types of information that are collected or observed to monitor volcanoes.

6. A scientist can predict the exact time and size of an eruption by monitoring a volcano. True or False?

Student Page

Name _____

Reducing Volcanic Risk—Questions -continued

Developing an Emergency Plan

7. List the three components of an emergency plan.

8. Describe some steps that could have been taken to prevent the human disaster that resulted from the 1985 eruption of Nevado del Ruiz, Colombia.

Difficulties in Emergency Decision-Making

9. Describe what can happen if: (1) emergency officials are too quick to evacuate people near a volcano; (2) if they delay evacuation for too long.

10. Did Mount Pinatubo in the Philippines continue to pose hazards after the end of its 1991 eruption? Explain your answer.

Your Community

11. Make a list of activities that could reduce volcanic risk in YOUR community.

Teacher Page

Reducing Volcanic Risk—Answers

1. List the three recommended steps to reduce volcanic risk.

ANSWER:

Identify hazardous areas
Monitor for signs of increased volcanic unrest
Develop an emergency plan

Identifying Hazardous Areas

2. List at least three strategies that scientists use to determine what to expect during an eruption.

ANSWER:

Examine written and oral histories
Make detailed studies of volcanic deposits
Identify areas affected by past eruptions
Draw hazard maps that show distribution of volcanic deposits and relative danger to populated areas

3. Describe how hazard maps are useful in preparation for responding to volcanic activity.

ANSWER:

Hazard maps illustrate areas that are most likely to be affected by future volcanic eruptions. These maps are also useful as a guide to help communities determine safe places to build public structures (like water supply reservoirs, dams, bridges, utility stations, schools, etc.) and safe areas for evacuation.

Monitoring Volcanoes

4. Changes at volcanoes commonly provide warning of possible future eruptions. True or False?

ANSWER:

True

Teacher Page

Reducing Volcanic Risk—Answers -continued

5. List at least three types of information that are collected or observed to monitor volcanoes.

ANSWER:

Widening of ground cracks
Rise or fall of the ground
Changes in volcanic gases
Change in number and type of earthquakes

6. A scientist can predict the exact time and size of an eruption by monitoring a volcano. True or False?

ANSWER:

False

Developing an Emergency Plan

7. List the three components of an emergency plan.

ANSWER:

Inform the population about hazards
Determine a way to announce warnings
Test and practice the plan

8. Describe some steps that could have been taken to prevent the human disaster that resulted from the 1985 eruption of Nevado del Ruiz, Colombia.

ANSWER:

Informing the population about possible volcanic hazards, better education about volcano hazards, showing the hazard map to the population, developing an emergency plan, testing and practicing the emergency plan.

Teacher Page

Reducing Volcanic Risk—Answers -continued

Difficulties in Emergency Decision-Making

9. Describe what can happen if: (1) emergency officials are too quick to evacuate people near a volcano; (2) if they delay evacuation for too long.

ANSWER:

Responding too quickly could cause a false alarm. People may ignore future warnings, move back to the dangerous zones near the volcano, or distrust the advice of government officials and scientists in the future. Evacuations cause lots of disruption. If the evacuation is delayed, there may be increased lose of life and property.

10. Did Mount Pinatubo in the Philippines continue to pose hazards after the end of its 1991 eruption? Explain your answer.

ANSWER:

Yes, the volcano was still dangerous for months to years after the eruption. Pyroclastic flows and lahars filled the valleys near the volcano with debris. Rain caused this unstable debris to be mobilized down valleys as lahars, endangering other populations. Scientists were forced to make a new emergency plan.

Your Community

11. Make a list of activities that could reduce volcanic risk in **YOUR** community.

ANSWER:

Preferred answers making a hazards map, making an emergency plan, and monitoring the volcano. Students might also note they can learn about volcano processes and how volcanoes are monitored, be acquainted with the location of —hazard zones in their community, be familiar with evacuation plans in their community, and inquire how public officials advise them to respond.

Don't Be Scared—
Be Prepared!

Living with a VOLCANO in Your Backyard
MOUNT RAINIER

Grade Level: 2–12

Learner Objectives:

Students will:

- Recognize the four steps for greater preparedness
- Possess materials that help prepare students, their class, and family for natural disasters

Setting: Classroom

Timeframe:

Emergency Contact Paper: Homework Assignment—20 minutes class

Home Treasure Hunt for Disaster Kit Supplies: Homework Assignment—30 minute class

Assemble a Classroom Emergency Kit: Homework Assignment—50 minutes class

Develop a Safety Plan for Your School: Homework Assignment—50 minutes class

USGS science for a changing world

NATIONAL PARK SERVICE

Living with a Volcano in Your Backyard-An Educator's Guide with Emphasis on Mount Rainier

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

Students learn simple steps for developing preparedness by performing basic tasks with their class and family for natural disasters.

Materials:

Visualizing Topography

- "Family Emergency Preparedness Plan" (included)
- Aid from family members for development of contact list
- Literature distributed by American Red Cross and Emergency Management Departments, student contact information. (optional)

Home Treasure Hunt for Disaster Kit Supplies

- "Family Emergency Preparedness Plan" (included)
- Home resources for Family Disaster Supplies Kit

Assemble a Classroom Emergency Kit

- "Family Emergency Preparedness Plan" (included)
- Materials for emergency kit

Activity last modified: September 5, 2014

Develop a Safety Plan for Your School
Assemble a Classroom Emergency Kit

- "Family Emergency Preparedness Plan" (included)
- Existing school safety plan

Skills: Interpret, apply, participate

Vocabulary: Cascadia Subduction Zone, Disaster Supplies Kit, Emergency Contact Information, Family Emergency Preparedness Plan, volcanic hazards

Benchmarks:

See benchmarks in Introduction.

Teacher Background

Residents and visitors to the Pacific Northwest are at risk from a variety of potential natural processes—windstorms, floods, earthquakes, tsunamis and volcanic phenomena. Emergency officials recommend that families prepare to "shelter in place," meaning reliance on home-stored supplies of food, water and medicine for a minimum of 72 hours. They recommend that each family prepare an emergency contact list and have knowledge of evacuation routes.

When families are adequately prepared, emergency officials can focus their efforts on larger issues of community recovery, such as performing necessary evacuations, coordinating emergency workers, and keeping transportation facilities and utilities intact. In this educator guide, we're concerned primarily with volcanic hazards. However, if you are prepared for volcanic unrest with the procedures listed below, you will be ready for other natural hazard emergencies, as well.

In the accompanying document, ***Family Emergency Preparedness Plan***, officials recommend the following four steps toward preparedness:

- Find out what disasters could happen to you.
- Create a disaster plan.
- Put your plan into action.
- Practice and maintain your plan.

How do I know if I am at risk from volcanic hazards?
Hazard assessments have been assembled for many Cascade volcanoes. For an in-depth discussion of volcanic hazards and a hazards map of Mount Rainier, visit the activity **The Next Eruption of Mount Rainier.** Find references for volcano hazard assessments for other volcanoes on the **Internet Resources Page**.

Studies by emergency managers show that information about preparedness that is discussed in the classroom does not always reach home and prompt improved home preparedness. Teacher assignments that require family discussion enhance family preparedness. In the words of emergency managers, development of an EMERGENCY CONTACT LIST that involves all family members is the single most valuable preparedness homework that a teacher can assign.

Procedure

Preparing Your Students

Write a journal entry about a volcanic eruption to assess knowledge of volcanic processes and terms.

1. Discuss the reasons for preparedness with your students, as noted in the teacher background above. Inquire about students' experiences with the listed natural hazards. Discuss the hazards that affect either your community or another nearby. If you have questions about hazards in your community, contact your local emergency-management agency.

2. Motivate students' thinking by asking them a series of questions about their present state of preparedness. For example, ask them to make a list of emergency measures that would be required if they could not leave their home for 72 hours. Ask how they would contact their family if they were unable to join or phone them at home. What items would they choose to take with them if they had reason to evacuate their home? Listen to students' perceptions of current preparedness in their homes.

3. Conduct Procedure ***A*** (below) and one or more of the other procedures, ***B*** through ***D*** listed below.

A. Emergency Contact Information

Students work with their family to prepare a list of family emergency contacts. Use the "Emergency Telephone Numbers" form in the accompanying "Family Emergency Preparedness Plan" as a guide (page 25 of the document). In the Pacific Northwest, emergency managers recommend that out-of-area contacts be chosen from areas outside the Cascadia Subduction Zone, the geologically active region that stretches from Vancouver, British Columbia, to just north of San Francisco, California, and from the Pacific coast to central Washington, Oregon, and California. After checking for completeness, make photocopies of the form—one for the student and the other for the family. Students should keep this list, or a version at reduced size (an index card works well) in their school folder or backpack.

B. Home Treasure Hunt for Disaster Kit Supplies

Using the Emergency Preparedness Checklist as a guide, go on a treasure hunt in your home to accumulate items for your family disaster supplies kit. Refer to recommendations on pages five through seven of the accompanying Family Emergency Preparedness Plan. Check off items you find and make a list of those your family needs to obtain to complete your emergency preparedness kit. Review your list with your family and prepare a plan to complete your kit. Also, review volcano-preparedness measures in the accompanying

list entitled Volcanic Ashfall—How to be Prepared for an Ashfall and determine your family's preparedness for a volcanic eruption. Place a copy of your community's volcano evacuation plan (if one exists) with your emergency plan. If these items are unavailable, contact the American Red Cross or your local emergency management agency to obtain copies or similar literature. Facilitate a class discussion about students' findings on their home treasure hunt to conclude the activity.

C. Assemble a Classroom Emergency Kit

Become familiar with your classroom's emergency preparedness kit and procedures that you will follow during a hazardous event, such as an earthquake, a volcanic eruption, or lahar. Discuss the value of a NOAA Weather Radio.

D. Develop a Safety Plan for Your School

Contact a member of a local emergency management agency and invite them to your classroom. Ask them how they would advise you to respond during a natural hazards emergency such as a windstorm, earthquake, flood, or volcanic eruption. Invite them to visit your school and prepare a list of questions to ask prior to their visit. Finally, develop a plan for how your class will respond to volcanic eruptions.

Adaptations

- Volcano hazard workgroups have developed plans of action for other Cascade Range volcanoes. Perform an Internet search for them. In Washington, the plans are found on the Emergency Management Division Web site.
- Direct younger students to draw a picture of a volcanic eruption and label the drawing.

Extensions

- Students and teachers can prepare wallet-sized emergency contact cards to be kept in wallets and backpacks, on in the inside jacket of book covers.
- Use library or internet resources to learn about a natural disaster and how people's preparedness, (or lack of it), helped or hindered their recovery from the event.
- Create a poster that encourages others to be prepared for natural disasters. Use paint, crayons, computer, etc. to produce your poster.

Assessment

After completing this activity, students should be able to develop their own emergency contact list, disaster supplies kit, and a disaster plan. They should have an enhanced awareness of the procedures to follow during an emergency at their school. Assess each student's ability to record information in a practical form and then recall it.

References

Driedger, C., and Scott, K., 2002, Mount Rainier—Learning to live with volcanic risk: U.S. Geological Survey Fact Sheet 034–02, 4 p.

Dent-Cleveland, L., 2003, The beautiful mountain in the sky—How to be safe if a lahar flows down the mountain: Washington Military Department-Emergency Management Division, Elementary Edition K-6 Booklet, 24 p.

Federal Emergency Management Agency and American Red Cross, 1993, Helping children cope with disaster: FEMA L-196, ARC 4499, 4 p.

Harris, S.L., 2005, Fire mountains of the west: The Cascade and Mono Lake volcanoes: Missoula, Mont., Mountain Press Publishing Company, 454 p.

Hoblitt, R.P., Walder, J.S., Driedger, C.L., Scott, K.M., Pringle, P.T., and Vallance, J.W., 1995, Volcano hazards from Mount Rainier, Washington—1998 volcano-hazards assessment report: U.S. Geological Survey, Open-File Report 98–428, 11 p.

Kennedi, C.A., Brantley, S.R., Hendley J.W., II, Stauffer, P.H., 2000, Volcanic ash fall–a "hard rain" of abrasive particles: U.S. Geological Survey Fact-Sheet 027–00 (revised April 2002), 2 p.

Myers, B., Brantley, S.R., Stauffer, P.H., and Hendley J.W., II, 1998, What are volcano hazards? (revised April 2002): U.S. Geological Survey Fact Sheet 002–97, 2 p.

Mount Rainier Volcano Hazards Work Group, 1999, Mount Rainier volcano hazards response plan: Pierce County Department of Emergency Services, 103 p.

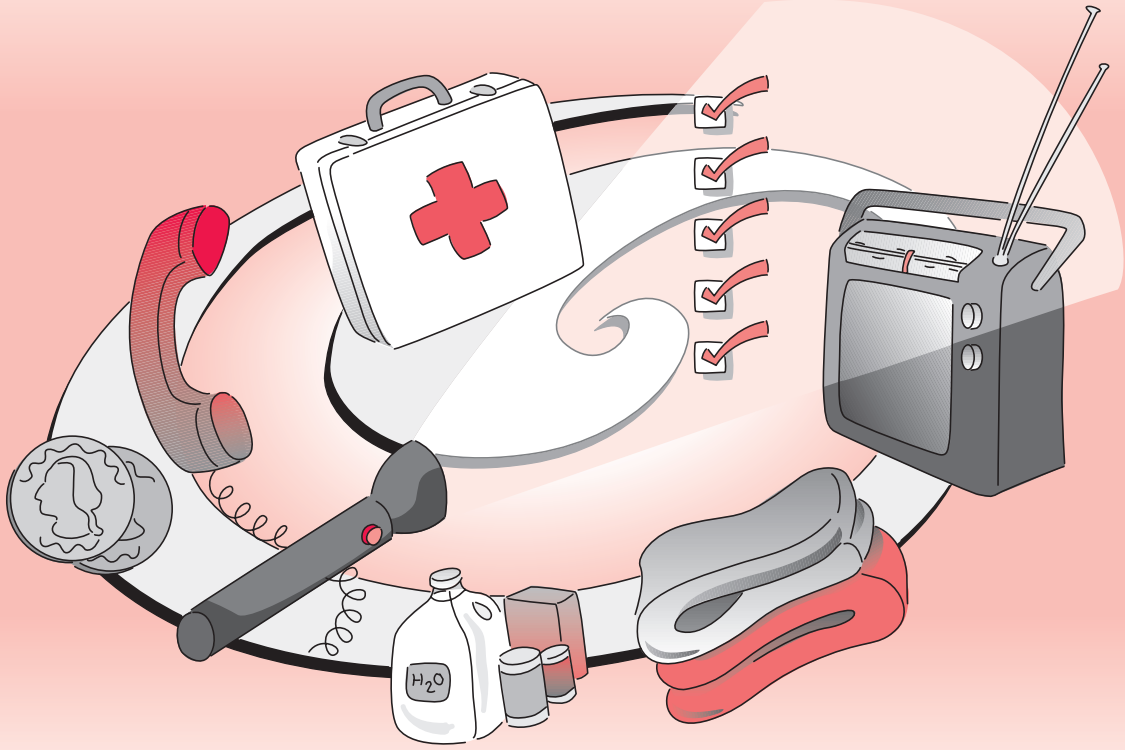
Prager, E.J., and Woodman, N., 2001, Volcano!: Washington, D.C., National Geographic Society, 32 p.

Washington Emergency Management Division, Group Health Cooperative of Puget Sound, Seattle-King Coounty Chapter of The American Red Cross, 1996, Family Emergency Preparedness Plan: Washington Emergency Management Division, 25 p. (Included with this activity)

Washington Military Department, Emergency Management Division, 2003, Volcanic ash fall—how to be prepared for an ash fall: Washington Military Department, Emergency Management Division, 3-page tri-fold.

Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

Family Emergency Preparedness *Plan*



FAMILY NAME

DATE PREPARED

NEXT REVIEW DATE

Washington Military Department
Emergency Management Division

Group Health Cooperative
of Puget Sound

Family **Emergency Preparedness** *Plan*

Why Plan? **1**

Four Steps to Disaster Planning **2**

Disaster Supplies Kit **5**

Hazard Hunt **8**

Floor Plan **9**

Utilities **10**

Planning For Specific Disasters **12**

Fire *14*

Floods *15*

Earthquakes *17*

Winter Storms and Extreme Cold *18*

Power Outages *20*

Hazardous Material Accidents *21*

Nuclear Power Plants *23*

Water Purification **24**

Emergency Telephone Numbers **25**

Credits

The Family Emergency Preparedness Plan was jointly developed by the Office of Emergency Preparedness at Group Health Cooperative of Puget Sound, the Seattle-King County Chapter of The American Red Cross, and the Washington State Military Department, Emergency Management Division.

Why Plan?

Communities throughout the Pacific Northwest are subject to a number of potential natural disasters such as fires, flooding, severe storms, earthquakes, dam failures, volcanic eruptions and landslides. While we all hope that such occurrences never happen, it has been shown time and time again that being prepared for disasters is prudent. Emergency services and government agencies may not be able to respond to your needs immediately. Their buildings, equipment, personnel, communications, and mobility may be severely hampered by the event. They will be overwhelmed. Experts tell us to plan to be on our own for a minimum of 3 days.

We cannot stop these disasters from occurring, but we can limit their impact on us and those we love. Contrary to what you may think, the chances of being killed or injured in a disaster are very low. More likely you will be unable to live normally in your home. It may be damaged and let in the weather, it may be cold with no heat, you may have no power or water, or it may not even be safe for you to go back into. In short, disasters make life very uncomfortable. Proper planning and preparation will help you and your family be more comfortable in the event that your home is damaged, or you can't get back into it. Think of it as a "quality of life" issue. The most important concept in developing a **family emergency preparedness plan** is communication. Every member of the family needs to be involved so that when disaster strikes, everyone will know what to do. How well you manage the aftermath of disaster depends a great deal on your level of preparedness when disaster strikes.

In the following pages you will find a step-by-step guide to disaster planning along with other essential information you will need in building a comprehensive family emergency preparedness plan. Be sure to involve all the members of your household when developing your preparedness plan. A plan will only work when everyone knows about it and agrees to operate within its guidelines.

Once your family is prepared, it is time to look to your neighbors. In times of disaster your neighbors will probably be the first ones available to come to your aid. Find out before disaster strikes what resources you share and how you can work together for the good of one another. Good luck! And don't forget to review your plan annually.

Prepare... *Because you care*

Four Steps to Disaster Planning

1 Find Out What Disasters Could Happen To You

- [ ] Ask what types of disasters are most likely to happen in your area.

_____

_____

_____

- [ ] Learn about your community's warning signals: what they sound like and what you should do when you hear them. Also, learn which radio stations will provide emergency information for your area.

_____

- [ ] Ask about animal care after a disaster.

_____

- [ ] Find out how to help elderly or disabled persons, if needed.

_____

- [ ] Find out about the disaster plan at your workplace, your children's school or childcare center and other places your family frequents.

_____

2 Create A Disaster Plan

Meet with your family and discuss why you need to prepare for disaster. Plan to share responsibilities and work together as a team.

- [ ] Discuss the types of disasters that are most likely to happen. Explain what to do in each case.

_____

_____

_____

_____

_____

- [ ] Discuss what to do in an evacuation. Plan to take care of your pets.

- [ ] Ask an out-of-area friend or relative to be your "family contact." It's often easier to call long distance following a disaster. (See pg. 25)

_____

- [ ] Pick two places to meet:
  1. Right outside your home in case of fire.
  2. Outside your neighborhood in case you can't return home. Everyone must know the address and phone number.

     Address _____

     _____

     _____

     Phone Number _____

3 Put Your Plan Into Action

- [ ] Post emergency telephone numbers by phones.
- [ ] Teach children how and when to call 911 or your local emergency medical services number for emergency help.
- [ ] Show each family member how and when to turn off the water, gas and electricity at the main switches.
- [ ] Check for adequate insurance coverage.
- [ ] Install an ABC type fire extinguisher in your home, teach each family member to use it, and show them where it is kept.
- [ ] Install smoke detectors on each level of your home, especially near bedrooms.
- [ ] Conduct a home hazard hunt (see page 8).
- [ ] Stock emergency supplies and assemble a disaster supplies kit (see page 5).
- [ ] Take a first aid and CPR class.
- [ ] Determine the best escape routes from your home. Find two ways out of each room. (Complete escape diagram on page 9).
- [ ] Find safe spots in your home for each type of disaster.

4 Practice and Maintain Your Plan

- [ ] Review your plans every six months so everyone remembers what to do.

  Next review: _____

- [ ] Conduct fire and emergency evacuation drills.

  Date of last drill: _____

  Date of next drill: _____

- [ ] Test and recharge your fire extinguisher(s) according to manufacturer's instructions.

  Date inspected: _____

  Next inspection due: _____

- [ ] Test your smoke detectors monthly. Change the batteries every six months and clean the dust from the detector each time you change batteries.

  Date of last battery change: _____

  Next battery change due: _____

- [ ] Replace stored water and food every six months.

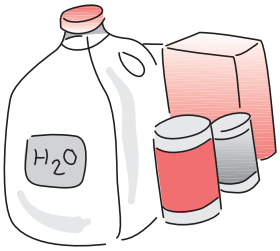
  Date of last rotation: _____

  Date of next rotation: _____

HINT: When you set your clocks in the fall and the spring, also replace your stored water and food, change your smoke detector batteries, and do other things necessary to maintain your plan.

Disaster Supplies Kit

There are six basics you should stock in your home: water, food, first aid, clothing and bedding, tools, and emergency supplies and special items. Keep the items you will most likely need during an evacuation in an easy-to-carry container such as a large, covered trash container, camping backpack or duffle bag. Keep a smaller version of the disaster supplies kit in the trunk of your car.



How to store water

Store your water in thoroughly washed plastic, fiberglass or enamel-lined metal containers. Never use a container that has held toxic substances. Plastic containers, such as soft drink bottles, are the best. You can also purchase food-grade plastic buckets or drums.

Seal water containers tightly, label them and store in a cool, dark place. Replace every six months.

Water

- [ ] Store one gallon of water per person per day
- [ ] Have purifying agents available

See page 24 for purification information.

Food

Store at least a three day supply of non-perishable food for each person. Select foods that require no refrigeration, cooking or preparation. Select food items that are compact and lightweight and rotate the food supply every six months.

- [ ] Ready to eat canned meats, fruits and vegetables
- [ ] Soups – bouillon cubes or dried soups in a cup
- [ ] Milk – powered or canned
- [ ] Stress foods – sugar cookies, hard candy
- [ ] Staples – sugar, salt, pepper
- [ ] Juices – canned, powered or crystallized
- [ ] Smoked or dried meats such as beef jerky
- [ ] Vitamins
- [ ] High energy foods – peanut butter, nuts, trail mix, etc

Non-Prescription Medications

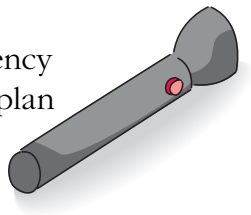
- [ ] Aspirin or non-aspirin pain reliever
- [ ] Antacid
- [ ] Laxative
- [ ] Rubbing alcohol
- [ ] Activated charcoal
- [ ] Anti-diarrhea medication
- [ ] Emetic (to induce vomiting)
- [ ] Eye wash
- [ ] Antiseptic or hydrogen peroxide

First Aid Kit

You should have two first aid kits — one for your home and the other for your car. The kit should include:

- [ ] Sterile adhesive bandages in assorted sizes
- [ ] 2-inch sterile gauze pads (8-12)
- [ ] 3-inch sterile gauze pads (8-12)
- [ ] Hypoallergenic adhesive tape
- [ ] Triangular bandages (3)
- [ ] 2 & 3-inch sterile roller bandages (3 rolls each)
- [ ] Scissors
- [ ] Tweezers
- [ ] Needle
- [ ] Safety razor blade
- [ ] Bar of soap
- [ ] Moistened towelettes (8-10 packages)
- [ ] Antiseptic spray
- [ ] Non-breakable thermometer
- [ ] Tongue blades and wooden applicator sticks
- [ ] Tube of petroleum jelly or other lubricant
- [ ] Assorted sizes of safety pins
- [ ] Cleansing agent – soap
- [ ] Latex gloves

Tools and Supplies

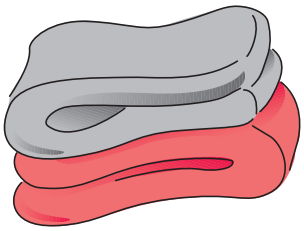


- [ ] Mess kits, or paper cups, plates and plastic utensils
- [ ] Family emergency preparedness plan
- [ ] Battery operated radio and extra batteries
- [ ] Flashlight and extra batteries
- [ ] Cash or traveler's checks, change
- [ ] Non-electric can opener, utility knife
- [ ] Fire extinguisher, small canister, ABC type
- [ ] Tube tent
- [ ] Pliers
- [ ] Tape
- [ ] Compass
- [ ] Matches in a waterproof container
- [ ] Aluminum foil
- [ ] Plastic storage containers
- [ ] Signal flare
- [ ] Paper, pencil
- [ ] Needles, thread
- [ ] Medicine dropper
- [ ] Shut-off wrench for gas and water
- [ ] Whistle
- [ ] Plastic sheeting
- [ ] Dust mask and work gloves

Sanitation

- [ ] Toilet paper, towelettes
- [ ] Soap, liquid detergent
- [ ] Feminine supplies
- [ ] Personal hygiene items
- [ ] Plastic garbage bags, ties
- [ ] Small shovel, to dig expedient latrine
- [ ] Plastic bucket with tight lid
- [ ] Disinfectant
- [ ] Household chlorine bleach

Clothing and Bedding



Include at least one complete change of clothing and footwear per person

- [ ] Sturdy shoes or work boots
- [ ] Rain gear
- [ ] Blankets or sleeping bags
- [ ] Hat and gloves
- [ ] Thermal underwear
- [ ] Sunglasses

Special Items

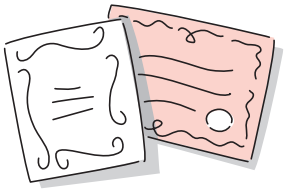
Remember family members with special needs such as infants, elderly, or disabled individuals.

For Baby

- [ ] Formula
- [ ] Diapers
- [ ] Bottles
- [ ] Powdered milk
- [ ] Medications

For Adults

- [ ] Heart and high blood pressure medications
- [ ] Insulin
- [ ] Prescription drugs
- [ ] Denture needs
- [ ] Contact lenses and supplies
- [ ] Extra eye glasses
- [ ] **Entertainment** — games for children; books for adults.



Important Family Documents — Keep these records in a waterproof, portable container.

- [ ] Will, insurance policies, contracts, deeds, stocks and bonds
- [ ] Passports, social security cards, immunization records
- [ ] Bank account numbers
- [ ] Credit card account numbers and companies
- [ ] Inventory of valuable household goods, important telephone numbers
- [ ] Family records (birth, marriage, death certificates)

Hazard Hunt

Conduct a hazard hunt to identify hazards in your home. State the action required to correct each problem. When the hazard has been corrected, put a check mark in the box.

☐ **Water heater** _____
(action required)

☐ **Top heavy free standing furniture** _____
(action required)

☐ **Heavy or breakable objects** _____
(action required)

☐ **Electronic equipment/appliances** _____
(action required)

☐ **Hanging plants** _____
(action required)

☐ **Mirrors/heavy pictures** _____
(action required)

☐ **Unsecured cupboard doors** _____
(action required)

☐ **Poisons, toxics and solvents** _____
(action required)

☐ **House foundation** _____
(action required)

☐ **Chimney and roof** _____
(action required)

☐ **Utilities** (flexible gas connections, electrical wiring, shut off valves/switches)

_____
(action required)

Date completed: _____

Date of next review: _____

Floor Plan

Sketch the floor plan of your home and establish two exit routes.

Floor One

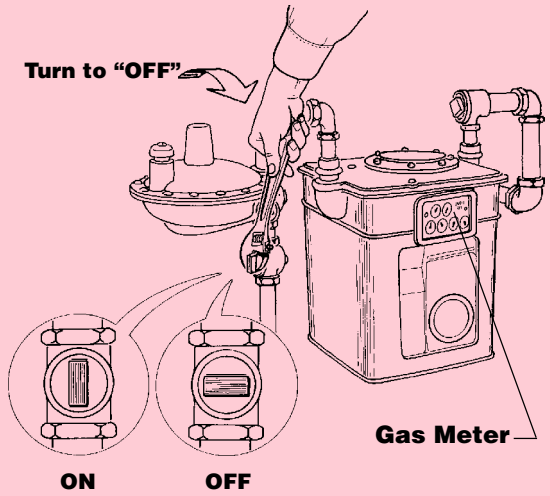
Floor Two

Utilities

Gas

- Locate your gas meter shutoff valve and learn how to turn the gas off.
- If you suspect the shutoff valve may be corroded and not working properly, call your utility company for an operational check of the valve.
- Ensure a wrench is immediately available for turning the gas meter off in an emergency.
- If you smell natural gas, get everyone out and away from the home immediately. Do not use matches, lighter, open flame appliances or operate electrical switches. Sparks could ignite gas causing an explosion.
- Shut off the gas **ONLY** if you smell gas and cannot locate the leak. **Let the gas company turn the gas back on**.
- Seek the assistance of a plumber to repair gas pipe damage.

Gas Shut-off



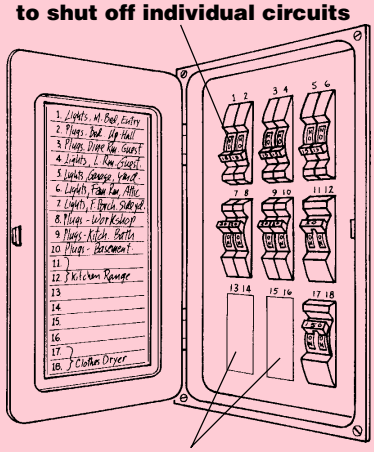
Sewer

- Your sewer system could be damaged in a disaster such as an earthquake, landslide or flood. Make sure the system is functioning as designed before using it to prevent contamination of your home and possibly the drinking water supply.
- Have a bucket or portable toilet available for disposing of human waste. Plastic bags placed in the toilet bowl will also work.

Electricity

- Locate your main electrical switch or fuse panel and learn how to turn the electrical power off.
- Remember, electrical sparks can cause a fire or explosion.
- If you are using a generator as a backup power supply remember to:
  - Follow the generator manufacturer's instructions.
  - Connect lights and appliances directly to the generator and not the electrical system.

Breaker Panel

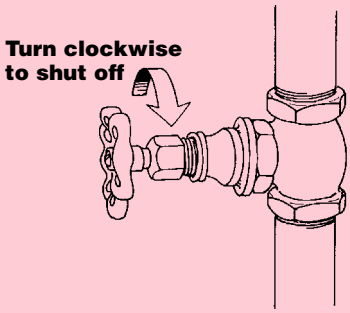


(Generators connected to a utility company's electrical system must be inspected by the utility and the state electrical inspector. Failure to have the system inspected may result in death or injury to utility crews trying to restore service to the area)

Water

- Label the water shut off valve and learn to turn off the water supply to your home.
- Identify the valve with a large tag.
- Ensure valve can be fully turned off. If the water valve requires the use of a special tool, make sure the tool is readily available.
- Shut off the main valve to prevent contamination of the water supply in your water heater and plumbing.

Water Shut-off



Planning For Specific Disasters

Fire. More than 24 million fires are reported annually, resulting in over $11 billion in property damage.

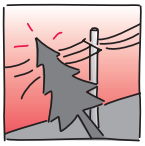
The United States has one of the highest fire death rates per capita in the world. At least 6,000 people die in fires each year, and an additional 100,000 are injured. Senior citizens and children under 5 are at highest risk. Fire is fast, dark and deadly, emitting smoke and gases that can render a person unconscious within minutes. It is the most likely disaster that families will experience.

Wildland fires in the Pacific Northwest burn thousands of acres in an average year. Most of these fires are caused by man. If you live in wildland areas, where flammable vegetation is abundant — your house could be a target for wildland fire.

Floods. Floods are the most common and widespread of all natural disasters and can occur nearly anywhere in the United States. Flooding has been responsible for the deaths of more than 10,000 people since 1900. Property damage attributable to flooding now totals over $1 billion each year. The sheer force of just six inches of swiftly moving water can knock people off their feet. Cars are easily swept away in just two feet of water. Flash floods can occur with little or no warning — and can reach full peak within minutes. Rapidly rising walls of water can reach heights of 30 feet or more and are generally accompanied by a deadly cargo of debris.

Earthquakes. Seventy million people in 39 states are at high risk from earthquakes. People in all states, however, are at some risk. Earthquakes can cause buildings to collapse, disrupt utilities and trigger landslides, avalanches, flash floods, fires, tsunamis and volcanoes. In the Pacific Northwest, thousands of earthquakes occur every year; catastrophic earthquakes will occur in the future.

Winter Storms. Heavy snowfall and extreme cold can immobilize an entire region. Even areas which normally experience mild winters can be hit with a major snow storm or extreme cold. The results can range from isolation to the havoc of cars and trucks sliding on icy highways.



Power Outage. Everyone experiences power interruptions from time to time. Unfortunately, many of these outages come at times of weather extremes or accompany various disasters. When the power is out we lose our primary source of artificial light and many loose their source of heat and water as well. When the power is out, safety becomes a major concern.

Hazardous Materials. As many as 500,000 products pose physical or health hazards and can be defined as hazardous materials. Accidents involving toxic substances have occurred in communities across the country. For example, tank cars containing toxic substances derailed and burned in Kentucky, forcing 7,500 area residents to evacuate. A train derailment near Marysville, Washington resulted in a hazardous materials fire and the evacuation of over 100 homes.

Nuclear Power. In the United States, nuclear power plants have been generating power for more than 35 years. Nuclear power plants operate in most states in the country and produce about 20 percent of the nation's power. The Pacific Northwest has fixed nuclear power plants within its boundaries as well as several mobile nuclear power plants like ships and submarines and small non-power reactor sites.

The following pages give you specific instructions on what to do for fire, flood, earthquakes, winter storms, power outages, hazardous materials and nuclear power accidents. The preparedness steps in this section are in addition to those identified in the section "Four Steps to Disaster Planning." You should first complete "Four Steps to Disaster Planning."

Fire

Getting Prepared

Working smoke detectors double your chance of surviving a fire.

- Install smoke detectors, according to the manufacturer's directions, on every level of your house: outside bedrooms on the ceiling or high on the wall, at the top of open stairways, or at the bottom of enclosed stairs and near (but not in) the kitchen.
- Clean smoke detectors once a month and change batteries at two specified times each year, when you set your clocks for Daylight Savings or Standard Time.
- Plan two escape routes out of each room. Contact your local fire authority for help in planning for the safe escape of those with disabilities.
- Make sure windows are not nailed or painted shut and security grating on windows have a fire safety opening feature.
- Teach everyone to stay low to the floor when escaping from a fire.
- Pick a meeting place outside your home for the family to meet after escaping from a fire. ONCE OUT, STAY OUT!
- Practice your escape plans at least twice a year.
- Clean out storage areas. Store flammable and combustible liquids in approved containers. Keep containers in the garage or an outside storage area.
- Inspect electrical appliances and extension cords for bare wires, worn plugs and loose connections annually.
- Clean and inspect primary and secondary heating equipment annually.
- Learn how to turn off the gas and electricity in an emergency.
- Install A-B-C type fire extinquishers: teach family members how to use them.
- Inspect or service your fire extinguisher annually.

In Case of Fire

Not sure you can control the fire? Evacuate and then call the fire department from a neighbor's house.

- Do not attempt to extinguish a fire that is rapidly spreading.
- Use water or a fire extinguisher to put out **small** fires.
- Never use water on a electrical fire.
- Smother oil and grease fires in the kitchen with baking soda or salt, or put a lid over the flame if it is burning in a pan.

- If your clothes catch fire — **Stop–Drop–Roll** — until the fire is out.
- Sleep with your door closed.
- If the smoke alarm sounds, crouch down low, feel the bottom of the door with the palm of your hand before opening it. If the door is hot, escape through the window. If the door is not hot and this route is your only means of escape, crawl below the level of the smoke and use the first available exit door to escape. If you cannot escape, leave the door closed, stay where you are and hang a white or light-colored sheet outside the window.

After a Fire

Don't throw away damaged goods until an official inventory has been taken.

- Stay out of the burned structure.
- Notify your local disaster relief service if you need housing, food, etc.
- Call your insurance agent.
- Ask the fire department for assistance in retrieving important documents.
- Keep records of all clean-up and repair costs.
- Secure personal belongings.
- If you are a tenant, notify the landlord.

Floods

Getting Prepared

Learn what to do when you hear flood warning signals.

- Find out if you live in a flood-prone area and identify dams in your area.
- Ask your local emergency manager about official flood warning signals.
- Know the terms Flood Watch, Flash Flood Watch, Flood Warning, Flash Flood Warning, and Urban and Small Stream Warning.
- Plan for evacuation.
- Consider purchasing flood insurance.
- Take steps to floodproof your home. Call your local building department or emergency management office for information.
- Keep all insurance policies and your household inventory in a safe place.

In Case of Heavy Rains

If there is any possibility of a flash flood occurring, move immediately to higher ground.

- Be aware of flash floods.
- Listen to radio or television stations for local information.
- Be aware of streams, drainage channels and areas known to flood suddenly.
- If local authorities issue a flood watch, prepare to evacuate.
- Secure your home. If time permits, secure items located outside the house.
- If instructed, turn off utilities at the main switches or valves.
- Fill your car with fuel.
- Fill the bathtub with water in case water becomes contaminated or services are cut off. Sterilize the bathtub first.
- Stay away from flood waters.
- When deep flooding is likely, permit the flood waters to flow freely into your basement to avoid structural damage to the foundation and the house.

After a Flood

Flood waters may be contaminated by oil, gasoline, or raw sewage. The water may also be electrically charged from underground or downed power lines.

- Stay away from flood waters.
- Stay away from moving water. Moving water six inches deep can sweep you off your feet.
- Be aware of areas where flood waters have receded and may have weakened road surfaces.
- Stay away from and report downed power lines.
- Stay away from disaster areas unless authorities ask for volunteers.
- Continue listening to the radio for information about where to get assistance.
- Consider health and safety needs. Wash your hands frequently with soap and clean water if you come in contact with flood waters.
- Throw away food that has come in contact with flood waters.
- Call your insurance agent.
- Keep records of all clean-up and repair costs.
- Take photos of or videotape your belongings and your home.
- Don't throw away damaged goods until an official inventory has been taken.

Earthquakes

Getting Prepared

Look for items in your home that could become a hazard in an earthquake.

Conduct earthquake drills with your family.

- Securely fasten water heaters and gas appliances.
- Repair defective electrical wiring, leaky gas and inflexible utility connections.
- Place large or heavy objects on lower shelves. Fasten shelves to walls. Brace high and top-heavy objects.
- Store bottle foods, glass, china and other breakables on low shelves or in cabinets that can fasten shut.
- Anchor overhead lighting fixtures.
- Be sure house is firmly anchored to its foundation.
- Know where and how to shut off all utilities.
- Locate safe spots in each room.
- Identify danger zones in each room.
- Consider buying earthquake insurance.

When the Ground Moves

Doorways are not always a safe place to be during an earthquake.

- If indoors — take cover under sturdy furniture or against an inside wall, and hold on. **Drop, Cover & Hold**. Stay away from the kitchen!
- If outdoors — stay there. Move away from buildings, street lights and utility wires.
- In a high-rise building — take cover under sturdy furniture away from windows and outside walls. Stay in the building on the same floor. An evacuation may not be necessary. Wait for instructions from safety personnel. Do not use elevators.
- In a vehicle — stop as quickly as safety permits, and stay in the vehicle. Avoid stopping near or under buildings, trees, overpasses or utility wires.

When the Shaking Stops

Do not use candles, matches or open flames indoors because of the possibility of gas leaks.

If you live near coastal waters evacuate to high ground immediately.

- If the electricity is out — use flashlights or battery powered lanterns.
- If you smell gas or hear a hissing or blowing sound — open a window and leave the building. Shut off the main gas valve outside.
- Be prepared for aftershocks.
- Check for injuries; yourself and those around you.
- If there is electrical damage — switch off the power at the main control panel.

- If water pipes are damaged — shut off the water supply at the main valve.
- Wear sturdy shoes in areas covered with fallen debris and broken glass.
- Check your home for structural damage. Check chimneys for damage.
- Clean up spilled medicines, bleaches, gasoline and other flammable liquids.
- Visually inspect utility lines and appliances for damage.
- Do not flush toilets until you know that sewage lines are intact.
- Open cabinets cautiously. Beware of objects that can fall off shelves.
- Use the phone only to report a life threatening emergency.
- Listen to news reports for the latest emergency information.
- Stay off the streets.
- Stay away from damaged areas, unless your assistance has been specifically requested by proper authorities.
- Be aware of a possible tsunami. Go to high ground and remain there until you are told it is safe to return to home.

Winter Storms and Extreme Cold

Getting Prepared

Dress for the weather and keep a "winter car kit" in the trunk of your car.

- Know the terms used by weather forecasters.
- Consider purchasing a battery-powered NOAA weather radio and stock extra batteries.
- Keep rock salt to melt ice on walkways and sand to improve traction.
- Make sure you have sufficient heating fuel.
- Make sure you have an alternate heat source and a supply of fuel.
- Install storm windows or cover windows with plastic.
- Insulate walls and attics.
- Caulk and weatherstrip doors and windows.
- Keep your car "winterized" with antifreeze. Use snow tires.

During a Winter Storm

When using kerosene heaters, maintain ventilation to avoid a build-up of toxic fumes.

- Listen to the radio or television for weather reports and emergency information.
- Wear several layers of loose-fitting, light-weight, warm clothing rather than one layer of heavy clothing.
- Wear mittens instead of gloves.
- Wear a hat — most body heat is lost through the top of the head.
- Avoid overexertion.
- Watch for signs of frostbite. If symptoms are detected, get medical help immediately.
- Watch for signs of hypothermia. If symptoms are detected, get medical help immediately.
- Conserve fuel if necessary by keeping your house cooler than normal.
- Refuel kerosene heaters outside and keep them at least three feet from flammable objects.
- If you must travel consider using public transportation.

Caught in Your Car During a Blizzard

Remain in your vehicle and wait to be found.

- Pull off the highway and set your hazard lights to flash. Hang a distress flag from the radio antenna
- Run the engine and heater about ten minutes each hour to keep warm. While the engine is running, slightly open a window and keep the exhaust pipe free of snow.
- Exercise lightly to maintain body heat. Huddle with passengers to stay warm.
- Take turns sleeping.
- Be careful not to run the car battery down.
- If stranded in a remote rural or wilderness area, spread a large cloth over the snow to attract attention of rescue personnel.
- Once the blizzard passes, you may need to leave the car and proceed on foot.

Power Outages

Getting Prepared

Cordless phones do not work when the power is out.

- Register life-sustaining equipment with your utility.
- Consider purchasing a small generator or know where to rent one if you use life sustaining equipment that requires electrical power.
- Post the telephone number of the New Construction, Repairs and Power Outage listing of your local utility.
- If you own an electric garage door opener, learn how to open the door without power.
- Prepare a power outage kit. For short duration outages consider having glow light sticks, flashlights, battery-powered radio, extra batteries and a wind-up clock on hand.
- Make sure you have an alternate heat source and a supply of fuel.
- Have a corded telephone available.
- When installing generators, follow the manufacturer's instructions and have it inspected by the utility company and the state electrical inspector.

When the Lights Go Out

Report power outages to the utility company.

- If your house is the only one without power, check your fuse box or circuit breaker panel. Turn off large appliances before replacing fuses or resetting circuits.
- If power is out in the neighborhood, disconnect all electrical heaters and appliances to reduce the initial demand and protect the motors from possible low voltage damage.
- If you leave home, turn off or unplug heat producing appliances.
- Unplug computers and other voltage sensitive equipment to protect them against possible surges when power is restored.
- Conserve water, especially if you are on a well.
- Keep doors, windows and draperies closed to retain heat in your home.
- Keep refrigerator and freezer doors closed. If the door remains closed, a fully loaded freezer can keep foods frozen for two days.
- Be extremely careful of fire hazards caused by candles or other flammable light sources.

- When using kerosene heaters, gas lanterns or stoves inside the house, maintain ventilation to avoid a build-up of toxic fumes. *Never use charcoal or gas barbeques inside; they produce carbon monoxide.*
- Connect lights and appliances directly to a generator, not to an existing electrical system.

NOTE: Leave one light switch in the on position to alert you when service is restored.

Hazardous Material Accidents

Getting Prepared

Evaluate the risks to your family.

- Ask your local fire department about emergency warning procedures.
- Find out precise information about where reportable quantities of extremely hazardous substances are stored and where they are used.
- Ask your Local Emergency Planning Committee (LEPC) about community plans for responding to hazardous material accidents.
- Determine how close you are to freeways, railroads or factories which may produce or transport toxic materials.
- Be prepared to evacuate.
- Have materials available to seal off your residence from airborne contamination.

Responding to a Hazardous Material Incident

Strictly follow all instructions given by emergency authorities.

- If you are a witness — call 911 or your local fire department.
- If you hear a warning signal — listen to local radio or television stations for further information. Follow all instructions.
- Stay away from the incident site to minimize the risk of contamination.
- If caught outside — stay upstream, uphill or upwind. Try to go one-half mile (10 city blocks) from the danger area.
- If you are in a car — close windows and shut off ventilation.
- Evacuate if told to do so.
- If local officials say there is time, close all windows, shut vents, and turn off attic fans and other ventilation systems to minimize contamination.

- To reduce the possibility of toxic vapors entering your home, seal all entry routes as efficiently as possible.
- If an explosion is imminent — close drapes, curtains and shades.
- If you suspect gas or vapor contamination — take shallow breaths through a cloth or towel.
- Avoid contact with any spilled liquid materials, airborne mist or condensed solid chemical deposits.
- Do not eat or drink any food or water that may have been contaminated.

After a Hazmat Incident

Follow decontamination instructions from local authorities.

- Seek medical help for unusual symptoms.
- If medical help is not immediately available and you suspect contamination — remove all clothing and shower thoroughly.
- Place exposed clothing and shoes in tightly sealed containers without allowing them to contact other materials: get directions for proper disposal.
- Advise others of your possible contamination.
- Get direction from local authorities on how to clean up your land and property.
- Return home only when directed to do so.
- Upon returning home, ventilate the house.
- Report lingering vapors or other hazards.

Nuclear Power Plants

Getting Prepared

Time, distance and shielding are the keys to minimizing radio-active exposure.

- Know the terms that describe a nuclear emergency:
  - Notification of Unusual Event
  - Alert
  - Site Area Emergency
  - General Emergency
- Learn your community's warning system. Commercial nuclear power plants are required to install sirens and other warning systems within a ten mile area.
- Obtain public emergency information materials from the company operating the plant.
- Learn the emergency plans for schools, day care centers, nursing homes and other places where members of your family might be.
- Be prepared to evacuate.

Responding to a Power Plant Emergency

Local instructions take precedence over advise in the handbook.

- Keep calm. Not all incidents result in the release of radiation.
- Stay tuned to your local radio or television stations for information.
- Evacuate if you are advised to do so.
  - Close and lock home doors and widows.
  - Keep car windows and vents closed; use recirculating air.
  - Listen to the radio for evacuation routes and other information.
- If not ordered to evacuate — stay indoors.
  - Close doors and windows
  - Turn off air conditioner, ventilation fans, furnace and other air intakes.
  - Go to a basement or other underground area if possible.
  - Keep a battery-powered radio handy at all times.
  - If you must go outdoors — cover your nose and mouth with a handkerchief.
- Shelter livestock and give them stored feed, if time permits.
- Do not use the telephone unless absolutely necessary.
- If you have just been outdoors — shower and change clothes. Put clothing and shoes in a plastic bag; seal it up and store it out of the way.

Three ways to purify water

In addition to having a bad odor and taste, contaminated water can contain microorganisms that cause diseases such as dysentery, typhoid and hepatitis. You should purify all water of uncertain purity before using it for drinking, food preparation or hygiene.

There are many ways to purify water. None is perfect. Often the best solution is a combination of methods.

Two easy purification methods are outlined below. These measures will kill most microbes but will not remove other contaminants such as heavy metals, salts and most other chemicals. Before purifying, let any suspended particles settle to the bottom, or strain them through layers of paper towel or clean cloth.

1 **Boiling.** Boiling is the safest method of purifying water. Bring water to a rolling boil for 3-5 minutes, keeping in mind that some water will evaporate. Let the water cool before drinking.

Boiled water will taste better if you put oxygen back into it by pouring the water back and forth between two clean containers. This will also improve the taste of stored water.

2 **Disinfection.** You can use household liquid bleach to kill microorganisms. Use only regular household liquid bleach that contains 5.25 percent sodium hypochlorite. Do not use scented bleaches, colorsafe bleaches or bleaches with added cleaners.

Add 16 drops of bleach per gallon of water, stir and let stand for 30 minutes. If the water does not have a slight bleach odor, repeat the dosage and let stand another 15 minutes.

The only agent used to purify water should be household liquid bleach. Other chemicals, such as iodine or water treatment products sold in camping or surplus stores that do not contain 5.25 percent sodium hypochlorite as the only active ingredient, are not recommended and should not be used.

NOTE: While the two methods described above will kill most microbes in water, distillation will remove microbes that resist these methods, and heavy metals, salts and most other chemicals.

3 **Distillation.** Distillation involves boiling water and then collecting the vapor that condenses back to water. The condensed vapor will not include salt and other impurities. To distill, fill a pot halfway with water. Tie a cup to the handle on the pot's lid so that the cup will hang right-side-up when the lid is upside-down (make sure the cup is not dangling into the water) and boil the water for 20 minutes. The water that drips from the lid into the cup is distilled.

Emergency Telephone Numbers

Out-of-Area Contact

Name _____

City _____

Telephone (day) (___) _____ (Evening) (___) _____

Local Contact

Name _____

City _____

Telephone (day) (___) _____ (Evening) (___) _____

Nearest Relative

Name _____

City _____

Telephone (day) (___) _____ (Evening) (___) _____

Family Work Numbers

Father _____ Mother _____

Other _____

Emergency Telephone Numbers

In a life threatening emergency, dial 911 or the local emergency medical services system number.

Police Department _____

Fire Department _____

Hospital _____

Family Physicians

Name _____ Telephone _____

Name _____ Telephone _____

Name _____ Telephone _____

The Out-Of-Area Contact is one of the most important concepts in your disaster plan. When disaster occurs, you will be concerned about the welfare of your loved ones.

In a disaster, local telephone service may be disrupted. However, long distance lines, because they are routed many different ways out of your community, may be open. It is also important to remember that the telephone company's emergency telephone network is the pay telephone system. They will restore it before the rest of the system. So, if you have change to make a pay telephone call and an out-of-area contact, you may be able to communicate with loved ones in the disaster area indirectly through your out-of-area contact.

Reunion Locations

1. Right outside your home _____

2. Away from the neighborhood, in case you cannot return home _____

_____

Address _____

Telephone _____

Route to try first _____

_____

Reunion Points. After a disaster it may be impossible for family members to return home for one reason or another. It is very important that you select a meeting point in the community where you can once again join the members of your household.

Notes

Working with neighbors can save lives and property. Meet with your neighbors to plan how the neighborhood could work together after a disaster until help arrives.

ADSV.60360 6/96 REV.3

A Volcano Tussle—
How Much Do We Risk?

Living with a VOLCANO in Your Backyard
MOUNT RAINIER

Grade Level: 5–12+

Learner Objectives:

Students will:

- Improve their understanding of the complexity and interconnected relationship of geologic and societal issues pertaining to volcanoes and their hazards, especially those within Mount Rainier National Park

Setting: Classroom

Timeframe: Advance instructions and student preparations required; 45 minutes+ for a class "public meeting"

Materials:

- *"List of Meeting Attendees"* student page
- Library or internet access

Vocabulary: Debris flow, earthquakes, glacial outburst flood, lahars, lava flow, pyroclastic flows, rockfall

USGS science for a changing world

NATIONAL PARK SERVICE

Living with a Volcano in Your Backyard-An Educator's Guide with Emphasis on Mount Rainier

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

Students play the role of a visitor or other person with interest in facilities at Mount Rainier National Park. Students write a position paper on an issue and later defend their points in class or at a public meeting.

Skills: Research, debate, clarify, apply, draw conclusions

Benchmarks:

See benchmarks in Introduction.

Activity last modified: September 5, 2014

Teacher Background

Scenario: Students will play the part of people with vested interests in the management of campgrounds at Mount Rainier National Park. Park managers are considering the closure of some campgrounds because of recent ***rockfalls*** and small ***debris flows*** that threaten these facilities. Cougar Rock Campground and White River Campground are under consideration for closure. Thousands of tent campers, trailer, and motor home campers use these "front country" campgrounds every year.

Preparing Your Students

Before presenting this activity, students should have completed other Educator Guide activities that help them understand geologic processes at Mount Rainier. Show the video **Understanding Volcanic Hazards** or conduct the activity **Volcanic Processes**. Discuss how the hazards pertain to Mount Rainier. The video, **Perilous Beauty—the Hidden Dangers of Mount Rainier**, addresses volcanic hazards with particular reference to Mount Rainier. Students should understand that some geologic hazards (rockfall, ***glacial outburst floods***, debris flows, ***earthquakes***, and some ***lahars***) can take place during non-eruptive times. Other hazards such as ***lava flows***, ***pyroclastic flows*** and lahars derived from melting of snow and ice, during volcanic eruptions.

Procedure

A Volcano Tussle

Students write position papers on a controversial geological hazard issue, and then defend their position at an "in–class" or real public meeting.

1. Begin this activity by asking students to identify how they, their families, and neighbors "relate" to Mount Rainier National Park. Are they day visitors, campers, or people who never use the Park? Ask students to help make a list of other people who might have an interest in park policy. Add your list of "meeting attendees" to those on the student page.

2. Assign roles to students. Instruct them to write a position paper that addresses the scenario and provides recommendations for consideration by Park Service managers. Students should defend their position at the "public meeting," in class or an actual meeting within the community. Three paragraphs is the recommended position paper length. This can be assigned as homework or class work.

3. Conduct a "public meeting" in your classroom. Students on the Park Advisory Board should ask for opinions from meeting participants.

4. Students on the Park Advisory Board then deliberate and prepare a recommendation regarding campground closure or some other action that should take place to safeguard visitors from geologic hazards.

Adaptations

- Choose any other natural hazard in your community or elsewhere in the world. Follow the same procedures presented in the activity.

Extensions

- Students prepare a position paper about a current issue and present their view at a public meeting within their community.

Assessment

Pay particular attention to how students apply their basic knowledge of volcanic processes and hazards to decision making. Students should be able to write knowledgeably about these hazards, present the hazards objectively, and relate hazards to human activity within the park.

References

Driedger, C., and Scott, K., 2002, Mount Rainier—Larning to live with volcanic risk: U.S. Geological Survey Fact Sheet 034–02, 4 p.

Hoblitt, R.P., Walder, J.S., Driedger, C.L., Scott, K.M., Pringle, P.T., and Vallance, J.W., 1998, Volcano hazards from Mount Rainier, Washington—1998 volcano-hazards assessment report: U.S. Geological Survey, Open-File Report 94–428, 10 p.

Mount Rainier Volcano Hazards Work Group, 1999, Mount Rainier volcano hazards response plan: Pierce County Department of Emergency Services, 103 p.

Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

Student Page

List Of Meeting Attendees

Instructions: *Your teacher will assign each of you the role of a participant at a public meeting. Use Internet searches, library resources, and interviews to write a position paper addressing your view of the scenario. Provide recommendations that National Park Service managers should consider. You will be asked to defend your position at a "public meeting" within your classroom.*

SCENARIO: Students will play the part of people with vested interests in the management of campgrounds at Mount Rainier National Park. Park managers are considering the closure of some campgrounds because of recent rockfalls and small debris flows that threaten these facilities. Cougar Rock Campground and White River Campground are under consideration for closure.Thousands of tent campers, trailer, and motor home campers use these "front country" campgrounds every year.

1. ***Meeting moderator (a representative to the superintendent of the park)***
   The meeting moderator wants the opinions of geologists, emergency managers, visitors and community members before making a decision about closure of campgrounds. *(Teacher or student can play this role.)*

2. ***Park Advisory Board***
   Three to ten students can serve as members of the Park Advisory Board. This group listens to all opinions then deliberates and prepares a recommendation on campground closure and other actions to safeguard visitors.

3. ***Restaurant owner in Eatonville***
   He runs a restaurant in Eatonville that caters to Mount Rainier visitors. He has heard about lahar hazards and wants to learn more, but fears that education about hazards and park closures might scare visitors away.

4. ***A motor home visitor from Kansas City***
   This Missouri retiree has driven his large motor home to Washington for his first view of glaciers on Mount Rainier. He recently retired from a large manufacturing firm and spent a major part of his savings ($75,000) to purchase his motor home.

5. ***Backpacker from Yakima***
   She is a college student hiking the Wonderland Trail on summer break, fulfilling a lifelong dream. She intends to work as an environmental educator when she completes her schooling.

List Of Meeting Attendees-continued

6. ***Mountain climber from Germany***
   He has been climbing most of his life, and successfully climbed many major peaks of the European Alps. His schedule for climbing Mount Rainier is limited to four days.

7. ***Lodge employee working in the restaurant at Paradise***
   This is the summer between her high school graduation and college. She came to Mount Rainier to see the sights; however, she spends most of her summer waiting on cranky visitors.

8. ***Resort owner in Greenwater***
   This man runs The Firs, a family-owned log cabin resort on the banks of the White River. It has been a popular visitor destination for more than 80 years. His business depends upon the availability of visitors and upon the White River remaining within its channel.

9. ***Frequent camper at White River Campground***
   This nineteen-year-old enlisted man from Fort Lewis, spends as many summer weekends as possible camping with a group of buddies at White River Campground.

10. ***Ranger and (or) campground host***
    She has been an employee of the National Park Service for five years. Closure of a campground will require her to change jobs.

11. ***Mountaineering guide***
    She is a first-year mountaineering guide on Mount Rainier. She is an experienced climber and collegiate athlete who took this job because she enjoys physical challenge.

12. ***Search and Rescue (SAR) employee***
    This Tacoma native has been involved in SAR since becoming an Eagle Scout in high school. He participated in a search last year for two children caught in a debris flow. Both children were found, but shaken by the experience.

13. ***Geologist***
    This geologist has been studying lahars as a consultant to Mount Rainier National Park and has an in-depth knowledge of the long record of debris flows and lahars in the park. He observed rockfall at the north end of Cougar Rock Campground during an earthquake many years ago, and witnessed a debris flow on Kautz Creek in 2001.

List Of Meeting Attendees-continued

14. Senator

After serving on the Natural Resources subcommittee for ten years, this senator from Ohio decided to complete a fact-finding tour of western parks.

15. Tent camper from Yelm

This family has been visiting Mount Rainier all their life and considers Mount Rainier as their private playground.

Living Well With a Volcano in Your Backyard

Grade Level: 3–2

Learner Objectives:

Students will:

- Recognize the benefits and attractions of living near a volcano
- Balance concerns about volcanic unrest with the recognition that volcanoes can be safe and desirable destinations

Setting: Classroom, assembly, home

Timeframe: Variable

Stories about an Imaginary Eruption—30 minutes

Poll Attitudes about Volcanic Hazards Homework; 50 minutes class

Begin a Pen Pal Program—50 minutes

Volcanoes as Community Assets—50 minutes

Cascade Volcanoes Influence the Vitality and Ecology of Your Community—50 minutes

Create a Mechanism Whereby a Cascade Volcanoes Can Bring Economic Benefit to Your Community—50 minutes

USGS science for a changing world

Living with a Volcano in Your Backyard-An Educator's Guide with Emphasis on Mount Rainier

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

This activity invites students to examine the advantage of living near an active volcano.

Draw a Picture or Write a Story about a Visit to a Cascade Volcano—50 minutes

Make a Paper Cone Representation of Mount Rainier—30 minutes

Materials:

Stories About an Imaginary Eruption

- Writing materials

Poll Attitudes about Volcanic Hazards

- Community cooperation

Begin a Pen Pal Program

- Library or Internet Resources
- Educators at schools in communities near other volcanoes

Volcanoes as Community Assets

- Library or Internet Resources

Cascade Volcanoes Influence the Vitality and Ecology of Your Community

- Library or Internet Resources

Create a Mechanism Whereby a Cascade Volcano Can Bring Economic Benefit to Your Community

- Library or Internet Resources

Draw a Picture or Write a Story about a Visit to a Cascade Volcano

- Drawing materials

Draw a Picture or Write a Story about a Visit to a Cascade Volcano

- Volcano cone cutout (provided)
- Drawing materials

Activity last modified: November 21, 2014

Vocabulary: Eruption, geothermal, lahar, lava flow, volcanic ash, volcanic gas

Skills: Apply, interpret, participate, explain

Benchmarks:

See benchmarks in Introduction.

Teacher Background

Student fascination with volcanoes is almost universal. The risk from volcanoes in the Pacific Northwest adds some complexity as some students' homes, schools, or places where their parents work are at risk from the effects of eruptions and lahars. Balance the emphasis of hazards and recommendations with any or all activity procedures ***A*** through ***H***. Recommendations address community involvement and the benefits of living near a volcano.

Prepare Students:

Before conducting this activity, students should have knowledge of volcanic processes and Mount Rainier volcanic hazards. As appropriate, show older students one or more of the videos, **Understanding Volcano Hazards, Perilous Beauty—The Hidden Dangers of Mount Rainier**, or instruct them to obtain information from the Internet and library research. For younger students, conduct the activity **Volcanic Processes** in Chapter 2.

Procedures

Choose from any or all of these activities for your students.

A. Stories about an Imaginary Eruption

Students write a story about an imaginary eruption at a Cascade volcano and how they and their classmates respond to it. Your class may have already recorded their ideas about this scenario in **Eruption,** the first activity in Chapter 1. If so, advise students to compare their earlier story with their present one and report on how their ideas have changed.

B. Poll Attitudes about Volcanic Hazards

Students design and conduct a survey about volcanic-hazards knowledge in the classroom, school, or community. The survey should capture opinions on what measures should be taken for education and protection from volcanic hazards. Report the results of your poll to your class and to your school safety officer.

C. Begin a Pen Pal Program

Start a Pen Pal program for your students with others who live in the vicinity of other Cascade volcanoes, or at other volcanoes around the world. Students can learn about other volcanic areas and communities at risk by researching the Internet.

D. *Volcanoes as Community Assets*

Students use library and Internet searches to investigate how volcanic eruptions around the world can be beneficial to towns or nearby communities and then make a poster, report, or computer presentation about their findings. Their findings should include some of the following concepts:

- ***Lava flows*** add new land to Earth's crust
- ***Volcanic gases*** developed Earth's atmosphere
- Volcanic rocks provide building stones, gemstones, natural abrasive material, and raw material for early man's tools
- ***Geothermal*** steam can be used for indoor heating
- Geothermal energy converts steam to electrical power. It is a clean energy resource in some areas of the world
- ***Volcanic ash*** contains minerals that enrich the farmlands
- Spectacular scenery is created
- Volcanoes generate income from tourism

E. *Cascade Volcanoes Influence the Vitality and Ecology of Your Community*

Students use the library and Internet to investigate the different ways a Cascade volcano currently influences the ecology and vitality of nearby communities. Water, glaciers, and tourism are some ideas for investigation.

F. *Propose a Plan that Can Bring Economic Benefit to Your Community*

Your class assembles a special committee to examine how having a nearby Cascade volcano can bring economic benefit to your community. Student groups might consider tourism, community artwork, signs, or other business and public projects that build on your community's close proximity to a beautiful Cascade volcano. Students work in groups to develop several plans and then write a plan of action and draw maps and pictures of their ideas. Students present their ideas to a local community group and encourage the group to use them.

G. *Draw a Picture or Write a Story about a Visit to a Cascade Volcano*

Invite students to draw a picture or write a story about a recent trip to Mount Rainier or another Cascade volcano. Invite students to express their feelings about the beauty of the volcano and its ecosystems and share their creation with the class.

H. Make a Paper Cone Representation of Mount Rainier

Students color, cut, fold, and glue the model included in this activity. This project works best when photocopied with enlargement on 11 x 17-inch paper (see graphic). Assess the student's ability to understand how to apply their knowledge of volcanic hazards on a local and a global scale.

I. School Volcano Museum

Choose any or all of these ideas for your students. After completion, display students' products in a "school volcano museum" for viewing by other students and by their families. Your museum can include emergency preparedness information and student projects from other activities, such as **Cascade Volcano Timeline**, **A String of Volcanoes**, **Play-Dough Topo**, **Planning your Trip to Mount Rainier National Park!**, and **The Next Eruption of Mount Rainier**.

Assessment

(A) Pay particular attention to how a student's ideas have grown between the first and last writing. Do students have a better understanding of the geologic processes common to Cascade volcanoes?

(B, C) Assess the student's ability to understand how to apply their knowledge of volcanic hazards on a local and a global scale.

(D, E and F) Assess the student's ability to apply their new knowledge about volcanoes to a real-world situation. Students who are beginning a study of volcanoes might not recognize that volcanoes can bring benefits to their community and to the world at large. To assess a student's current understanding, pay particular attention to their research findings, creativity and depth of involvement.

(G, H) Use standard rubrics to assess a student's ability to express their ideas in written form and to the class. Look for evidence that students have a greater familiarity with Mount Rainier or another Cascade volcano. Students might indicate a working knowledge of places they have visited or intend to visit.

References

Decker, R., and Decker, B., 1981, Volcanoes: New York, N.Y., W.H. Freeman and Company, 244 p.

Dent-Cleveland, L., 2003, The beautiful mountain in the sky—how to be safe if a lahar flows down the mountain: Washington Military Department–Emergency Management Division, Elementary Edition K-6 Booklet, 24 p.

Dzurisin, D., Stauffer, P.H., and Hendley J.W., II, 1997, Living with volcanic risk in the Cascades: U.S. Geological Survey Fact Sheet 165–97 (revised March 2003), 2 p.

Harris, S.L., 2005, Fire mountains of the west—the Cascade and Mono Lake volcanoes: Missoula, Mont., Mountain Press Publishing Company, 454 p.

Hoblitt, R.P., Walder, J.S., Driedger, C.L., Scott, K.M., Pringle, P.T., and Vallance, J.W., 1998, Volcano hazards from Mount Rainier, Washington–volcano hazards assessment report: U.S. Geological Survey, Open-File Report 98–428, 10 p.

Northwest Interpretive Association, 1999, Rainier the mountain (DVD) (re–recorded 2005): Seattle, Wash., Northwest Interpretive Association Press, 60 minutes.

Pierce County Department of Emergency Management, 1999, Mount Rainier volcano hazards response plan: Pierce County Department of Emergency Services, 103 p.

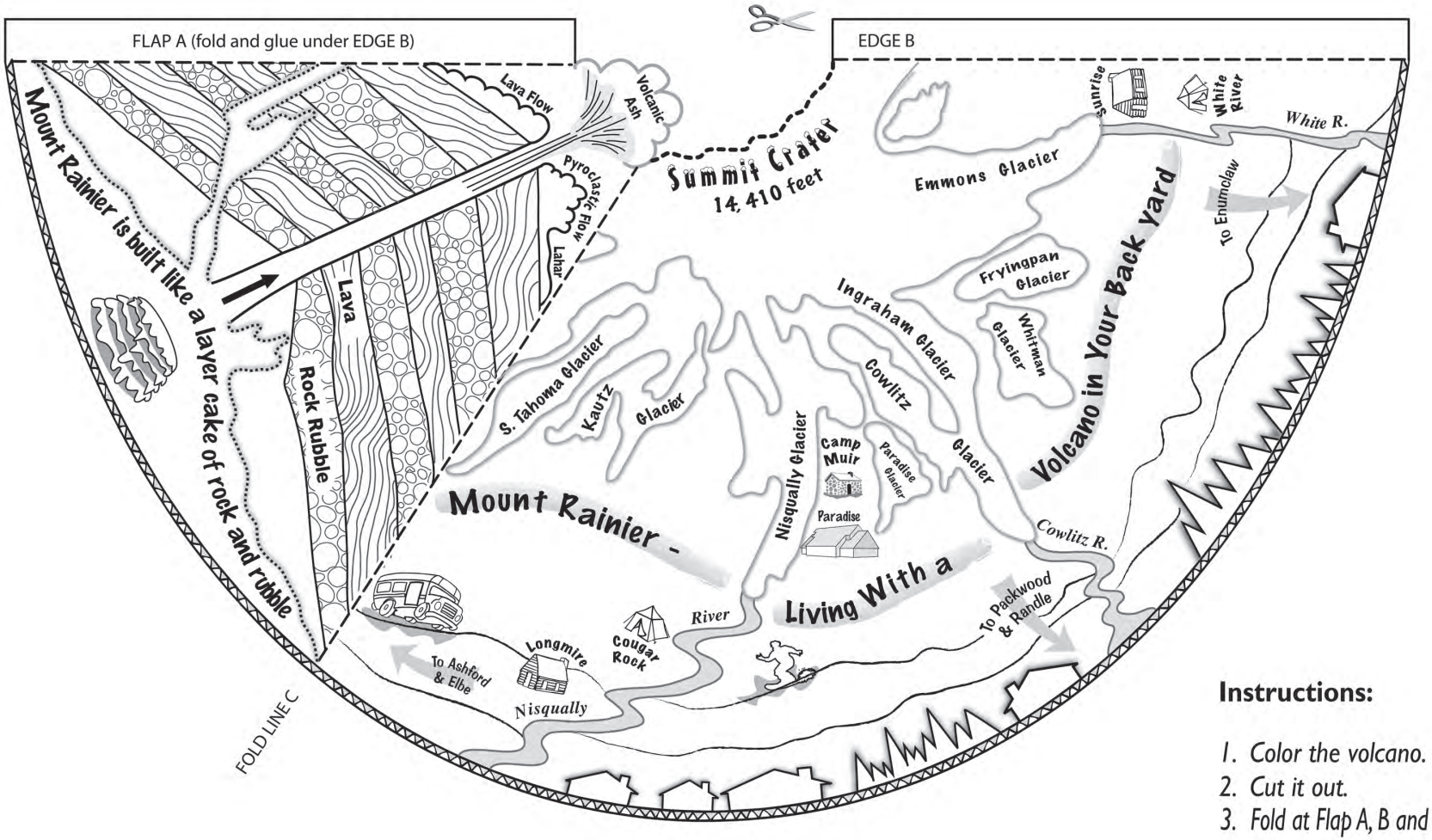
Prager, E.J., and Woodman, N., 2001, Volcano!: Washington, D.C., National Geographic Society, 32 p.

Simkin, T., and Siebert, L., 1994, Smithsonian Institution volcanoes of the world, 2nd edition—a regional directory, gazetteer, and chronology of volcanism during the last 10,000 years: Geoscience Press, Inc., Tuscon, Ariz., 349 p.

Mount Rainier Volcano Hazard Work Group and U.S. Geological Survey, Cascades Volcano Observatory, 1999, Volcanic ash fall–how to be prepared for an ash fall: Washington Emergency Management Division and U.S. Geological Survey, 3-page tri-fold.

Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

Volcano Cone Cutout



Instructions:

1. Color the volcano.
2. Cut it out.
3. Fold at Flap A, B and Line C.
4. Glue Flap A to B.

Living with a volcano in your backyard—An educator's guide with emphasis on Mount Rainier
Coordinated by Carolyn Driedger, Anne Doherty, Cheryl Dixon, and Lisa Faust
U.S. Geological Survey General Information Product 19
http://pubs.usgs.gov/gip/19/

Appendixes I–V

I. Volcanism in a Plate Tectonics Perspective

II. A Short History of Mount Rainier

III. Journey Back in Time—Field Guide

IV. Internet Resources

V. Glossary

This page left intentionally blank

APPENDIX I

VOLCANISM IN A PLATE TECTONICS PERSPECTIVE

Contributed by Tom Sisson

Volcanoes and Earth's Interior Structure

(*See* **Surrounded by Volcanoes** *and* **Magma Mash** *for relevant illustrations and activities.*)

To understand how ***volcanoes*** form, it is necessary to know something about the inner structure and dynamics of the Earth. The speed at which ***earthquake*** waves travel indicates that Earth contains a dense ***core*** composed chiefly of iron. The inner part of the core is solid metal, but the outer part is melted and can flow. Circulation (movement) of the liquid outer core probably creates Earth's magnetic field that causes compass needles to point north and helps some animals migrate. The outer core is surrounded by hot, dense rock known as the ***mantle***. Although the mantle is nearly everywhere completely solid, the rock is hot enough that it is soft and pliable. It flows very slowly, at speeds of inches-to-feet each year, in much the same way as solid ice flows in a ***glacier***.

Earth's interior is hot both because of heat left over from its formation 4.56 billion years ago by meteorites crashing together (accreting due to gravity), and because of traces of natural radioactivity in rocks. As radioactive ***elements*** break down into other elements, they release heat, which warms the inside of the Earth. The outermost part of the solid Earth is the ***crust***, which is colder and about ten percent less dense than the mantle, both because it has a different chemical composition and because of lower pressures that favor low-density ***minerals***. Due to its low ***density***, the crust can be thought of as floating on the mantle. The crust underlying the oceans is no more than a few miles thick, whereas that which forms the continents is twenty to forty miles thick. Crustal rocks are relatively cold, so they are stiff and tend to move as rigid plates, bounded along their margins by major ***faults***, belts of ***volcanoes***, or both. Single plates can be thousands of miles across but are only miles to tens of miles thick. The motion of these plates atop the flowing mantle is known as ***Plate Tectonics***. At ***transverse*** ("***transform") plate boundaries***, plates slide past one another along major fault systems, like the San Andreas in California. At ***divergent plate boundaries***, such as the ***Juan de Fuca Ridge***, plates move away from each other with volcanic activity creating new crust where the plates separate. At a ***convergent plate boundary***, such as where the ***Juan de Fuca Plate*** meets the ***North America Plate,*** one plate sinks beneath an adjacent plate creating mountain ranges, great earthquakes, and chains of volcanoes.

Last modified: September 5, 2014

Principal Types of Magma

The principal types of ***magma*** vary considerably in their chemical and physical properties (composition, temperature, ***density***, ***viscosity***), depending on their origin and subsequent history. Magmas are classified mainly by their chemical compositions. The most abundant ***elements*** in common magmas and rocks are oxygen (chemical symbol O), silicon (Si), and aluminum (Al). For historical reasons having to do with early methods of chemical analysis, the composition of rocks or magmas is usually expressed as oxides (SiO_2, Al_2O_2, etc.) in weight percent units (as opposed to molecular or volume fractions). With increased concentration of SiO_2 ("***silica***"), common magmas or ***volcanic rocks*** are referred to as basalt (up to 52 percent SiO_2), ***andesite*** (52 to 62 percent SiO_2), ***dacite*** (62 to 72 percent SiO_2), or ***rhyolite*** (more than 72 percent SiO_2). ***Basalts*** are widespread in ocean basins and are formed by partial melting of mantle rocks; andesites and dacites predominate along ***subduction zones***, and are accompanied by smaller amounts of basalt and rhyolite. Rhyolites erupt voluminously in continental interiors. Magma temperatures and densities generally decrease, and viscosities increase, from basalt, through andesite and dacite, to rhyolite.

SEAFLOOR SPREADING

(*See* **Surrounded by Volcanoes**, **Soda Bottle Volcano**, *and* **Riding the Magma Elevator** *for relevant illustrations and activities.*)

Most of Earth's Volcanoes Are Beneath the Seas

It may be surprising to learn that most of Earth's ***volcanoes*** are under the oceans. These volcanoes are lined up in long, narrow, undersea mountain ranges, known as ***mid-ocean ridges***, which lie along ***divergent plate boundaries***. As the flanking plates move away (diverge) from the mid-ocean ridges, new ***magma*** rises from the ***mantle*** to fill the space that would otherwise be created. Some of these magmas erupt onto the seafloor as ***lavas,*** whereas others solidify short distances underground as ***intrusive igneous*** rocks. Together these rocks attach to the margins of the diverging plates, creating new ***crust***. The combined process of plate growth and divergence is known as ***seafloor spreading***.

Oceanic Crust is Older and Older away from Mid-Ocean Ridges because of Seafloor Spreading

One consequence of seafloor spreading is that volcanic rocks are young at the ***mid-ocean ridges*** and are progressively older (were erupted longer and longer ago) at greater distances away from the ridges. ***Lavas*** recently erupted at the mid-ocean ridges have little or no ***sediment*** covering them. However, fine sediments, including shells of tiny marine organisms, continually rain down onto the seafloor and bury the volcanic rocks. Because ***oceanic crust*** rocks that are progressively farther from the mid-ocean ridges were erupted longer ago (spreading has since carried them from the ridges), more time has elapsed for sediments to bury them, and the thickness of deep ocean sediments therefore increases progressively away from the mid-ocean ridges. Deep-sea drill samples show that as distance from the ridges increases, fossils in the sediments directly atop the lavas are older species, some of which are now extinct.

The ***eruption*** age of ***volcanic rocks*** can be determined by a variety of methods. One technique is to measure the amount of the element argon in the rock (strictly speaking, one measures argon isotopes—types of argon atoms differing in their neutron abundances). Argon is produced by natural radioactive decay of the element potassium, so by measuring the abundances (and isotopic compositions) of argon and potassium, and knowing the radioactive decay rate of potassium, it is possible to calculate the time elapsed since the magma cooled. An indirect dating method utilizes the magnetic character of a volcanic rock. Earth's magnetic field reverses polarity at erratic intervals (about every one million to several tens of millions of years), and volcanic rocks record this polarity as they cool. Due to seafloor spreading, the oceanic crust develops a symmetric mirror-image pattern of normal and reversed rock magnetic polarity on either side of the ridges. Wide bands of normal or reversed rock magnetic polarity result from long periods when Earth's magnetic field remained constant. Likewise, narrow bands result from brief magnetic periods. This fingerprint-like magnetic pattern of the seafloor is revealed by towing a sensitive magnet behind a ship. By correlating the magnetic patterns to areas where lava ages have been measured directly, it became possible to estimate the ages of the seafloor, and the rates of seafloor spreading and plate motion, over most of the oceans to a precision not attainable on land.

Among other successes, the theory of seafloor spreading explains matches of old fossils, rock types, and rock ages on opposite sides of the Atlantic Ocean, which had perplexed earth scientists, most of whom had believed that land masses remained fixed in place, only moving up and down during cycles of mountain building and ***erosion***. It is now known that North and South America were once connected to Europe and Africa, but split away during opening of the Atlantic Ocean by spreading along the mid-Atlantic Ridge. This tearing apart of large landmasses by newly forming ***spreading ridges***, sometimes called continental rifting, has also been a major process for isolating plants and animals, assisting the evolution of new species. For example, the native mammals of Australia are chiefly marsupials because rifting and seafloor spreading isolated Australia from other land masses long ago. Ensuing evolution took a different course there than on the other continental landmasses that were co-joined until more recently.

Mid-Ocean Ridges Are Oases of Life

Mid-ocean ridges are also interesting because they support oases of life in the total darkness of the deep oceans, and it is possible that such places are where life first began on Earth. In the late 1970s, scientists using deep-diving research submarines, such as the ALVIN, were surprised to find dense communities of clams, crabs, worms, and other creatures clustered at hot springs along the mid-ocean ridges. Prior to this time, it had been believed that all life depended directly or indirectly on sunlight; however, microorganisms living off the heat, and in some instances using sulfur instead of oxygen for metabolism, are the primary food sources for these deep-sea communities. Early in its history, Earth's atmosphere was poor in oxygen, and thus had little ozone (ozone is a gaseous molecule made of three oxygen atoms) to filter out harmful ultraviolet radiation from the sun. Without ozone, areas exposed to sunlight would be bathed in intense ultraviolet radiation that can break up organic molecules, preventing or killing early life forms by inflicting lethal sunburns. Water filters out ultraviolet radiation, much as it does visible light, so hot springs along early Earth's mid-ocean ridges could have supplied energy for life and would have been shielded from lethal radiation. Once begun, life could have migrated to shallower waters and evolved the ability to photosynthesize, using light and carbon dioxide as

fuels, giving off oxygen as a by product. About 2.3 billion years ago photosynthetic organisms made Earth's atmosphere oxygen-rich, creating ozone at high altitudes. With time, the ozone filtered out ultraviolet radiation, allowing life to survive everywhere on Earth's surface.

Magma Results from Reduction of Pressure Beneath the Mid-Ocean Ridges

Magmas form beneath ***mid-ocean ridges*** by an unfamiliar process. Normally we think of things melting because they are heated (ice on a warm day, butter in a hot pan), but melting below mid-ocean ridges results from reduced pressure as hot mantle rocks rise to shallower levels, replacing rocks that moved away from the mid-ocean ridge by seafloor spreading. A rule of thumb is that lower density (larger volume for the same mass) substances are favored at lower pressures (and vice versa). Magma is less dense than solid rock, so if a rock is close to its melting temperature and the pressure is reduced enough, the rock will start to melt. As the hot rock of the mantle wells up beneath mid-ocean ridges, the weight of overlying rocks is less (they move aside at shallow levels), so the pressure drops, and upwelling mantle rock melts by a small amount. Being liquid, the newly created magmas rise faster than the upwelling mantle and escape toward the surface, forming the volcanic and intrusive igneous rocks of the ***oceanic crust***. Conversion of solid (rock) to liquid (magma) absorbs heat, so the rising mantle and the resulting magma actually cool-down slightly as melting progresses. Pressure release melting due to mantle upwelling is the dominant process that creates magma on Earth.

Melting due to reduced pressure is similar to water boiling at cooler temperatures high in the mountains (lower atmospheric pressure). This lower boiling temperature is why pasta and rice take much longer to cook in the mountains (it is not just that you are hungrier and it seems to take longer). Explorers used to estimate the elevations of unknown regions by measuring the boiling temperature of water, using the relation between air pressure (less at higher elevation), altitude, and boiling temperature (the boiling temperature of water is lower by 1° Celsius or 1.8^{o} Farenheit for every 1,000 feett above sea level). Ice is anomalous in its melting, since liquid water is denser than ice (ice, after all, floats). Unlike rock, ice can melt if the pressure increases.

SUBDUCTION ZONE VOLCANISM

Subduction zones recycle oceanic crust back into the mantle

(See **Surrounded by Volcanoes**, **Soda Bottle Volcano**, *and* **Riding the Magma Elevator** *for relevant illustrations and activities.)*

If new crust continually forms along ***mid-ocean ridges*** and then spreads away from the ridges, where does it go? One possibility entertained by a few scientists was that the Earth was expanding over time and ***seafloor spreading*** resulted from this expansion. Much evidence weighed against this expansion model, and the correct interpretation is that oceanic crust and the top of the underlying ***mantle*** eventually sink back into Earth's interior along what are known as ***subduction zones***. Subduction zones were first recognized as regions of frequent, powerful ***earthquakes*** arranged in inclined sheets extending far into the mantle from near the surface. The shallow ends of these sheets of earthquakes begin beneath the oceans, commonly near the submarine valleys or "***trenches***" that run parallel to the margins of some continents and volcanic

island chains. The earthquakes are deeper in the mantle at greater distances away from the trench in the direction of the continent or island chain. Rocks have to be relatively cold to crack and create earthquakes (if hot, they bend easily and flow, like stiff clay), so the inclined sheets of earthquakes show the locations of cold slabs of rock that penetrate into the mantle, beginning at the deep ocean trenches. Scientists have since gathered much additional evidence that ***oceanic crust*** eventually sinks back down (***subducts***) into the mantle. Because of the relative motion of the plates, subduction zones are sometimes referred to as convergent plate boundaries. The deadly Indian Ocean ***tsunami*** of December 26, 2004, resulted from faulting and a powerful earthquake along the subduction zone adjacent to the island of Sumatra, Indonesia.

Ocean-Floor Rocks Subduct because Cooling Increases Their Density

When ***oceanic crust*** forms by volcanic processes at mid-ocean ridges, it and the underlying mantle are hot, but seawater circulating through cracks cools the crust and eventually the uppermost mantle, too. As rocks cool, they shrink slightly but their weight and mass remain the same, so their ***density*** (mass divided by volume) increases. Hot or cold, the rocks of the oceanic crust are less dense than rocks of the mantle, so the oceanic crust does not sink into the mantle on its own. Cooling penetrates into the upper part of the underlying mantle, and when cooled, the upper mantle rocks are denser than rocks of the deeper, hotter mantle. Therefore, the cooler upper mantle rocks eventually sink back into the Earth at ***subduction zones***, carrying along the attached oceanic crust. As the oceanic crust is carried deeper and deeper into the mantle, it is squeezed by the increasing weight of overlying rocks. Eventually the pressure reaches the point that ***minerals*** in the subducted oceanic crust convert into denser types, chiefly garnet. Once this metamorphosis takes place, even the subducted oceanic crust is denser than mantle rocks, causing it to sink on its own account. The continents do not subduct because they have much greater thicknesses of low-density rocks, although at times continents have been dragged into subduction zones and locally have been forced under the edges of adjacent continents. This process of continental collision accounts for some of Earth's largest mountain ranges, notably the Himalayas.

Seafloor Spreading and Subduction Control the Age of the Ocean Floor

All oceanic crust remaining on the seafloor is younger than 200 million years, although scraps of older oceanic crust are preserved by having been faulted up onto continents. Two hundred million years may seem old, but the Earth formed 4.56 billion years ago, and there is good evidence for the presence of surface water as far back as 4.0 billion years. Seafloor spreading and subduction were probably active since that time, and perhaps earlier, so the oceanic crust that formed over more than ninety-five percent of Earth's history is gone, having been recycled back into the mantle.

Subduction Zones—Homes for the Second-Most Abundant Volcanoes on Earth

Subduction zones are home for the second most abundant ***volcanoes*** on Earth, and these are the most important for people because of the ***hazards*** they pose and also because they create watersheds, fertile soils, recreation areas, and many ore deposits. At subduction zones, ***active***

volcanoes are lined up along the margin of the nonsubducting plate (sometimes referred to as the overriding or upper plate, or in miner's terms the "hanging wall"). The upper plate can be made of either continental or oceanic crust. Subduction-zone volcanoes encircle much of the rim of the Pacific Ocean, forming what is known poetically as the ***Ring of Fire***. The Ring of Fire includes the active volcanoes of the Andes and Central America, the Cascades (northern California to southern British Columbia), the Aleutians (Alaska), Kamchatka and the Kuriles Russia), Japan, the Philippines, the island chains of Tonga and Kermadec extending south to New Zealand, and a branch forming the Izu-Bonin and Marianas island chains (southwest Pacific). Along the Ring of Fire, oceanic crust subducts beneath most of the landmasses surrounding the Pacific Ocean. This contrasts with the Atlantic Ocean where subduction only takes place in small areas along the Lesser Antilles (Caribbean) and the South Sandwich Islands (between South America and Antarctica). Another major area of subduction zone volcanoes is in Java and Sumatra (Indonesia), due to subduction of the Indian Ocean seafloor.

Water Induces the Melting of Rocks Deep below Subduction-Zone Volcanoes

Different subducting plates dive into the mantle at different slopes and sink to increasing depths away from the plate boundary (illustrate this by slowly sliding a sheet of paper off the edge of your desk). The volcanoes usually sit in a line above where the subducting plate passes through about 100 kilometers (60 miles) depth in the Earth. Depending on the subducted plate's steepness, this line of volcanoes can be close to (steeply dipping plate), or far from (gently dipping plate), where the ***oceanic plate*** starts to descend into the mantle. The earliest theory for the origin of subduction-zone volcanoes was that the sinking plate releases water as it warms up in the mantle (think of the plate as sweating). This water causes small amounts of melting in the hotter rocks of the nearby mantle. These low-density ***basaltic magmas*** then rise toward the surface. Some of these basaltic magmas feed volcanoes directly, but most basaltic magmas cool to varying degrees and shed dense ***crystals***, thereby changing in chemical composition to ***andesitic*** and ***dacitic*** magmas. Hot basaltic magmas may also incorporate and melt rocks from the crust, leading to similar or greater changes in composition and thus in density, ***viscosity***, and temperature. An alternate theory is that the subducting plate itself heats up enough to melt by small amounts, creating magmas that rise to the surface. Because it is conceptually easy, this idea of plate melting is commonly presented in introductory science textbooks; however, calculations of the temperatures of sinking plates have long shown that the plates do not generally get hot enough to melt. Notable exceptions are where the subducting plate has only recently formed at a mid-ocean ridge and is still hot when it begins to subduct. Temperatures sufficiently high for melting are also inconsistent with the abundant deep, powerful subduction-zone earthquakes that require rocks to be cold enough to crack.

How Adding Water Melts Hot Rock

The ability of water or steam to induce melting in hot mantle rocks is similar in principle to the ability of salt to melt ice on a road or sidewalk. As a rule, adding a chemical substance that can dissolve in a liquid but not in a solid promotes the conversion of the solid to the liquid. Salt will dissolve in water, but practically none can be incorporated into the structure of ice. Adding salt to ice will melt some of the ice, as long as the ice is already close to its melting temperature.

Because melting absorbs heat (the atoms need energy to move quickly and freely in a liquid), adding salt to ice also lowers the temperature below the freezing point of fresh water. This is why salt-ice mixtures are used to lower the temperature in old-fashioned ice cream makers. At the high pressures of subduction zones, much water can dissolve in ***magma***, but very little can be absorbed into hot mantle rocks. The release of water from the subducting plate therefore partly melts the adjacent hot mantle and cools it slightly. The localization of volcanoes to 100 kilometers (60 miles) above the subducting plate may indicate the breakdown of a specific water bearing ***mineral***, either in the subducting plate or in the adjacent mantle, leading to copious melting.

HOTSPOT VOLCANISM

Some Long Chains of Volcanoes Are Evidence of Plate Movement over Hotspots

Other major sites of ***volcanism*** on Earth are isolated ocean island groups and ***seamounts*** (Galapagos, submarine mountains), ocean island or seamount chains (Hawaii), broad submarine plateaus (Kerguelen in the south Indian Ocean), and in continental interiors (Yellowstone). Volcanic island chains like Hawaii form as a tectonic plate moves over a localized site of melting in the underlying ***mantle*** (some call these sites of melting "***hotspots***"). ***Magma*** rises from the site of melting and pierces through the plate, creating a volcanic seamount that may become an island. As the moving tectonic plate gradually carries the seamount or island away from the underlying source of magma, volcanism at that edifice eventually dies out. A new ***volcano*** forms above the melting region at the leading end of the volcanic chain and a new seamount or island is created. The progressive growth of these volcanic chains is somewhat like a sewing machine (the hotspot) stitching through moving fabric (the plate), leaving a line of stitches that is young at one end (the active volcanic island) and gets progressively older away from the needle (the island chain).

Because of plate motion, some chains of volcanoes and seamounts are quite long and vary progressively in age along their length, with young ***active volcanoes*** at one end and volcanoes that systematically increase in age up the chain. The island of Hawaii (the Big Island) is the young end of the Hawaiian island chain. Along the chain to the northwest, the volcanic islands are so old that most have been eroded away and remain as a line of submarine seamounts extending north to nearly the Aleutian Islands.

Hotspots in Motion

Until recently it was thought that ***hotspot***s did not move relative to each other and to Earth as a whole, thereby providing reference locations against which absolute plate motions could be determined. More careful observations have shown that hotspots are not truly fixed in position. They do move relative to one another but at speeds less than the motion of the tectonic plates. The slow motions of hotspots are taken as evidence that they are rooted deeply in the ***mantle*** and are not shallow features that would be influenced by tectonic plate motion. The most widely accepted explanation of hotspots is that they are narrow plumes of mantle rock that are hotter and less dense than the surrounding mantle and rise through it, much as warm air and smoke rise from a chimney or smokestack. As the plume rises, pressure-release melting creates magmas that rise to the surface, feeding the active end of the volcanic island chain.

Outpourings of Basalt Form Lava Plateaus

Oceanic plateaus form by infrequent, but voluminous outpourings of ***magma*** in restricted locations on the seafloor away from mid-ocean ridges. These plateaus are the oceanic analogs of "***flood basalts***" that form thick blankets of basalt at some continental areas such as central Washington and large areas of India, Brazil, western Africa, and Siberia. A popular but speculative explanation for oceanic plateaus and flood basalts is that they form by partial melting of the large, blob-like top of a mantle plume (a "plume head" or "mantle ***diapir***") that has just risen to depths shallow enough to start melting. It is unlikely that the many small volcanic seamounts and isolated volcanic oceanic islands are each caused by mantle plumes; they are too small and short lived and they are not aligned in order of age. Volcanic seamounts are more abundant in some regions of the oceans than in others, particularly the equatorial-to-southwest Pacific. There is some evidence from ***earthquake*** speeds that the mantle beneath that region is slightly hotter than elsewhere (hotter rocks transmit earthquake waves more slowly). A subtle bulge in the average shape of Earth's surface also coincides with this region, and it may be that the mantle is upwelling slightly over an enormous region, counterbalancing the down-flow of mantle due to ***subduction*** along the ***Ring of Fire*** to the north, west, and east. This very gentle upwelling leads to traces of melting that fuel the numerous small seamounts of the southwest Pacific.

Volcanism in Continental Interiors

Most large volcanic centers in continental interiors, such as at Yellowstone, are fueled from below by hot ***basaltic*** magmas that originate in the mantle, but most of the erupted ***lavas*** and ashes at these centers are unlike those of the mid-ocean ridges and ***hotspots***. Much of the western United States from eastern California to western Utah, and from Mexico north through eastern Oregon has been pulling apart for about 30 million years. This pulling apart thins the crust, reducing the pressure on the underlying mantle, leading to small amounts of melting. Some of these melts rise to the surface directly and erupt as basaltic lava flows. Many, however, engulf and melt blocks of rock from the crust, or grow and shed dense ***crystals*** upon slow cooling at great depth, and through these processes transform into lower temperature and more viscous magmas like ***dacite*** and rhyolite. Yellowstone itself lies at the eastern end of a chain of large, ***extinct*** volcanic centers that are progressively older to the west. The age succession and great volumes of magma produced are similar to ocean island chains like Hawaii. Many scientists have proposed that Yellowstone lies atop a hotspot, perhaps fed by a deep mantle plume. Others disagree, and efforts are underway to produce 3D images of the upper mantle below Yellowstone, using earthquake speeds to search for a hot mantle plume, but results to date are inconclusive. Whatever their original cause, the mantle-derived ***basalts*** stall in the deep crust, crystallizing to great degrees, and engulfing and melting rocks of the continent, giving rise to the rhyolitic magmas that dominate Yellowstone ***volcanism***.

BIRTH OF A VOLCANO

(*See* **Surrounded by Volcanoes**, **Cascade Volcano Timeline**, **Soda Bottle Volcano**, **Riding the Magma Elevator**, **A String of Volcanoes**, *and* **Volcano Hall of Fame** *for relevant illustrations and activities.*)

The Lifespan of a Volcano is Generally Greater Than the Lifespan of a Human

There are surprisingly few accounts of the births of wholly new ***volcanoes***, probably because volcanoes exist over ***geologic time*** spans that are long compared to human history. For example, the ***active volcanoes*** of the Cascades started to grow several tens of thousands to roughly half a million years ago. Several grew atop the eroded remains of volcanoes that had occupied the same locations, in some cases for as far back as one million years ago. Evidence of human habitation in North and South America does not become widespread until about 13,000 years ago, close to the end of the last Ice Age. In fact, skeletons like those of modern humans have been found as old as about 160,000 years (in Africa and Eurasia), but no older, so it is likely that modern humans had not even evolved at the time that most of the present Cascade and many other ***active volcanoes*** started to grow. Lacking observations, accounts of the inception of volcanoes are necessarily general and center on processes.

Magmas Form by Melting Events—They are Not Tapped from a Long-Lasting Molten Zone in the Earth

Regardless of setting, the events leading to a volcano begin by partial melting of rocks deeper in the Earth. Contrary to popular conception, the tectonic plates ride on hot rock, not liquid, and there is no large region or layer of melt in the Earth other than the outer core. The molten metal of the outer core is far too distant and dense to rise to the surface and feed volcanoes. In most cases melting begins in the upper mantle where temperatures are quite high—about 1,300° Celsius (2,400° Farenheit). Rocks melt incrementally over a range of temperature or pressure and it is rare for a rock to melt entirely to liquid. Instead, small amounts of melt form, coexisting with abundant crystals. Because the liquid is less dense than the rock, it filters upward initially as thin films between melting crystals, but gradually the liquid accumulates into veins and pods. One might expect this melt would rise to the surface directly and rapidly so that specific eruptions would represent specific melting events, or that the volcanoes would erupt continuously during the periods of melting; but this does not seem to be so. Magmas that erupt or reach shallow levels in the crust typically are cooler (down to about 700° Celsius (1,300° Farenheit) than melts formed directly from mantle rocks. Their chemical compositions have changed in route to the surface, and these changes strongly influence how the magmas erupt. As magma rises through the crust, it loses heat to its surroundings, and this cooling forces the magma to start to grow crystals. It so happens that the first crystals to grow are rich in some chemical elements, but not in others, so that crystal growth changes the chemical composition of the remaining melt. Typically, crystallization enriches the melt in silicon, sodium, potassium, and dissolved water, and impoverishes it in magnesium, iron, and calcium. Since the new crystals are also denser than the melt, the crystals tend to lag behind the rising melt, and this separation of crystals from melt changes the bulk composition of the magma. Because of differences in chemical composition, many crustal rocks melt at lower temperatures than mantle rocks, so hot magmas produced in the mantle can also incorporate and melt rocks of the crust, which further

cools the mantle-derived magma and modifies its composition. Cooling, crystallization, and chemical changes take time and are evidence that magmas reach the surface with some difficulty, stalling at various levels, and in many cases failing to reach the surface at all.

Crustal Conditions Influence Ascent of Magma

Some factors that impede ascent of magma are: (1) The shallow crust is relatively cool and loss of heat to the crust forces magmas to grow crystals, which make the magmas more viscous and dense and slows them down. Many small batches of magma lose so much heat that they solidify completely within the crust and never reach the surface. (2) The magma has to open a pathway to the surface and this requires breaking rock and moving it aside. Breaking and moving rock takes work (try it), and this work is accomplished only if enough magma accumulates so that its buoyant (floating) force breaks and displaces overlying rock. In areas that are spreading apart, like mid-ocean ridges, cracks open easily and there is little resistance to the ascent of magmas. Other regions are squeezing together and uplifting mountains, and in these areas it is more difficult for magmas to move to the surface. Larger masses of magma have to accumulate and ascent rates are slower. In some cases the magma doesn't reach the surface at all, and instead solidifies underground, forming ***granite*** and other similar ***intrusive igneous*** rocks like ***gabbro*** and ***diorite*** (granite is ***rhyolite*** or ***dacite*** magma that crystallized underground; similarly, most gabbros crystallized from ***basalts***, and most diorites crystallized from ***andesites***).

Gases Propel Some Magmas to Earth's Surface

Eventually, enough magma may work its way to shallow levels in the crust that some breaks through to the surface and starts the growth of a new volcano. The final few miles of ascent are very different from everything up to that point because the pressure falls low enough that ***gases*** boil out of the magma, making it much more voluminous and less dense. The abundant gases are steam (H_2O) and carbon dioxide (CO_2), with lesser sulfur compounds (SO_2, H_2S). Deep in the crust and upper mantle, the pressures are high enough that most or all of these gases are dissolved in the melt, like the carbon dioxide in an unopened can of soda or a bottle of champagne. With the sudden reduction in pressure close to the surface, the vigorous boiling-out of gases jets the magma out of the ground at high speed, again like a rapidly opened carbonated drink (think of the champagne opened by the winning team at the end of the World Series). High speeds and sudden expansion of gas bubbles fragment the magma into bubbly molten lumps and bits that either cool and harden into various types of ***tephra***, including ***pumice***, or that fall back to the ground while still molten and feed ***lava flows***.

In some situations the gases escape before the magma reaches the surface, in which case the degassed magma is more likely to feed a lava flow or ***lava dome***. Magmas that come nearly directly from the mantle (basalts) are hot, fluid, and relatively poor in dissolved gases. The fluidity of those magmas allows gas bubbles to escape easily, and their ***eruptions*** tend not to be very explosive. The explosive periods are short (hours) and the lavas generally fountain no more than 500 meters (1,500 feet) into the air (fine-grained ***ash*** particles rise higher). Once a clear conduit has opened to the surface, the gas bubbles can escape readily, and eruptions become effusive, feeding lava flows. Most eruptions in Hawaii are of this type.

Magmas that move through the crust slowly, and that cool and change in chemical composition by growth and separation of ***crystals***, and by melting of crustal rocks (andesites, dacites, rhyolites), are viscous (thick, resisting flow) and can have high concentrations of dissolved gases (especially H_2O). Their eruptions can be extremely explosive because of the large quantity of gases and because the magma's increased ***viscosity*** keeps the bubbles from escaping until very close to the surface. Explosive eruptions of dacites and rhyolites can throw magma to more than 20,000 meters (65,000 feet) into the air. So much magma can erupt in a short time that the ground collapses, forming a caldera, like at Yellowstone, Crater Lake, or Long Valley (eastern California). Other, smaller explosions are created where magma encounters groundwater at shallow depths. The groundwater is heated to steam, thereby expanding significantly, leading to explosions that are usually small. For a new volcano, the early explosions are likely to be small and caused by groundwater heated to steam either directly by shallow magma or by hot gases released by shallow magma. Eventually, the groundwater dries out, and larger explosions caused by direct release of magmatic gases take over.

A New Volcano May be Heralded by Events Weeks to Hundreds of Years before the First Explosions

Releases of magmatic gas and boiling of shallow groundwater shake the ground, and produce small ***earthquakes*** and ***steam vents***. It is likely that a new ***volcano*** would be signaled with subtle rise or fall of the ground surface over a broad area, accompanied by frequent small earthquakes, and the release of volcanic ***gases*** either from new cracks in the ground, or into shallow groundwater or springs. Springs and streams might become warmer and richer in sulfur or chlorine derived from the degassing magma at depth. Steam could issue from the ground, or the water could condense underground, leaving only invisible carbon dioxide to reach the surface. Weeks to hundreds of years might pass before the first explosions, depending on the amount of magma involved. The first explosions would probably be small and caused by boiling of groundwater near the surface, and again, weeks to hundreds of years could pass before the first eruptions of magma. Once eruptions commence, the volcano can remain intermittently active for as little as a few decades, or for as much as a million years, depending on the supply of magma.

PRINCIPAL TYPES OF VOLCANOES

(*See* **Lava Building Blocks of Mount Rainier**, **Volcanic Processes**, *and* **Understanding Volcanic Hazards** *for relevant illustrations and activities.*)

Shield Volcanoes

Particular ***volcanoes*** tend to erupt the same kinds of ***magma*** over their history and this results in the volcanoes developing into characteristic shapes. If a volcano mainly erupts high-temperature, fluid, gas-poor magmas (***basalts***), its ***lavas*** can spread as thin ribbons and sheets for long distances in various directions. More lava accumulates close to the ***vent*** than farther away, so if the volcano is active long enough, it builds up into a very broad, gently rounded hump.

Seen from a distance, these volcanoes look like enormous shields resting on the ground, and consequently they are known as ***shield volcanoes***.

Shield volcanoes are typically big and long-lived. They include the largest and most active volcanoes on Earth—Mauna Loa and Kilauea in Hawaii. Many shield volcanoes are capped by a circular depression known as a caldera (a broad pit many times larger than any included ***vents*** or ***craters***), and the surfaces of shield volcanoes can be decorated by many smaller shields, ***cinder cones***, and craters. Some particularly large shield volcanoes have systems of aligned fissures where lava erupts preferentially, leading to growth of raised, ridge-like "rift zones" many tens of kilometers (miles) in length. In some cases shield volcanoes are so broad and gently sloping (typically less than 5 degrees steepness) that they are difficult to recognize as volcanoes. In the Pacific Northwest, the broad raised area south of Bend, Oregon, is the shield of Newberry Volcano. Similarly, a broad, raised area east of Mount Shasta, northern California, is the shield of Medicine Lake volcano. Steeper slopes are typical for the submarine portions of oceanic shield volcanoes because water chills lava, reducing the flow distance. Due to ***density*** of water being greater than the density of air, the water also provides buoyancy, allowing lava and rock debris to accumulate to steeper slopes before failing. Nevertheless, steep submarine slopes sometimes collapse, producing large submarine ***landslides*** whose deposits are spread across the deep ocean floor surrounding the volcano. The Hawaiian Islands and the Galapagos (among others) are areas where large submarine landslides have been discovered. Though infrequent (perhaps a few worldwide every 100,000 years), these events are capable of producing large, ocean-spanning ***tsunamis***.

Stratovolcanoes

Many ***volcanoes*** in ***subduction zones*** erupt pasty, viscous magmas (mostly ***andesite*** and ***dacite***, with some ***rhyolite***). Compared with shield volcanoes, their ***lava flows*** tend to be thick and travel short distances, and commonly the magmas break up into fragments, either during explosive ***eruptions*** or by crumbling of the margins of slowly moving lava. End results are that the volcanoes are tall, steep-sided (25 degrees is common), and are made up of diverse combinations of lava flows, ***lava domes*** (flows that are so pasty they just pile up atop the ***vent***), and fragmental rock debris. Typically the upper surface of each lava flow consists of blocky lava fragments and ***ash***, so that successions of flows appear as alternating layers of dense rock (the slowly cooled flow interiors) and ***rubble*** (each flow's rubbly carapace). This distinctly layered or stratified appearance gives rise to the name ***stratovolcano*** (also known as ***composite*** volcano because they are composites of diverse volcanic materials). Like shield volcanoes, some stratovolcanoes are capped by a caldera or crater, though ***calderas*** on stratovolcanoes are usually products of especially large and explosive eruptions (Crater Lake, Oregon), whereas many calderas on shield volcanoes result from summit collapse during the quiescent eruption of large volumes of fluid magma. Because stratovolcanoes are steep, often tall, and are made of poorly consolidated materials, their flanks can collapse, leading to very destructive ***landslides*** and ***lahars*** (fast moving volcanic mud or ***debris flows***). In slightly more than 100 years, there have been four large collapses of stratovolcano flanks (Mount Bandai-san, Japan, 1888; Bezymianny, 1956; and Shiveluch, Kamchatka, Russia, 1964; Mount St. Helens, USA, 1980), and countless smaller debris flows. The well-known tall volcanoes of the Cascades are all stratovolcanoes.

Cinder Cones

A cinder cone is a third type of volcanic edifice that forms where gas-bearing but fluid magmas (some basalts) erupt from a single location. Most ***basaltic*** magmas have low concentrations of ***gases***, so the gases only boil out very near the surface and jet the magma up to a few thousand feet in the air. The rapid motion and sudden boiling break up the magma into frothy lumps and particles that cool and harden into dark cinders riddled with holes left from the escaping gas bubbles. Because the magma is jetted only short distances into the air, the cinders fall back to the ground right around the ***vent*** and pile up into a cone. ***Cinder cones*** usually form during only one eruption or ***eruptive period***, though this period may consist of multiple separate eruptions spaced over years or even decades. Cinder cones are small features, typically no more than one kilometer (slightly more than half a mile) across and up to 300 meters (1,000 feet) high. In Hawaii, eruptions frequently begin with many hours of ***lava fountaining***, where magma jets into the air from vents spaced closely along a crack in the volcano's surface. Quickly the eruption narrows to one or a few locations and the height of magma fountaining lowers. Cinders start to accumulate around these vents, piling up as cinder cones. At times, magma will well up within a cinder cone and breach its wall. The magma then pours from a notch or gap in the side of the cone, feeding a lava flow. This can happen several times, but continued low fountaining of magma at the vent can quickly heal the gap by filling it with cinders. When the eruption ends, the lava flow can deceptively appear to have tunneled out the side of the cinder cone.

Large Ash-Flow Calderas

Ash-flow calderas are another major type of ***volcano***. These volcanoes are usually many tens of kilometers (miles) across and develop over hundreds of thousands to more than a million years, during which large volumes of gas-rich, viscous magma erupt suddenly and explosively, one or more times, separated by extended periods of intermittent ***lava*** eruptions. During the explosive events, the magma first jets high into the atmosphere, breaking up into ***pumice*** and ash, but then so much material erupts in a short time that pumice and ash collapse down and sweep across the landscape as a high-velocity sheet of hot ***tephra***. These eruptions bury the landscape in blankets of hot ash tens to locally hundreds of meters thick. In some, the ash and pumice are still so hot when the flows comes to rest that the grains stick together, squeezing out hot ***gases*** and air, and collapsing and cooling into dense rock—a process known as "welding." So much magma can erupt in a short time that the ground surface collapses, creating a circular or oval depression kilometers to tens of kilometers (miles to tens of miles) across, and in some cases swallowing up part or all of the preexisting volcanic edifice. Because large ash flows travel many tens of kilometers (miles), the resulting volcanoes have low, broad forms, much like a shield volcano capped by a large caldera. Subsequent eruptions of pasty lava often partly fill the caldera, and shallow intrusions of magma can bow the caldera floor upward, both obscuring its shape. Yellowstone is probably the premier example of a large ash flow caldera.

VOLCANO AND MOUNTAIN BUILDING IN THE PACIFIC NORTHWEST

(*See* **Cascade Volcano Timeline** *and for relevant illustrations and activities.*)

Current Volcanoes of the Cascade Range Grew upon Older Mountains

Images of the Pacific Northwest center on forested mountains sloping down to the sea. The mountains are snow capped in their highest reaches and formed in two ways. Most are made of rocks that were pushed up by squeezing and sliding forces along the edge of the North American tectonic plate, much like rumpled covers on an unmade bed. The currently ***active volcanoes*** of the Cascades grew atop these mountains by ***eruption*** and accumulation of ***lava***, like gigantic versions of castles made from dripping wet sand by children at the beach. While the two types of mountains formed in different ways, they are not unrelated. Many of the rocks forced up by squeezing and sliding processes were originally lavas and other ***volcanic rocks*** that erupted tens of millions of years ago, or are ***granites*** that crystallized miles underground from ***magmas*** that failed to erupt. Active volcanoes are few and small in the North Cascades, the highest part of the Cascade Range. It is likely that strong squeezing and uplift there prevents most magma from penetrating the crust. Instead, magma probably ponds near the base of the ***crust*** and, in part, buoys up the region.

Coastal Mountains Built by Faulting and Squeezing along the Continental Margin

The detailed development of the Pacific Northwest landscape is complicated. In simple terms, two parallel mountain belts, the Coast Ranges (including the Olympics) and the Cascades, are separated by a valley occupied in the south by the Willamette River and in the north by Puget Sound. Offshore, ***oceanic crust*** generated at the ***Juan de Fuca Ridge subducts*** in a northeasterly direction beneath North America. As the oceanic crust subducts, sandstones, mudstones, and volcanic hills are shoved beneath the edge of the continent and warp it upward. Much of the Coast Range, particularly in the Olympics, are built of rocks scraped off the subducting oceanic crust. Since the subducting oceanic crust is moving oblique to the north-trending edge of the continent, the rocks of the Coast Ranges are also being shuffled to the north and are twisting or rotating slowly clockwise. This slight northward shuffling extends into the valleys east of the Coast Range and drives motion on recently discovered ***faults*** that cut beneath the cities of Seattle and Portland. Many of the rocks that are uplifting to form the Coast Range, and that underlie the valley between the Coast Ranges and the Cascades, are lavas that erupted under the sea. These lavas probably erupted as ***seamounts*** near a mid-ocean ridge, as is indicated by the lavas' distinctive chemical compositions. It is likely that the Willamette Valley, Puget Sound, and the eastern margin of the Olympics are floored by a fragment of oceanic crust that formed about 60 to 45 million years ago, as demonstrated by radiometric measurements of the lavas' ***eruption*** ages. In places these lavas are inter-layered with sandstones and shales composed of ***sediments*** derived from the land showing that the seamounts grew not far off the margin of the continent. The seamount lavas are overlain by thick accumulations of ***sedimentary rocks***, varying between 50 and 40 million years in age. This indicates that by about 40 million years ago the region had become attached to the edge of North America.

The North Cascades are Built Mainly of Granites and Metamorphic Rocks

The North Cascades, from Snoqualmie Pass (due east of Seattle) into British Columbia to the north, are made chiefly of highly metamorphosed (recrystallized by heat and pressure) volcanic and sedimentary rocks that are intruded by masses of granite. The original volcanic and sedimentary rocks were erupted or deposited from about 100 million to perhaps slightly more than 1 billion years ago, and were assembled by ***fault*** action to form narrow northwest-trending belts of related rocks, each belt about 25 kilometers (15 miles) wide and 160 kilometers (100 miles) long. Where these ***metamorphic*** rocks originated, and how they came together, is not understood well at all. Granites of roughly two ages intrude (cut and displace) the metamorphic rocks and many of the faults. These granites crystallized as the deep underground roots of subduction-zone ***volcanoes*** that have since been eroded away. One group of granites crystallized about 90 million years ago. The other group is younger, having crystallized between about 35 and 15 million years ago, but there are also very small masses of granite as young as about 2 million years. Many of the older granite masses solidified roughly 25 kilometers (15 miles) deep in the ***crust***, while the younger granites crystallized at much shallower levels, perhaps no more than about 8 kilometers (5 miles) deep. The difference in crystallization depths shows that the region was uplifted into mountains and deeply eroded at least once, and possibly several times over the last 90 million years.

South of Snoqualmie Pass, the Cascade Mountains Consist of Volcanic and Sedimentary Rocks

From near Snoqualmie Pass southward, most of the Cascade Range is composed of ***lava,*** sedimentary rocks derived from lava (sandstones and breccias), and some pyroclastic rocks. The earliest of these ***volcanic rocks*** erupted about 40 million years ago and partly bury the older sandstones and shales that cover the seamount lavas flooring the Puget and Willamette basins. The appearance of widespread volcanic rocks at 40 million years ago marks the beginning of the Cascades magmatic arc, a belt of vigorous volcanic activity driven by ***subduction*** off the margin of North America that extends from northern California to southern British Columbia. Many ***volcanoes*** began, grew, and died, and the currently active Cascade volcanoes are only the latest products of this ongoing process. At first, volcanoes spread lava flows and related sediments broadly over a relatively flat region along the edge of the continent, and under part of the ocean. Eventually, taller volcanoes grew and their eruptive products overlapped one another. From time to time, periods of modest squeezing and faulting uplifted, tilted, and folded (bent) the volcanic rocks. ***Erosion*** incised gentle valleys through the volcanic debris, and later eruptions refilled some valleys with volcanic rocks. Gradually, the volcanoes grew high enough to cast a rain shadow east of the Cascades. At the same time, the crust underneath much of the volcanic range was subsiding, allowing the accumulation of perhaps as much as a 15-kilometer (about 10 mile) thickness of volcanic rocks spanning the Cascades from southern Washington through Oregon.

Subsidence of the crust ended in the southern Washington Cascades near or shortly after about 14 million years ago, and was followed by strong uplift. This uplift raised the volcanic rocks, and erosion cut into these, exposing small masses of granite that were the underground feeder systems for long-lived volcanic centers. The youngest granites in southern Washington solidified at about 8 kilometers (5 miles) below the surface from 17 to 14 million years ago. That these granites are

now exposed on the surface shows that as much as 8 kilometers (5 miles) of uplift and erosion have taken place since then. A large, nearly flat basin lay to the east of the active Cascades volcanic chain. Over the period of 17.5 to 13.5 million years ago, a great outpouring of hot, fluid lava erupted from near the present Washington-Idaho-Oregon border and flowed westward to the eastern foot of the Cascades. These lava flows, known as the ***Columbia River flood basalts***, form great stacks of flat-lying, dark lavas along the Columbia River and its tributaries east of the Cascades. Some of the flood ***basalts*** even reached the Pacific Ocean through the gap in the Cascades carved by the Columbia River. The flood basalts are uplifted and tilted eastward along the east side of the Cascades in Washington, confirming that much of the uplift of the Cascade Range is younger than about 14 million years ago. Uplift results mainly from regional squeezing and shearing motions along the ***North American Plate*** margin and probably continues today.

The Cascade Range in Oregon—Less Complex than in Washington

In Oregon, the Cascade Range has not been squeezed and uplifted to the extent it has in Washington. As a result the volcanic rocks in Oregon are not as steeply or complexly tilted. Instead, the mountain range in Oregon is spreading apart slightly, with the western slope moving to the west and north relative to the eastern slope. Global Positioning System (GPS) measurements show that this sense of motion continues today. The minor extension (spreading) allows fissures to open easily and ***vents*** magmas to the surface over broad areas. Whereas in Washington, the large ***active volcanoes*** are separated by 100 to 160 kilometers (60 to 100 miles) of folded, tilted, and eroded older rocks, the large volcanoes in Oregon are separated by chains of smaller volcanoes whose lava flows were fed by ***basaltic*** magmas that ascended though these fissure systems. Magmas were able to rise quickly along the fissure systems and arrived at the surface hotter and less modified chemically than most lavas erupted in the Washington Cascades.

Pacific Northwest Plate Tectonics Summary

Plate tectonic processes forged the landforms of the Pacific Northwest. In the North Cascades, the dominant mountain-building processes are squeezing and uplifting of older rocks. Few young volcanic deposits remain, and possibly few magmas are able to reach the surface because of tectonic forces holding fissures closed. Granite intrusions are the chief products of magmatism preserved in the North Cascades. It is also possible that some of the ongoing uplift in the North Cascades is due to buoying up of the region by magmas trapped beneath the ***crust***. In Oregon, constructional volcanic features define the landforms of the Cascade crest. Southern Washington represents a complex transition area, where much lava has erupted. However, the region has also been squeezed and uplifted, mainly in the last 14 million years, so that most landforms result from faulting, ***folding***, and ***erosion*** of relatively young volcanic rocks. To human observers, the currently active Cascade ***volcanoes*** are large, impressive, and potentially dangerous, but in the overall history of the Cascades, they are comparatively small volcanic centers.

MOUNT RAINIER AND SOME COMPARISONS WITH NEIGHBORING CASCADE VOLCANOES

(*See* **Fire, Flood, and Fury**, **Nineteenth–Century News**, **A String of Volcanoes**, **Volcano Hall of Fame**, **Lahar in a Jar**, *and* **The Next Eruption of Mount Rainier** *for relevant illustrations and activities.*)

Eruptions Built Cones of Many Cascade Volcanoes during the Ice Ages

All of the large ***active volcanoes*** in the Cascades started to grow during the ***Ice Age*** (a period from around 2 million to 10,000 years ago) among earlier, older mountains. ***Glaciers*** filled most of the high mountain valleys, and mountain slopes were sheathed with snow and ice fields. It is likely that many Cascade volcanoes began near or beneath snow and ice with early steam ***vents*** melting ice caves and pits. Meltwater from the glaciers would have flooded into the ***steam vents***, leading to small explosions. Eventually, small amounts of ***magma*** reached the surface, melted through and chilled against snow and ice, and formed small ***lava flows*** and ***lava domes***. Explosions would have spread muddy debris onto the glaciers, forming wet, boulder-rich slurries (***lahars***) that traveled far down the glacier systems. Between ***eruptions*** the glaciers would have ground away at the early lava flows, in some cases removing them entirely. As more and more ***magma*** reached the surface, eruptions would have become more frequent and voluminous, building volcanic edifices that were large enough to support their own glacier systems. At the end of the Ice Age, the glaciers retreated to areas of highest elevation, such as at Mounts Rainier, Adams, St. Helens, Hood, Baker, Shasta, and Glacier Peak—all ***active volcanoes*** today.

Evidence that Mount Rainier is an Active Volcano

Anyone who has climbed to the summit of Mount Rainier will have seen evidence that the ***volcano*** remains active and will erupt again. The summit is capped by two ***craters***, each about 0.4 kilometer (0.25 mile) across. The crater to the west is the older and is overlapped by the east summit crater, which is a nearly perfect circle of outward sloping lava, uninterrupted or breached by the large glaciers that begin near the summit. If this were an old, ***extinct volcano***, the ***glaciers*** would have carved pieces out of the craters. Moreover, steam and warm mist emanate from areas along the inner walls of both craters and have melted a complex of caves into the ice that fills the crater floors. From the first ascent of Mount Rainier in 1870, climbers have sheltered in these caves, steamed on one side, and frozen on the other. The steam is evidence that Mount Rainier is still receiving heat from below. Besides these qualitative observations, age measurements of ***lavas*** and ashes from Mount Rainier show that the last lava erupted close to 2,200 years ago, and that ***pyroclastic flows*** erupted as recently as 1,100 years ago. Small amounts of ***ash*** and ***pumice*** erupted from Mount Rainier as recently as the 19th century. Minor pumice was deposited between A.D. 1820 and 1850 and there are reports of an observed ash eruption in late November and December of 1894. The truth of the 1894 accounts has been questioned, and no physical evidence (ash, pumice) has been found to corroborate an eruption. Nevertheless, many of the descriptions match the behavior of small ***ash clouds*** produced by very minor eruptions of other volcanoes, and it is likely that Mount Rainier did erupt in 1894 as reported. Mount Rainier has been active for the last 500,000 years; so the 2,200-year interval since the last known lava eruption is less than half a percent of the lifespan of the volcano. The style of volcanic activity remains the same, with no evidence of diminution. For these reasons, Mount Rainier is considered to be an ***active volcano***, and another eruption could begin with little warning.

Some Comparisons with Neighboring Volcanoes—Mount Adams and Mount St. Helens

The various Cascade ***volcanoes*** are subtly different in their eruption styles and magma types. Most of the time, Mount St. Helens erupts relatively low temperature, viscous magmas known as ***dacite***. Because these magmas are ***viscous***, gas has difficulty escaping and the eruptions can be very explosive, lofting ***pumice*** and ***ash*** in a great column high into the air. This ***tephra*** from Mount St. Helens has been carried by the wind, predominantly to the east, leaving extensive sheets of ash and pumice. In fact, most of the obvious ash layers visible in road and stream cuts at Mount Rainier were actually erupted from Mount St. Helens. If gas escapes from the dacite before an eruption, as often happens after an early explosive event, the dacite erupts as a slow-moving pasty mass that piles up atop the vent, or creeps slowly down the side of the volcano. Such extrusions are known as lava domes and made up most of Mount St. Helens prior to its catastrophic 1980 eruption. Most of the activity subsequent to the May 18, 1980 blast has been dome-building. Mount St. Helens is unusual in that it also erupted small amounts of high temperature fluid ***basalt*** and more voluminous dacite from the same vent. Obvious mixtures of basalt and dacite, that are intermediate in chemical composition and eruptive style, have also erupted. The present edifice of Mount St. Helens grew quickly, over the last 30,000 years, and the volcano has been, and is likely to continue to be, the most frequently ***active volcano*** in the Cascades. Recently discovered evidence shows that the location of Mount St. Helens has been volcanically active for several hundred thousand years, but it is unclear why no large edifice remains from that earlier activity. Possibly, the volcano collapses so frequently, as in 1980, that older edifices are destroyed; or perhaps there were very long spans of repose between vigorous ***eruptive periods*** so that ***erosion*** was able to strip away the earlier edifices.

Mount Adams is about as different from Mount St. Helens as any major Cascade volcano. Mount Adams has erupted countless flows of ***andesite*** lava, many of which are close to basalt in chemical composition, and hence eruptive style. Dacites are rare, and there are no known eruptions or deposits of pumice from Mount Adams. Its ***lava flows*** are more viscous and short-traveled than basalt, typically with rubbly flow tops, so Mount Adams is a ***stratovolcano*** with a high, rounded shape, unlike a ***shield volcano***. Sulfur-rich volcanic ***gases*** have emanated widely around Mount Adams' summit, condensing as acidic waters. The acidic waters have altered a wide region of the summit rocks into clay-rich, soft, yellowish-brown material that has collapsed as multiple small ***debris flow***s. Fortunately, few people live around Mount Adams. Mount Adams started to build around 500,000 years ago, but most of its growth was in two time intervals of about 25,000 years duration each.

Mount Rainier is intermediate between Mount St. Helens and Mount Adams in eruptive style and magma composition. Most of Mount Rainier is made of andesite and some dacite lava flows, and the volcano has erupted sizeable amounts of pumice throughout its history, though not as voluminously or as frequently as Mount St. Helens. Pyroclastic flows, formed by explosive fragmentation of magma rising through the conduit system and by collapse of lava flows traveling over steep terrain, are a minor but ubiquitous component of Mount Rainier's eruptive products. Lava domes are almost unknown at Mount Rainier, unlike Mount St. Helens, probably due to the overall more fluid andesitic magmas at Mount Rainier. Around 500,000 years ago, Mount Rainier started to grow atop the eroded remains of an earlier ancestral Mount Rainier that was active 1 to

2 million years ago. The modern edifice grew as a series of four alternating stages of voluminous and modest volcanic activity, averaging a little more than 100,000 years duration. The periods of high output saw the eruption of Mount Rainier's largest and longest reaching lava flows, some of which traveled about 24 kilometers (15 miles) from the summit and had volumes as great as 8 cubic kilometers (approximately 2 cubic miles). In the periods of modest volcanic output, including today, the lava rarely extends beyond 8 kilometers (5 miles) from the summit. Glaciers deeply filled the surrounding valleys over most of the volcano's history. Lava flows skirted the margins of the glaciers, and when the Ice Ages ended, the solidified lavas were left high above the newly exposed valley floors.

Like Mount Adams, Mount Rainer had sizeable areas of ***hydrothermally altered rock*** in its upper parts. Most of these rocks collapsed 5,600 years ago as an extremely voluminous lahar, known as the ***Osceola Mudflow***. The Osceola Mudflow swept down the west and main forks of the White River, reaching the then limit of Puget Sound near present-day Puyallup. The Osceola collapse left a horseshoe-shaped crater, open to the east-northeast, much larger than the crater produced by the 1980 eruption of Mount St. Helens. Most of the Osceola crater has been filled in by subsequent lava eruptions, most recently about 2,200 year ago. The ***Electron Mudflow*** swept hydrothermally altered rock from the west side of the volcano approximately 500 years ago.

Future Eruptions and Lahars at Mount Rainier

New eruptions of Mount Rainier will most likely be small, starting with steam and ash explosions at the summit, and progressing to the effusion of a small lava flow or the explosive release of a pyroclastic flow. Either type of eruption will probably create lahars that can reach heavily populated areas. Weak, hydrothermally altered rocks remain at high elevation on the volcano's west flank, and some of this material could be dislodged by ***earthquakes*** during an ***eruptive period***. We cannot rule out the possibility that altered material could collapse due to its own weakness, without a triggering eruption or earthquake. Many people live in the river valleys downstream from Mount Rainier, so these eruptive and collapse events pose substantial ***hazards*** that are the reason for concerted scientific studies of Mount Rainier.

APPENDIX II

A SHORT HISTORY OF MOUNT RAINIER

Volcanoes were present long before the birth of modern Mount Rainer

Modern Mount Rainier is the most recent of many volcanoes that were once active within the boundaries of Mount Rainier National Park. Those earlier volcanoes are so old that ***erosion*** and mountain building processes have destroyed their original forms. The ***active volcano*** is perched on a highland of peaks and ridges constructed of old volcanic rocks of the ***Ohanapecosh***, ***Stevens Ridge***, and ***Fife's Peak Formations***, and also granites of the ***Tatoosh Pluton*** that formed by ***magmas*** (hot, ***molten*** rock), which cooled slowly and solidified underground. About 40 million years ago, much of what is now western Washington lay beneath the sea. From 36 to 28 million years ago volcanoes, some of which were tall enough to stand above sea level, spread ***lava flows***, ***lahars***, and aprons of coarse volcanic ***sediments*** across the region. Over time these volcanic sediments became cemented into rough, dark ***breccias.*** Breccias and lava flows of the Ohanapecosh Formation can be seen along the hiking trail to Summerland, as the steep slopes of Mount Wow at the start of the West Side Road, and in road cuts and trailside outcrops near Longmire.

At about 26 million years ago the style of ***volcanism*** shifted to highly explosive as hot fast-moving avalanches of rock fragments and volcanic gases that are known as ***pyroclastic flows*** erupted from volcanic ***calderas*** and buried parts of the region. Products of these ***explosive eruptions*** include the light-colored rocks of the Stevens Ridge Formation that are exposed in road cuts along lower Stevens Canyon, as well as near the crest of Backbone Ridge. As the hot pyroclastic flows cooled, the weight of the accumulated material flattened still-hot ***pumice*** lumps into lens-shaped structures visible today in the cliffs of lower Stevens Canyon. Similar pyroclastic rocks, probably from the same eruption, make up Yellowstone Cliffs and the Northern Crags on the north side of the park.

Andesitic lava flows also spread across the region from scattered volcanoes, making up the Fife's Peak Formation (26 to 22 million years ago). These rocks are visible today mainly in the northwest part of the Park, such as in the vicinity of Mowich Lake, and also near the top of Unicorn Peak and extensively to the east of the Park. Many of these magmas failed to erupt and instead spread as subhorizontal sheets (sills) beneath the andesitic volcanoes. Volcanoes were highly active during this period, and the Fifes Peak rocks accumulated to many kilometers (miles) thickness.

Activity last modified: September 5, 2014

Molten rock of the Tatoosh Pluton then rose beneath the surface and punched into the overlying formations from the period of 18 to 14 million years ago. Because they remained deep underground, the Tatoosh magmas cooled slowly, allowing crystals to grow to large sizes, thereby producing several massive bodies of ***granodiorite***. Volcanoes were probably also fed by these underground magma bodies, but evidence for these has been eroded away.

By about 10 million years ago compressional forces along the western margin of the North American Continent began to uplift rocks, eventually leading to today's Cascade Range upon which the active volcanoes sit. As the mountains rose, erosion stripped away many of the overlying ***volcanic rocks*** exposng the Tatoosh Pluton, which supports the Tatoosh Range, a cluster of jagged peaks immediately south of Mount Rainier.

It is unclear if other volcanoes developed following emplacement of the Tatoosh Pluton, as rocks of that age have been eroded away, but an ancestral Mount Rainier grew from about 2 to 1 million years ago, and the modern volcano began to grow about 500,000 years ago.

Mount Rainier grew in alternating stages of high- and low-volume volcanic activity

Modern Mount Rainier volcano grew in four major stages of alternating high- or low-volume eruptive activity, each averaging a little more than 100,000 years duration. During high-volume stages, lava flows traveled as far as 24 kilometers (15 miles) from the ***vent***, and single lava flows had volumes of as much as 8 cubic kilometers (2 cubic miles). During periods of lesser lava output, such as in recent millennia, lava flows rarely extended beyond 8 kilometers (5 miles) from the summit, and individual lava flows had volumes typically of a tenth of a cubic kilometer (0.024 cubic miles) and rarely as much as 1 cubic kilometer (0.24 cubic miles).

Mount Rainier is built by the accumulation of lava flows and rock rubble

The edifice of Mount Rainier volcano was assembled of many individual lava flows erupted over a span of half a million years. The steep faces of the upper volcano have a stair-stepped appearance imparted by alternating cliffs and rubbly slopes. Each cliff exposes the dense interior of a once molten lava flow, and the overlying slope consists of the flow's rubbly top. Successively higher elevation pairs of cliffs and rubbly slopes preserve successively younger lava flows. In addition, about 10 to 20 percent of the rubbly materials are the ***deposits*** of pyroclastic flows. Many hundreds of lava flows are now exposed as thin cliffs high on the ***cone***, whereas thicker and more voluminous lava flows form the large ridges that radiate as far as 24 kilometers (15 miles) from the present summit.

Ice-age glaciers influenced the shape of Mount Rainier and the surrounding landscape

During the ***Pleistocene Epoch*** (1.8 million to 11 thousand years ago), a succession of ***ice ages*** took place. ***Glaciers*** have mantled Mount Rainier for most or all of its 500,000-year lifespan. They covered peaks and filled deep valleys and played an integral role in shaping the volcano. Many lava flows that erupted during ice ages were unable to melt entirely through the thick, valley-filling ice and instead chilled and hardened beside it. With continued eruptions, the lava would skirt the margin of the valley-filling glacier, advancing only where ice was thin or absent. With retreat of the glaciers at the end of the Pleistocene, the valleys emptied of ice, and the lava flows were left perched high on the sides and crests of ridges, much like docks stranded along the former shores of a shrinking lake or reservoir. This process accounts for why lava flows cap many of the ridges radiating from Mount Rainier, instead of filling the deep valleys. Today's glaciers are too small to exert much control on the movement of lava. Instead, eruptions of lava and of pyroclastic flows will melt snow and ice, causing destructive lahars.

Landslides and lahars at Mount Rainier

Mount Rainier is particularly susceptible to lahars and smaller ***debris flows*** because of the abundance of ice, loose volcanic rock, and surface water, and because some slopes have been weakened by the interaction of groundwater and volcanic gases. Most of Mount Rainier's far-traveled lahars formed during eruptions as hot lava and pyroclastic flows mixed with and melted snow and ice, thereby transforming into lahars. Some large lahars have also formed by collapse of hydrothermally weakened upper flanks of the volcano. ***Hydrothermal alteration*** takes place where hot, sulfur-rich volcanic gases encounter groundwater. The sulfur dissolves into the groundwater creating sulfuric acid that attacks and leaches chemical components from the rock. Commonly, the reactions replace much of the rock with clay minerals that are weak and water saturated, thereby promoting failure of the altered parts of the volcano. The presence of abundant soft, wet clay also aids in mobilizing the collapsed material, allowing it to flow like a thick liquid, rather than piling up at the base of the volcano like a rock slide or avalanche.

Figure 1 shows the location of three large lahars from Mount Rainier.

Osceola Mudflow

The ***Osceola Mudflow*** of 5,600 years ago was Mount Rainier's signature event during the ***Holocene*** (11,000 years ago to today). (The term lahar is now used more frequently than ***mudflow***.) During a period of eruptions, the volcano's summit and northeast slope slid away, creating a 1.8 kilometer-wide (1 mile-wide) horseshoe-shaped ***crater***, open to the northeast. This massive ***landslide***, which removed 2 to 3 cubic kilometers (0.5 to 0.7 cubic miles) of rock, ice, and debris, quickly transformed into a fast-flowing lahar that traveled through the location of present-day Enumclaw, where it broadened and flowed more slowly toward and into Puget Sound. Since that time, lava flows and other eruptive products refilled much of the crater and formed the present summit cone.

National Lahar

The ***National Lahar***, which occurred sometime between 2,200 and 500 years ago, is one of many lahars that formed by the melting of snow and ice during volcanic eruptions. The lahar originated on the south flank of Mount Rainier and flowed down the Nisqually River Valley as far as Puget Sound. It is notable as one of the larger examples of a lahar formed by snow and ice melt during an eruption, the most common cause of lahars on Mount Rainier.

Electron Mudflow

The ***Electron Mudflow*** of approximately 500 years ago is remarkable because it may have occurred without an accompanying eruption. The western flank of Mount Rainier collapsed and slid into the Puyallup River Valley, where it transformed into a lahar and flowed 100 kilometers (60 miles) downstream. Scientists continue to speculate about the origin of the landslide. The volcanic flank might have been destabilized by magma that rose into the volcano but failed to reach the surface as an eruption. Alternatively, it may have failed due to earthquake shaking, or it could have collapsed after an extended period of slope creep. The Electron Mudflow reminds us of the possibility that, occasionally, lahars may have noneruption origins and occur with little warning.

Modern debris flows

Almost annually, smaller flows similar in character to lahars but unrelated to eruptive activity flow across valley floors within Mount Rainier National Park. These events, known locally simply as debris flows, form by the erosion of unconsolidated rock debris as a result of increases in water from precipitation, glacier melt, and glacier floods. More than 40 of these events have occurred within the past few decades.

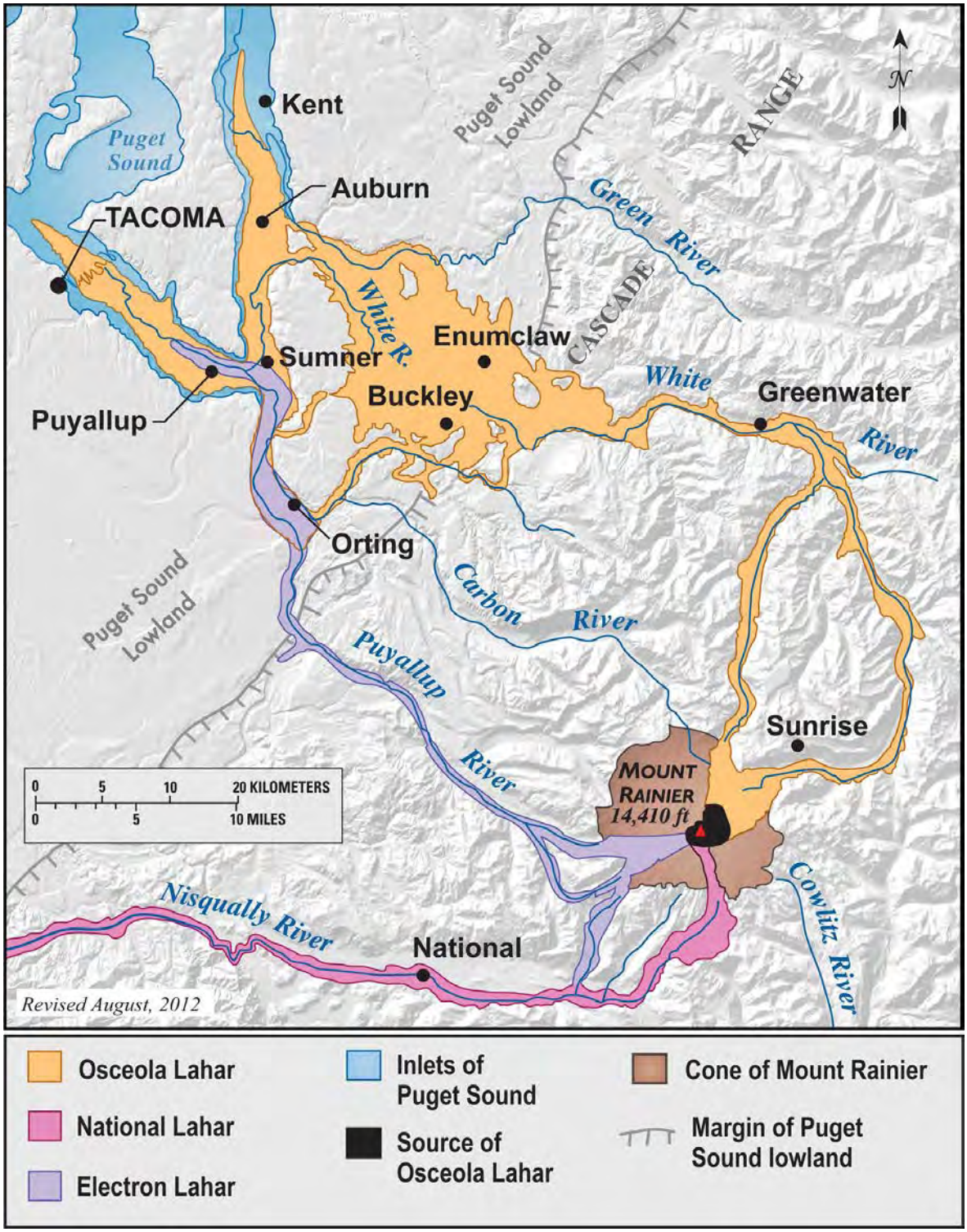


Figure 1*—Map showing location of three lahars from Mount Rainier volcano. Modified from Crandell (1971) and Vallance and Scott (1997).*

Mount Rainier remains an active volcano with potential to erupt again

All evidence suggests that Mount Rainier volcano will continue to erupt, grow, and collapse and will thereby constitute an enduring ***hazard***, as well as a scenic and natural resource that provides recreation, wildlife habitat, and water for drinking and power generation. When Mount Rainier erupts again, volcanic activity may affect people living in the surrounding areas, those visiting Mount Rainier National Park, and potentially those flying overhead. An eruption is likely to be preceded by weeks or months of small earthquakes centered beneath the volcano, by subtle deformation of the volcano, and by increases in volcanic-gas emissions and temperatures. Detection of these natural precursors can allow communities to go to heightened levels of alert and take basic precautions against lahars. Beyond their dependence on volcanic precursors, scientists recognize that lahars, like the Electron Mudflow, can form by slope failure during noneruptive times. This knowledge has motivated scientists to install equipment that detects more subtle movements and a lahar detection system that identifies lahars and warns of their movement before they reach populated areas.

Substantial progress has been made in understanding Mount Rainier's volcanic history and its hazards

Research during the 1980s to today provides an updated view of the history and hazards associated with Mount Rainier, and a challenge to residents, public officials, and scientists to consider seriously the threat of future volcanic activity. Scientists now call Mount Rainier an "active" volcano because of the recency of eruptions in the nineteenth century, its active hydrothermal system, its ongoing seismicity, and its location above a ***subduction zone*** where new magma forms. Mount Rainier has erupted more frequently than was previously known, and links between eruptions and lahars, including flank-collapse lahars, are stronger than had been thought. Collapse hazards are greatest on the west flank because of the presence of hydrothermally altered rock. The likelihood of lahars formed by lava-ice interaction chiefly by pyroclastic flows is higher than was previously supposed. Such eruption-generated lahars threaten all valleys that head on the volcano.

Timeline of Significant Geologic Events at Mount Rainier

See figures 2 and 3 to view Mount Rainier's growth rate and a simplified geologic map.

500,000 to 420,000 years ago

Rapid accumulation of lava

Geologists have strong evidence that the modern Mount Rainier began to erupt atop the deeply eroded remains of an ancestral volcano that had been active 2 to 1 million years ago. Eruptions did not die out entirely between the ancestral and modern volcanoes, but 500,000 years ago marks the beginning of the voluminous and continuous volcanic rock record that we call Mount Rainier; therefore, 500,000 years ago is taken as the onset of eruptions that have built the modern volcano. For the first approximately 80,000 years, the new volcano was highly active, producing a thick apron of pyroclastic flows that are well exposed above Glacier Basin. These pyroclastic flow deposits are preserved as high as Steamboat Prow (3,000 meters or 9,640 feet) where they dip directly away from the present summit, indicating that the new volcano quickly grew to a height similar to that of today. The pyroclastic flow deposits are capped by thick lava flows, such as at Burroughs Mountain, Grand Park, and Old Desolate. The Sunrise visitor facilities sit atop the Burroughs Mountain lava flow, the lower end of which is visible at an elevation of about 1,500 meters (4,800 feet) along the road to Sunrise, where ice-chilled lava columns jut from the tip of the lava flow like whiskers from a chin. The side of the lava flow forms the high cliff above the White River campground.

420,000 to 280,000 years ago

Reduced rate of lava accumulation

Geologists know less about this time period in Mount Rainier's history because infrequent and small eruptions left little evidence within the geologic record. An exception is the Rampart Ridge lava flow, which erupted 380,000 years ago. Visitors get a dramatic view of this ridge from Longmire, where they observe it from the valley floor once filled by glacier ice. Because of infrequent eruptions, the upper mountain was probably eroded substantially during this time and greatly reduced in height.

280,000 to 160,000 years ago

Rapid Accumulation of lava

Eruption rates increased again around 280,000 years ago and persisted to about 180,000 years ago, as shown by extensive lava flows on the flanks of Mount Rainier, including on the west at St. Andrews Park, Klapatche Point, and Sunset Park, and on the east at Meany Crest. The volcano grew to perhaps its greatest height, as shown by 200,000-year-old rocks preserved high on the Mowich Face on the volcano's upper west flank. So much magma passed though the volcano that its upper west and east flanks split open. Magma poured through these cracks, feeding large lava flows from flank vents. Some of the magma remained within the cracks where it eventually froze and is preserved as ***dikes***. These magma-filled cracks and dikes also provided heat and acidic volcanic gases that altered and weakened the upper west and east flanks of the volcano, setting the stage for the much younger collapses that spawned the Osceola and Electron Mudflows.

160,000 to 40,000 years ago

Reduced eruptions accompanied by erosion of the upper mountain

Eruption rates waned gradually after 180,000 years ago, with dikes and vents on the upper east side of Mount Rainier feeding the lava flows that constructed Little Tahoma, lending an oblong shape to the volcano. At about 105,000 years ago, new vents opened on the lower northwest flank of the volcano and lava flows of ***basaltic andesite*** (hotter, more fluid magmas than typical for Mount Rainier) spread across the Spray Park and Mist Park areas from cinder cones now preserved as Echo and Observation Rocks. Another lava type atypical for Mount Rainier erupted at 130,000 years ago from a vent well to the north of the volcano at Windy Gap and flowed against ice filling the present Carbon River Valley, producing the lava flow of Bee Flat. These north and northwest flank vents were probably fed from great depth, rather than laterally from the nearby Mount Rainier magmatic plumbing system.

With reduced eruption rates, erosion again incised the upper edifice, apparently removing much of the upper north and south flanks and reducing the summit elevation. There were some other notable constructional events, which produced features that we see today. An eruption 102,000 years ago produced a lava flow over which Comet Falls descends. A pyroclastic flow filled the headwaters of Kautz Creek. A lava flow that erupted about 91,000 years ago now caps Mazama Ridge, supports The Bench, and descends into Stevens Canyon.

40,000 to 15,000 years ago

Reconstruction of the upper mountain

Eruption rates increased again about 40,000 years ago, although not to the degree of the earlier high-effusion stages. With the exceptions of the Mowich Face and Little Tahoma, most of the upper headwalls and ridges on Mount Rainier were constructed during the period 40,000 to (roughly) 15,000 years ago, with many age determinations clustering near 40,000 years. These relatively youthful lava flows include those exposed on Liberty Ridge, Willis Wall, upper Curtis Ridge, Gibraltar Rock, Wapowety Cleaver, Success Cleaver, and Tahoma Cleaver, as well as the Tahoma Glacier Headwall. The only flank lava flow from this time is that of Ricksecker Point (40,000 years ago) that also supports Narada Falls. The Ricksecker Point lava flow was important for developing understanding that glaciers directed the courses of lava flows at Mount Rainier. Canyons 250 meters (800 feet) deep flank Ricksecker Point on the north and south, but 40,000 years is too brief a time to excavate to such depths by erosion. Impoundment of the lava flow against thick glaciers that filled the valleys to the north and south, followed by emptying of the canyons during ice retreat, provides a ready explanation for the great depths of the flanking canyons despite the relative youth of the lava flow. This stage of reconstruction of upper Mount Rainier overlaps the most recent period of thick glaciers formed during the most recent major ice age that peaked at 20,000 years ago. The rough ridge and headwall of the upper mountain results from thin lava flows encountering thick ice, as well as to simultaneous rapid glacial erosion and lava effusion. Growth of upper Mount Rainier is also roughly synchronous with growth of upper Mount Adams (less than 30,000 years old), as well as the beginning of growth of present-day Mount St. Helens (earlier volcanoes were present at that location).

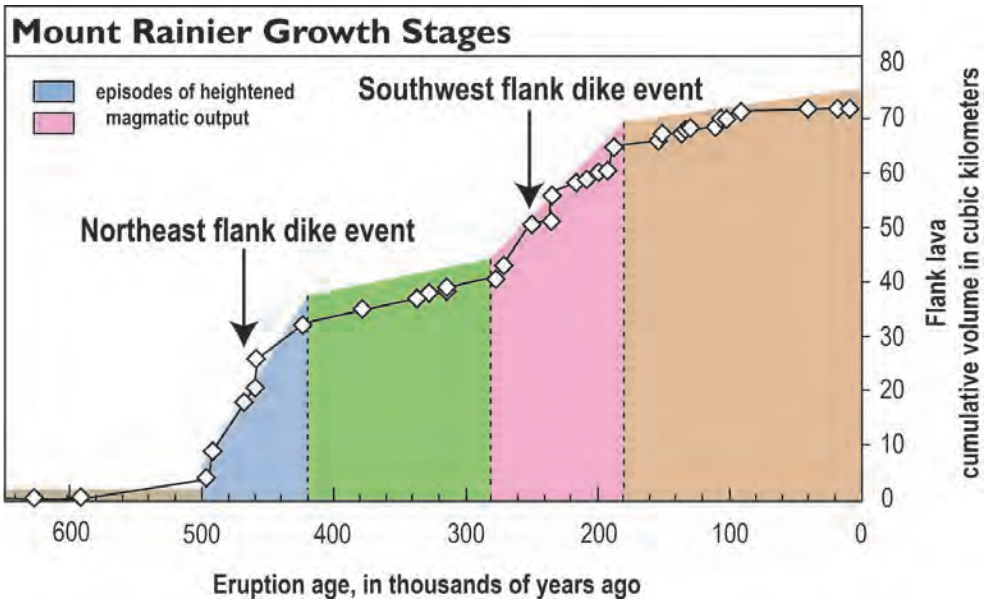


***Figure 2**—Graph of Mount Rainier growth stages showing times of heightened magmatic output and times of dike emplacement. Each symbol represents a mapped and dated flow or flow group. Adapted from Sisson, Vallance, and Pringle (2001).*

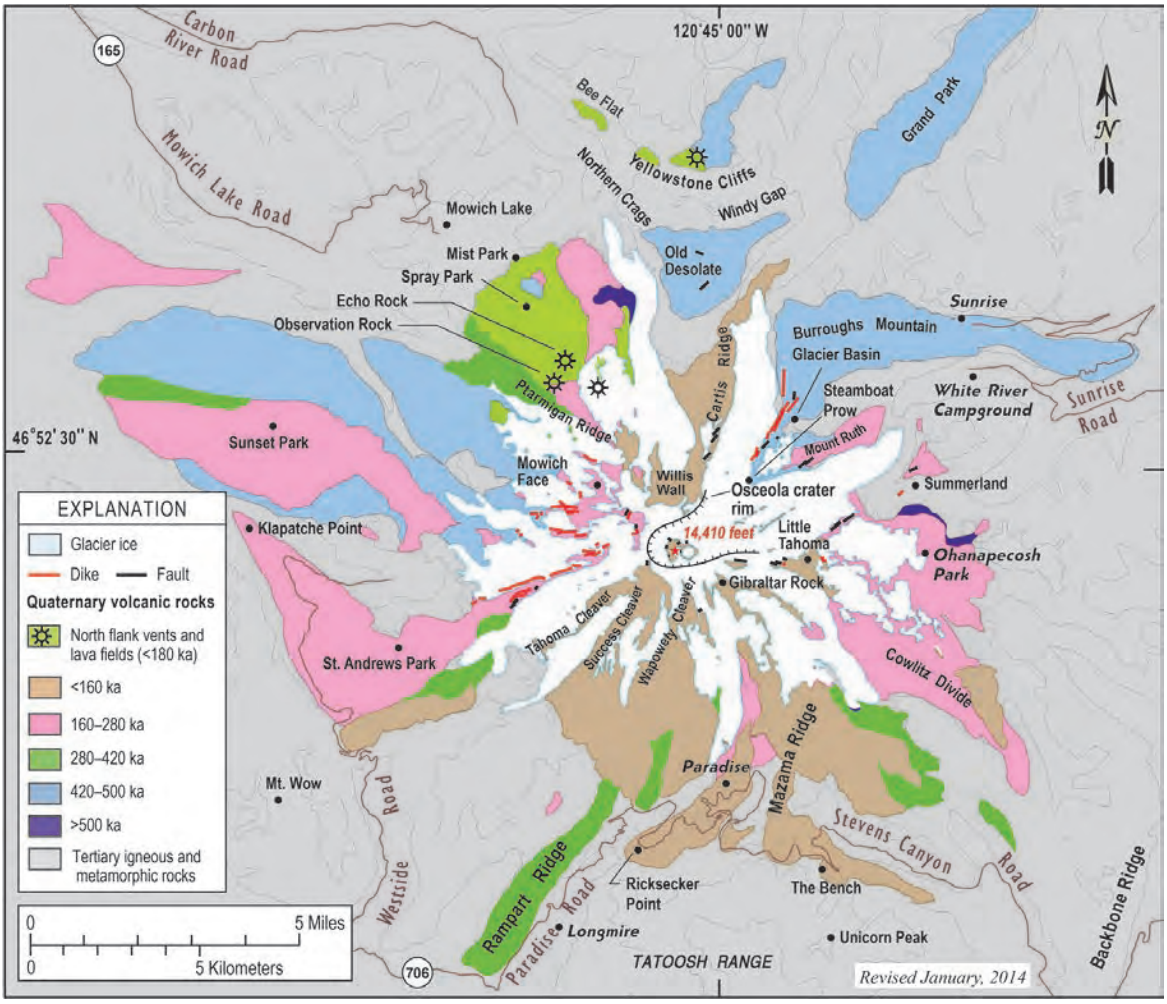


Figure 3—*Schematic map showing simplified geology of Mount Rainier volcano, Ka is thousands of years before present. Adapted from Sisson, Vallance, and Pringle (2001).*

Holocene (post-last ice age) eruptive periods

More detail is known about the recent part of the geologic record because it post-dates extensive ***glaciation,*** and therefore the products are well preserved. Various ***eruptive periods*** for Mount Rainier have been identified based on temporal clustering of ***tephra*** deposits, in most cases accompanied by numerous lahars. The periods are mostly named after locations where their deposits are particularly well preserved and complete. Six eruptive periods are noted between 11,000 years ago and the present. Each lasted perhaps a few years or for as long as more than one thousand years. See table 1 summary of notable Holocene events at Mount Rainier, 11,000 years ago to present.

The Holocene eruptive periods for Mount Rainier were determined from studies of volcanic ***ash*** layers on the volcano, which at this writing, remain in progress. Scientists often derive the age of ash layers by measuring the age of wood within or adjacent to them. Our knowledge of these eruptive period ages will become more precise as additional studies are done.

Sunrise eruptive period (approximately 11,000 years ago)

An eruption deposited volcanic ash (Layer R) across the northeast part of Mount Rainier National Park. One lahar, apparently of landslide origin, moved across Van Trump Park.

Cowlitz Park eruptive period (7,400 to 6,700 years ago)

Eruptions produced seven tephra layers and several lahars. Pyroclastic flows across snow and ice probably caused two or three lahars, at least one of which traveled as far as the Puget Sound lowland 70 kilometers (43 miles) downstream. About 7,300 years ago a collapse caused a lahar that spilled over the Paradise Ridge and moved as far as Reflection Lakes. Reflection Lakes exist within the low areas of this lahar.

Osceola eruptive period (5,600 to 4,500 years ago)

Early in this eruptive period, the Paradise Lahar swept down Mount Rainier's south side along the Nisqually River as far as the village of National. Later, explosive eruptions (***phreatic*** and ***phreatomagmatic eruptions***) triggered an edifice collapse that included the summit of the volcano and northeast flank. The 4 cubic kilometer (1 cubic mile) Osceola Mudflow evolved from this avalanche of altered rock and flowed down the White River Valley, across the Puget Sound lowland into Puget Sound, and at least 20 kilometers (12.4 miles) underwater to the present sites of Tacoma and the Seattle suburb of Kent. The Paradise Lahar, now recognized as the southern part of the Osceola Mudflow, swept down the Nisqually River Valley as far as the community of National. Eruption of several tephra layers suggests that a period of cone building ensued.

Summerland eruptive period (2,700 to 2,000 years ago)

About 2,700 years ago Mount Rainier began to erupt again, producing tephra, lahars, and a landslide-induced lahar called the ***Round Pass Mudflow***. A sequence of tephra falls, pyroclastic flows, and lahars followed, indicating continued eruptions separated by time intervals ranging from several tens to hundreds of years. The largest Holocene tephra eruption (Layer C: 0.1 to 0.2 cubic kilometers or 0.02 to 0.04 cubic miles) occurred about 2,200 years ago. It covers areas near Sunrise visitor center, as well as Burroughs Mountain. Summerland period lava flows descended from the summit and underlie much of the upper Emmons and Winthrop Glaciers. The upper part of Camp Schurman sits atop lava erupted from the summit at this time. Summerland lahars and associated sediment accumulated to depths of several meters thickness at sites as far downstream as Auburn. By the end of the Summerland eruptive period the summit of Mount Rainier had grown to its present form and altitude.

Twin Creeks eruptive period (approximately 1,500 years ago)

Several thin ash deposits restricted to subalpine meadows and far-traveled lahars of the ***Twin Creeks assemblage*** show that small eruptions took place about 1,500 years ago. Although these events involved the eruption of new magma, no lava flows were produced. In some literature, considered part of the ***Deadman Flats assemblage.***

Fryingpan Creek eruptive episode (1,100 to 1,000 years ago)

About 1,100 years ago, one or possibly two lahars flowed down the White River as far as Auburn. These lahars may have been generated as pyroclastic flows descended the Emmons and Winthrop Glacier and incorporated and melted snow and ice. Reworking of the lahar sediment caused extensive aggradation of the Duwamish River Valley as far as Puget Sound and the southernmost Seattle suburbs. No lava flows were produced.

Electron Mudflow (around A.D. 1503)

About A.D. 1503, an avalanche of hydrothermally altered rock from the west side of Mount Rainier caused a lahar (Electron Mudflow: (0.26 cubic kilometers or 0.06 cubic miles) that swept down the Puyallup drainage at least as far as Sumner. It is not known whether an eruption or some other event triggered the lahar. Other lahars descended the Nisqually and White River drainages at about this time.

New ideas about mid-nineteenth century eruptions—The X-tephra

Early studies of Mount Rainier's eruptive history report the presence of sparse tephra locally scattered on young ***glacial moraines***. This was named the X-tephra and was interpreted as a product of an eruption of Mount Rainier dating between A.D. 1820 and 1854. More recent study shows that this material is the 2,200-year-old tephra from the Summerland Eruptive Period. In some localities it was transported and redeposited on younger glacial moraines by snow avalanches, and in other areas it was incompletely eroded by late Holocene glacial advances and therefore lies within the perimeter of younger glacial deposits. The X-tephra therefore appears not to be a true eruption deposit.

1840s through 1890s—Steam Explosions

Occasional steam blasts at the summit of Mount Rainier were reported by early pioneers in the Puget Sound region. The most well documented report came in the winter of 1894–95, when many residents of Seattle saw ***explosions*** of steam and "black smoke" (accepted today as volcanic ash) rising from the summit. There is no evidence that new magma accompanied these explosions, which might have been caused by interactions of hot rock and water. Although there may have been small eruptions of Mount Rainier during the nineteenth century, no physical evidence remains as confirmation.

Summary of Notable Events—11,000 Years ago to present

Eruptive Period	Age or Date	Event	
Historic activity	A.D. 1980s to present	Several dozen debris flows in river valleys that head on Mount Rainier	
	A.D. 1963	Rock fall avalanche from Little Tahoma Peak	
	A.D. 1947	Debris flow and runout flow of glacial-outburst origin in Kautz Creek	
	A.D. 1930s to 1950s	Multiple debris flows in Nisqually River Valley	
	A.D. 1910 to 1927	Rock avalanche on Tahoma Glacier	
	A.D. 1894 to 1895	Reports of small steam and ash eruptions at summit	
	500 years ago	Rock avalanche-induced Electron Mudflow in Puyallup/Nisqually River Valleys; no documented association with volcanic eruptions	National Lahar in Nisqually River Valley sometime between 2,200 and 500 years ago
Fryingpan Creek eruptive episode	1,100 to 1,000 years ago	Lahar down Puyallup River at least as far as its confluence with Mowich River	
		Tephra and lahars in White River Valley as far as Kautz Creek	
Twin Creeks eruptive episode (Deadman Flats)	1,500 years ago	Tephras and lahars in valleys of the White River and Kautz Creek	
Summerland eruptive period	2,000 years ago	Lava flows formed summit cone, Columbia Crest	
	2,200 years ago	Eruption of Layer C tephra	
	2,200 to 2,600 years ago	Lahar in Nisqually River Valley deposits sandy layers	
	2,400 to 2,500 years ago	Eruption of block-and-ash flow in Puyallup River Valley; Eruption of tephra layers	
	2,600 years ago	Lahar-Round Pass mudflow descended Puyallup valley to Puget Sound lowland. Part of it descended Tahoma Creek and the Nisqually River	
	2,200 to 2,700 years ago	Multiple lahars in White River Valley	
Osceola eruptive period	4,500 years ago	Eruption of tephra layer B	
	4,700 years ago	Eruption of tephra layer H	
	5,600 years ago	Lahar-Osceola Mudflow in White River's main branch and West Fork extended to Puget Sound lowland. Eruption of tephra layer F; Paradise Lahar (part of the Osceola Mudflow) in Nisqually River Valley, extended as far as the community of National	
	>5,600 years ago	Eruption of tephra layer S	
Cowlitz eruptive period	6,700 years ago	Eruption of tephra layers N and D	
	7,400 to 7,200 years ago	Eruption of volcanic bomb-bearing rocks and lahars in White River Valley	
	7,400 to 7,200 years ago	Rock avalanche-induced lahar down the Nisqually River and at Reflection Lakes	
	7,400 to 7,200 years ago	Eruption of tephra layers L and A	
Sunrise eruptive period	11,000 years ago	Eruption of tephra layers L and R	

***Table 1**—Summary of notable events at Mount Rainier, approximately 11,000 years ago to present.*

Author Note

The authors of this section of GIP 19 acknowledge the valuable input to this text by USGS researchers James Vallance and Tom Sisson. More precise ages and information about eruptive history will be published and posted on USGS Web sites as new evidence emerges.

References

Crandell, D.R., 1971, Postglacial lahars from Mount Rainier volcano, Washington: U.S. Geological Survey Professional Paper 677, 75 p.

John, D.A., Sisson, T.W., Breit, G.N., Rye, R.O., and Vallance, J.W., 2008, Characteristics, extent and origin of hydrothermal alteration at Mount Rainier Volcano, Cascades Arc, USA—Implications for debris-flow hazards and mineral deposits: Journal of Volcanology and Geothermal Research, v. 175, p. 289–314.

Lescinsky, D.T., and Sisson, T.W., 1998, Ridge-forming, ice-bounded lava flows at Mount Rainier, Washington: Geology, v. 26, no. 4, p. 351–354.

Pringle, P.T., 2008, Roadside geology of Mount Rainier National Park and vicinity: Washington State Department of Natural Resources Information Circular 107, 190 p.

Scott, K.M., Vallance, J.W., and Pringle, P.T., 1995, Sedimentology, behavior, and hazards of debris flows at Mount Rainier, Washington: U.S. Geological Survey Professional Paper 1547, 56 p.

Sisson, T.W., Vallance, J.W., and Pringle, P.T., 2001, Progress made in understanding Mount Rainier's hazards: EOS, Transactions of the American Geophysical Union, v. 82, p. 116–120.

Sisson, T.W., and Vallance, J.W., 2008, Frequent eruptions at Mount Rainier over the last ~2,600 years; Bulletin of Volcanology, v. 71, Issue 6, p. 595.

Vallance, J.W., and Scott, K.M., 1997, The Osceola Mudflow from Mount Rainier sedimentology and hazards implications of a huge clay-rich lahar: Geological Society of America Annual Bulletin v. 109, p. 143–163.

APPENDIX III

Journey Back in Time

A Mount Rainier Geological Field Trip Guide for Teachers

Nisqually Entrance to Paradise

By Carolyn Driedger with contributions by Tom Sisson and Jim Vallance

"To a person uninstructed in Natural History, his country or sea-side stroll is like a walk through a gallery filled with wonderful works of art, nine-tenths of which have their faces turned to the wall."

Thomas Henry Huxley, *Aphorisms and Reflections*

Activity last modified: September 7, 2014

Teacher Instructions

Overview:

Journey Back in Time—A Mount Rainier Geological Field-Trip Guide for Teachers provides background information, suggested activities, and itinerary for a geology-oriented field trip to the southwest side of Mount Rainier National Park. This field-trip guide and its companion geologic overview, **A Short History of Mount Rainier**, are appendices in **Living with a Volcano in Your Backyard—an Educator's Guide with Emphasis on Mount Rainier** (hereafter called the Educator's Guide). This field-trip guide can be used in conjunction with classroom activities within the parent document.

Journey Back in Time assumes that your group will arrive through the Nisqually Entrance at the southwestern corner of the park, the only year-round access point, and will end at the Paradise visitor facilities. This guide describes stops at Kautz Creek, Longmire, Ricksecker Point, and Paradise. Sunshine Point, Tahoma Creek, Christine Falls, and the Glacier Bridge are places to drive past slowly for through-the-window observations and discussion. Use this field-trip guide to plan your trip. Although time limitations prohibit most people from exploring every stop and trail, this guide provides a variety of options. Consider use of the discussion questions and activities to promote observations and to maintain focus on key concepts. You might opt to tailor the questions to your group's abilities. Check for updates and accompanying materials in the "For Teachers" pages of the Mount Rainier National Park Web site http://www.nps.gov/mora/.

Planning your field trip to Mount Rainier National Park:

Read through this guide to determine which stops, activities and experiments work best for your group. Staff at Mount Rainier National Park run an Education Center at Tahoma Woods administrative facility, three miles west of Ashford, Washington, and can help arrange your visit, ***including fee waivers for educational groups***. Reach them at (360) 569-2211. Weather and road conditions should be a primary consideration for the timing of your trip. Summer and fall conditions allow maximum travel on roads and trails. The National Park Service strives to keep the road to Paradise plowed in winter and offers winter snowshoe walks. Uneven surfaces on trails and slopes can make trips challenging at any time of the year. Before making commitments, give careful consideration to the physical abilities of your group. Find directions to the park, current weather and travel conditions, and additional trip planning support at the park Web site. ***The authors strongly recommend a dry run of the proposed trip prior to your scheduled departure.***

Supporting activities:

Field trips are greatly enhanced when preceded and followed by associated classroom activities. Encourage student interest by conducting any of the activities in the Educator's Guide. The activity **Planning Your Trip to Mount Rainier National Park** provides pages for student planning before the field trip and reserves space for photographs and drawings. It includes several quick outdoor science experiments for stops at Kautz Creek, Longmire, and Paradise and along the Nisqually Vista, Glacier Vista, and Panorama Point Trails.

Key concepts addressed on this field trip:

During your journey within the park, you will find abundant evidence that supports several overarching geological principles. The authors base the scope of field trip descriptions and guided questions on geologic features that best support successful student observations. During your field trip, encourage discussion of the following principles.

- Ongoing geologic change is abundant and observable at Mount Rainier National Park. No two trips to Mount Rainier yield identical observations.
- Processes in the rock and water cycles, as studied in many classrooms, are manifested throughout the year at Mount Rainier National Park—snowfall, snowmelt, glacier motion, river flow, flooding, debris flows, rock weathering, erosion and deposition, rock fall, and hot springs and geothermal steaming from the volcano's warm interior.
- Volcanic and glacial processes are the principal forces that shape the landscape. The interaction of these forces created much of the landscape that we see today.
- Volcanic processes have rearranged the landscape intermittently. Scientific evidence abounds for ancient volcanic activity before the birth of Mount Rainier and for future volcanic eruptions.
- Geologic processes, past and present, influence the lives of humans, animals and plant life at Mount Rainier National Park.

For additional information:

Find more in-depth information about the geologic story of Mount Rainier, in the *Roadside Geology of Mount Rainier National Park and Vicinity,* Department of Natural Resources Information Circular 107, by Patrick T. Pringle, available from the Washington Department of Printing and some retail stores.

Student perceptions of volcanic activity:

Students may voice concern for their safety while visiting volcanic Mount Rainier National Park. You can lessen their concern by discussing how Mount Rainier is like a person sleeping. The mountain is presently at rest but will reawaken some day. The mountain cannot erupt without first displaying some symptoms of awakening. Explain to them that scientists are watching for evidence of rising magma, such as volcanic earthquakes, gas releases, and changes to surface elevation. These symptoms are evident for days to months or more preceding an eruption. When scientists detect these signs of reawakening, they will notify local and federal officials and the public.

The Route to the Park

Logistics:

Find driving directions to the Nisqually Entrance at the Mount Rainier National Park Web site: http://www.nps.gov/mora/

Figure 1— *Mount Rainier seen on approach, near National, Washington. USGS photo by C. Driedger.*

Features of Interest:

1. Glaciated Puget Sound lowlands
2. Nisqually River
3. Evidence of past lahars
4. Cascade Range

Background:

- ***Glaciers and volcanoes are the principal shapers of local terrain.***
  On at least six occasions between 1.8 million and 11,000 years ago lobes of glacier ice flowed southward from Canada to the Puget Sound lowland and filled the region between the Olympic Mountains and Cascade Range. Each ice lobe had a similar routine, hauling rocks southward, melting, and dropping rock debris. Beneath the ice, water flowing at high pressure carved broad valleys now flooded by Puget Sound and Lake Washington or sites of major rivers. Parts of Seattle, Tacoma, Everett, Olympia, and Bellevue sit high on thick stacks of compacted glacial rock debris called till. Renton, Puyallup, Kent, Auburn, Sumner, and Orting were built on valley floors. Enter, Mount Rainier! On perhaps hundreds of occasions, lahars (volcanic mudflows) rushed down valleys, and spread mud and boulders broadly, and raised the elevation of valley floors. The same valleys are at risk from lahars today.

- ***LaGrande to Nisqually Entrance—Follow the Nisqually River to its source on Mount Rainier.***
  The Nisqually River drains water from the south and southwest flanks of Mount Rainier. The route between LaGrande and Nisqually Entrance affords glimpses of the many uses of this river—hydropower generation, recreation, and fish and wildlife habitat. Fine sediments create the water's milky color that is common during summer and autumn. The abundant sediment load of sand and gravel causes braiding of the river channel. The Nisqually River Glacier extended as far as the west end of Ashford as recently as between 22,000 to 15,000 years ago.

- ***Look for evidence of past lahars (volcanic mudflows).***
  Lahars (volcanic mudflows) sped down the Nisqually River Valley on multiple occasions in the past. In Ashford, look for tan-colored deposits of the 5,600 year old Paradise Lahar at the restaurant parking lot across from the general store. Find more mounds perhaps from the Paradise Lahar on both sides of the road about 1 kilometer (0.6 mile) east of Ashford. You will learn more about this lahar later.

- ***Mount Rainier in the distance east of Ashford.***
  During clear weather, Ashford is an excellent location to view the landslide and glacier-scarred west flank of Mount Rainier. About A.D. 1502 or 1503, the mountain's west side slid away and rushed down the Puyallup River Valley as the Electron Mudflow. Scientists obtain these precise ages by using a combination of radiocarbon dating and tree ring studies on wood from buried trees.

Nisqually Entrance and Sunshine Point — Mile 0 & Mile 0.4

Logistics: Slow Pass

Visitors get a view of the Nisqually River during a "slow pass" along the river. Please do not stop the bus.

Features of Interest:

1. Close-up view of Nisqually River
2. Damage from the 2006 flood

Figure 2— *Nisqually River near Sunshine Point, December 2006. USGS photo by C. Driedger.*

Background:

- ***Floods of 2006 had a devastating effect on park facilities.***
  In a place as wet as western Washington, it is difficult to imagine that a few days of rainfall in 2006 led to floods so devastating that Mount Rainier National Park was forced to close for 6 months. All over the park, rivers and streams flowed out of their channels. The resulting floods caused destruction unlike anything the park had experienced in its 108-year history. The National Park Service estimates that damage to roads, trails, campgrounds, and buildings exceeded $36 million.

  On November 5, 2006, a steady rain began to fall on soils already saturated from previous precipitation. The rain continued, and by November 7 nearly 46 centimeters (18 inches) of rain had fallen at Paradise. Before the floods, a forest stood between the road and the river. Flood waters in the swollen river eroded the embankment, uprooted the trees, and collapsed the road and utility lines. River water swept away most of Sunshine Point and its campground and picnic area (now permanently closed). Approximately 0.3 kilometers (0.2 mile) east of the entrance station, visitors travel over the repaired road and get a stunning and close-up view of the Nisqually River.

  Evidence of the flood is visible in many river valleys around the park. The bridge over Tahoma Creek was buried by boulders and sediment. At Kautz Creek, the old channel was filled with boulders and sediment, and the creek cut a new channel to the east and left the old channel to the west nearly dry.

Discussion questions for drive to Longmire:

- Your entry into Mount Rainier National Park is an appropriate time to begin discussions and student observations about the rock cycle, water cycle, ongoing landform changes, the history of repeated volcanism and how these processes affect living things. Encourage discussion about how water and ice modify the landscape. Ask students for evidence that they are approaching a volcano. Ask students how the river might affect animal and plant ecosystems within the park and beyond.

Tahoma Creek — Mile 1.2

Safety note: A word of caution about debris flows—Be alert.

Debris flows occur most often during periods of hot weather in late summer and during severe rainstorms in autumn and early winter. If you are near a stream and hear a roaring sound coming from up valley, or note a rapid rise in water level, move quickly up the stream embankment, away from the stream channel, and to higher ground. Do not try to escape by moving downstream; debris flows move faster than you can run on a streambed of boulders. Observe National Park Service regulations provided for your safety. Here, as in most areas in other national parks, natural processes such as floods and debris flows are allowed to occur without human intervention.

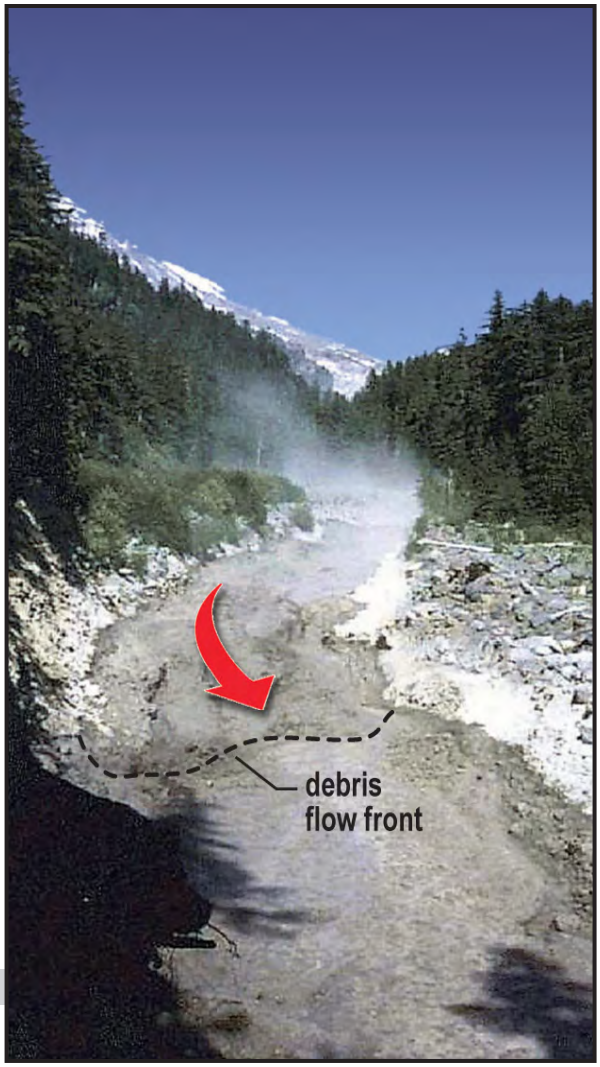


Figure 3— *Debris flow on Tahoma Creek, July 26, 1986. Wave front near the tip of the arrow was approximately 3 meters (10 feet) in height. USGS photograph by G.G. Parker.*

Logistics: Slow Pass

Catch a brief glimpse of Tahoma Creek. Please do not stop the bus on the bridge, but have the driver slow down and put on emergency flashers while crossing.

Features of Interest:

1. Glacial flour
2. Debris flow history of Tahoma Creek

Background:

- ***The scoop on debris flows:***
  Debris flows are masses of water, rock, vegetation, and mud that surge down valleys, leaving in their wake splintered trees and damaged structures. Traveling at speeds of 30+ kilometers per hour (20+ miles per hour), and loaded with boulders and mud, debris flows resemble flows of wet concrete. You cannot outrun a debris flow. Debris flows form by the mixing of loose rock with the excessive stream flow caused by intense rain or snowmelt or from sudden glacier outburst floods. The abundance of surface water and loose volcanic rock encourage the formation of debris flows almost annually within the park. In valleys, debris flows are one of the most common and efficient agents of landscape change. Debris flows form in remote areas nearly inaccessible to people but may move rapidly downstream into areas frequented by visitors.

- ***What is the significance of debris flows on Tahoma Creek?:***
  At least 27 debris flows rushed down the valley of Tahoma Creek between 1985 and today—more than in any other valley within the park. Since 1967, debris flows in the Tahoma Creek Valley have transported more than 10 million cubic meters (350 million cubic feet) of sediment, damaging roads and facilities upstream of the highway bridge. (That amount of sediment is enough to fill in 4,000 Olympic-size swimming pools!) Sediment has filled the river bed and raised the level of water so much that flooding threatens the surrounding area. Park employees periodically use bulldozers to extract excess sediment from the channel to keep the water and debris at a safe distance below the bridge. Why Tahoma Creek? South Tahoma Glacier melted drastically during the second half of the twentieth century and retreated upvalley, exposing a lot of loose sediment to the erosional powers of stream water.

- ***Glacial flour:***
  At the bed of a glacier, ice-bound rocks grind against bedrock and create a fine-grained rock powder called glacial flour. When glacial flour is combined with stream water, the gray-colored water is known as glacial milk. Glaciers move faster and grind more rock to powder in summer than in winter. Because of this, you might observe clear water in the glacial rivers around Mount Rainier.

Discussion questions for drive to Longmire:

- While driving slowly across the bridge over Tahoma Creek (there is no safe place to stop for students to get out here), you will be able to see the abundance of cobbles and boulders in the stream channel. Ask them to suggest hypotheses about what produces the current stream color and how the color might change through the seasons. Encourage students to consider processes that are part of the rock cycle and the water cycle. What evidence do they see of recent change? Encourage students to consider processes that are part of the rock cycle and the water cycle. What evidence do they see of recent change?

Kautz Creek Debris Flow Viewpoint — Mile 3.4

Logistics: 1.5 hours

30 minutes for viewpoint;
1 hour with **Lahar in a Jar** activity

Park in the lot on the south side of the highway. Observe the effects of debris flows safely by following the fully accessible trail to the viewpoint. Use care crossing the highway. Note: Tables in the picnic area are the best location for discussion and conducting the **Lahar in a Jar** activity found in the Educator's Guide.

Figures 4A and B—*Kautz Creek in 2001 and 2006, after rerouting of the stream by debris flows. USGS photos by C. Driedger.*

Features of Interest:

1. Terrain built by 1947 Kautz Creek debris flow
2. Channel changes at Kautz Creek during the November 2006 flood
3. Deposits from previous debris flows in stream embankment
4. On this route, first in-park view of Mount Rainier

Background:

- ***On October 2–3, 1947, a debris flow swept down the Kautz Creek Valley and covered the road with 25 to 30 feet (7 to 9 meters) of mud, rocks, and tree debris. From the west, the road climbs uphill on to the debris-flow deposit.***
  This debris flow originated at Kautz Glacier and resulted from a combination of intense rainfall (15 centimeters or about 6 inches) and a glacier outburst flood—a sudden release of water trapped within the glacier. A 2-kilometer-long (1.2 miles) segment of the lower Kautz Glacier was washed away by floodwaters. Eyewitnesses report that this debris flow had the consistency of wet concrete and carried chunks of ice, trees, and boulders as large as recreational vehicles. Note the tree snags. The best preserved trees are the tall pointed snags of western red cedar. All the living trees are younger than this debris flow event.
- ***Floods of 2006 change the channel of Kautz Creek.***
  During the floods of November 5 and 7, 2006, floods again modified the Kautz Creek Valley. A debris flow 1.6 kilometers (1 mile) upstream blocked the channel and forced Kautz Creek to flow through the forest and establish a new course approximately 200 meters (650 feet) east of the bridge. The flood undermined the road, damaged the buried power line, and caused severe erosion to nearby park maintenance facilities.

- ***Prognosis for the future:***
  We can expect that future floods and debris flows will change the course of Kautz Creek and, on occasion, will necessitate road closures. The buildup of rock debris in the streambed, known as aggradation, raises the water level in stream channels. This action threatens the long-term safety of road and building facilities in river valleys around the park.

Discussion questions for Kautz Creek viewpoint or parking lot:

General observations:

- You passed through old-growth forest on your way to Kautz Creek. Are trees near the Kautz Creek parking lot similar or different in age? ***Trees near the parking lot are smaller and younger.***
- What process(es) near the creek could have killed old growth trees? ***Burial by rock debris from flooding and debris flows or disease (best specific answer is the debris flow of 1947).***
- What processes have transported fresh rock debris to the area? ***Debris flows, and stream transport.***
- List several characteristics of Mount Rainier's environment that make it prone to debris flows and lahars. ***Abundance of loose rock from glacial and volcanic actions, abundance of water from precipitation and snowmelt, rapid changes in stream discharge, steep water-saturated stream banks, exposure of rock debris to erosion after melting of snow and ice.***

Rock and water cycles:

- Name some parts of the rock cycle and the water cycle that are evident here. ***Several stages of the rock cycle are in evidence—rocks intact within the face of Mount Rainier, rock layers in the river embankment, rocks in the riverbed, and fine-grained sediment carried in river water. Evidence of the hydrologic cycle include stream flow, flooding, deposits from past debris flow activity, and glacier activity upstream.***

Kautz Creek and the local ecosystem:

- Explore how the presence of debris flows and floods affected human, animal, and plant life in the vicinity of Kautz Creek. ***Repeated floods and debris flows have destroyed forest habitat for plants and animals and forced them to adapt. On multiple occasions, park employees rerouted the road, dredged channels, and created new highway drainage systems.***

> The picnic tables are an appropriate place to conduct the **Lahar in a Jar** activity. The activity is found in the Educator's Guide described on page 2 of this appendix.

Longmire

Mile 6.3

Logistics: 1–2 hours

Plan to use 1 hour for Longmire/Trail of Shadows walk;
30 minutes for Longmire Rocks walk;
30 minutes for the Nisqually River walk.

On arrival at Longmire, turn right into the parking lot (including spaces for buses) behind the National Park Inn. Plan to take one, two, or all three walks described here. ***Obtain a current map of trails at the Longmire Museum.***

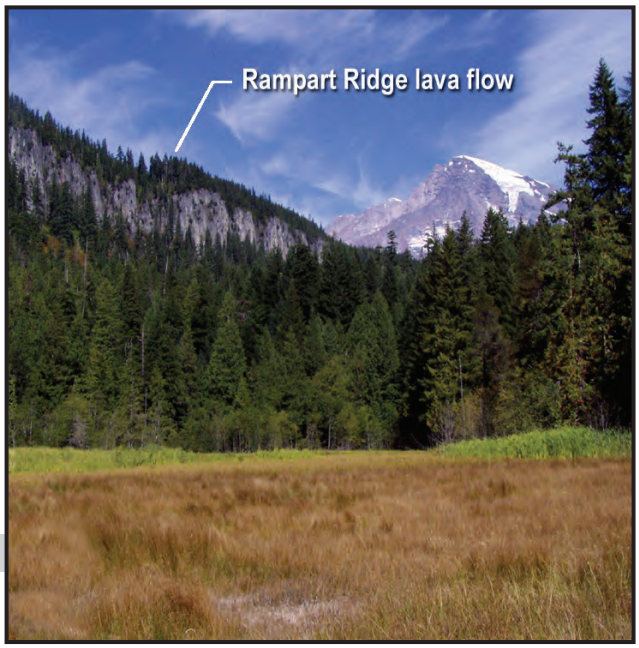


Figure 5*—Longmire meadow and springs flanked by Rampart Ridge lava flow. USGS photo by C. Driedger.*

Features of Interest:

1. View of Mount Rainier
2. Longmire Meadows and Trail of the Shadows with views of the warm mineral springs and the massive Rampart Ridge lava flow
3. Intrusive rocks used in buildings and bordering paths
4. Nisqually River road bridge

Background:

- ***Longmire is a grand setting for viewing Mount Rainier and related volcanic landforms.*** The story of James Longmire serves as a reminder of the natural human attraction to volcanic areas. In the 1880s, pioneer James Longmire established a homestead, hotel, and mineral springs resort here. At its height of popularity, thousands of visitors soaked in mineral waters. Later, the National Park Service built its park headquarters and a small natural history museum here, and the National Park Inn was opened. Today, only remnants of James Longmire's resort survive alongside some reconstructions. The museum and park headquarters building remain, although official headquarters are situated outside of the park. The historic gas station houses an exhibit that describes early transportation at the park. All of the park community of Longmire is now designated as a National Historic Landmark District. Longmire is a popular stop for today's visitors because of its trails, exhibits, gift shop, and lodge. It is the last field trip stop with restroom access before the Paradise visitor facilities.

The visit to Longmire can be a practical review for students who have completed the classroom activities **Fire and Ice** and **Magma Mash** in the Educator's Guide.

Longmire Area Trails—Mount Rainier National Park

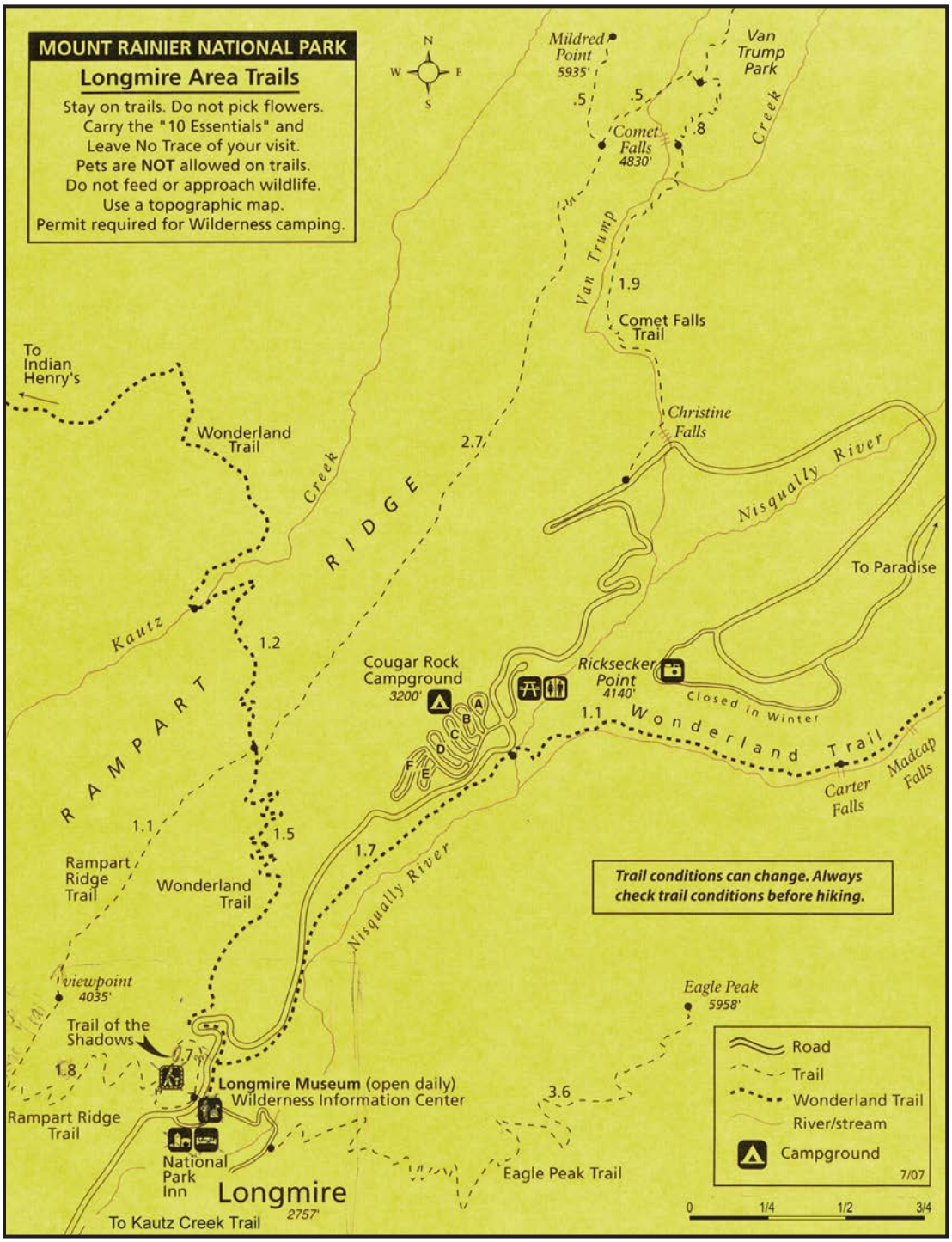


Figure 6— *National Park Service map of Longmire Area Trails, available at Mount Rainier National Park facilities.*

Longmire Walk 1—Longmire Meadows and Trail of the Shadows

Logistics: 1 hour

At the crosswalk, proceed cautiously across the highway to the meadow on the north side. Walk 0.2 kilometer (0.1 mile) to a small side trail on the left where interpretive signs provide general information about Longmire warm springs, Rampart Ridge, and local history. From there, walk along The Trail of the Shadows, a 1.1 kilometer (0.7 mile) loop around Longmire warm mineral springs, through forest and wet meadow. Interpretive signs describe the hotel, homestead, and spa built by James Longmire. Stop at each interpretive sign to obtain information about the springs, history, flora, and fauna. As with all hikes made within the park, students should remain on the trail. Use the questions below to encourage discussion.

Features of Interest:

1. Rampart Ridge lava flow
2. Longmire warm springs

Background:

Rampart Ridge lava flow:

- ***For much of the period when volcanism was building the mountain, glaciers covered a large part of Mount Rainier National Park.***
  Now try this mental exercise. Imagine yourself standing here in parka, hat, and gloves between 370,000 and 380,000 years ago. At your present location, you would be buried by 400 meters (1,300 feet) of glacial ice from the ancient Nisqually River Glacier. This enormous glacier stretched for tens of kilometers (tens of miles) from Mount Rainier's summit towards the Puget Sound lowlands to the west.

- ***Lava flows were constrained by large glaciers.***
  During this period of large glaciers and volcanic eruptions in what is now Mount Rainier National Park, many lava flows poured down the mountain's southwestern slope. Large glaciers in the Nisqually River and Kautz Creek Valleys constrained the movement of each lava flow. Each successive lava flow ponded between the two glaciers where it cooled and hardened. Later, changing climatic conditions caused the glaciers to thin and recede. The thick stack of cooled and hardened lava flows remains as Rampart Ridge.

- ***What formed the columns?***
  The lava flow cooled and hardened from the outside inward. Lava adjacent to glacier ice cooled within hours; the interior of the flow cooled over years to decades. As lava cooled and solidified, it contracted and cracked into long columns with polygonal cross sections. The columns aligned in the direction of greatest cooling. Columns on the cliff face are vertical because most heat is lost through the upper surface. Smaller horizontal columns that pointed horizontally toward the glacier margin once covered the lava flow sides, but most have been stripped away by erosion.

- ***Longmire warm mineral springs:***
  Longmire springs obtain their heat from hot rock located several miles beneath Mount Rainier. Water flows downhill and percolates through the volcanic rock and through the still warm feeder systems that supplied lava to the surface. At the same time, hot gases rise from magma stored 8 to 10 kilometers (5 to 6 miles) below the Earth's surface. The resulting hot water then mixes with cool shallow groundwater. The present temperature of springs is about 28 degrees Celsius (83 degrees Farenheit). During the 1920s, the park employees recorded the presence of about 50 springs, although the current number is less.

- ***Gas bubbles at Longmire warm springs consist largely of carbon dioxide (CO_2).***
  Most of the carbon dioxide at Longmire is volcanic in origin. Bubbles form because more CO_2 is supplied from below than can dissolve in the water. Carbon dioxide is denser than air, and can temporarily accumulate in low spots along the ground where it displaces oxygen and regularly kills birds and short-legged animals that venture into the springs for warmth and water. Not enough CO_2 is released at Longmire to be harmful to humans.

Figure 7— *Reconstruction of an historical visitor facility at Longmire. USGS photo by C. Driedger.*

Discussion questions for first stop in the meadow:

Rampart Ridge lava flow dominates the northern horizon:
Observe the cliff face on the ridge. Encourage discussion with the following guiding questions:

- Ten thousand or more years ago, what feature filled this valley? ***The ancestral Nisqually River Glacier***.
- What natural feature flanked and bounded the lava as it flowed into place? ***Glacier ice.***
- Explain why the lava flow top is hundreds of meters above the valley floor. ***The glacier once filled this valley to an elevation roughly equivalent to the present ridge top. Lava that flowed beside the glacier cooled and hardened as Rampart Ridge. The glacier melted and Rampart Ridge remains***.
- What is the origin of the columns (or "colonnades") in the cliff face? ***Interior rock cooled, contracted and fractured into polygon-shaped columns. These columns pointed toward the nearest cooling surface. Columns on the cliff face of Rampart Ridge point upward. Erosion has stripped away the smaller horizontal columns that abutted the glacier margin.***

Soda Spring:

The Soda Spring and site of the former Travertine Mound are ideal spots to ask the following guiding questions:

- Why do warm springs exist here? ***Warm rock beneath the surface heats groundwater.***
- Look for evidence that the spring's temperature is warm and not hot. If you have a thermometer, measure the temperature. ***The lack of persistent steam and the presence of vegetation nearby is an indication that the spring water is warm but not hot. The water temperature is variable and is dependent on the amount of groundwater present.***
- What causes bubbles to rise? ***Carbon dioxide rises through groundwater.***
- Is the water smelly? ***No.*** Is the air smelly? ***Potential odor from decaying vegetation.***
- Is the water clear or cloudy? ***Generally clear.***
- Why do dead trees exist in the springs area? ***Trees have been drowned by rises in water level caused by mineral buildup and by beaver dams.***
- Why are there so many mineral deposits around the outlets to the hot springs? ***Minerals dissolved in groundwater precipitate when the water cools.***
- Name some other volcanic areas of the world where water is heated by volcanic rock. ***Yellowstone, Lassen Peak, Mount Baker, Mount Fuji, Iceland, and others.***

Longmire Walk 2—Rocks on Buildings and Bordering Paths

Logistics: 30 minutes

Spend 30 minutes or so exploring the terrain in the vicinity of buildings at Longmire, including the small museum and log slice out front. With small groups of students, walk the pathways between National Park Inn, the museum, and the Wilderness Information Center (WIC) in the administration building (rustic building with the flag pole out front). Obtain a current map of Longmire from the Longmire Museum.

Figure 8—*Administration building at Longmire constructed with local rocks. National Park Service photo.*

Features of Interest:

1. Rocks within the building foundations and path borders at Longmire administration building have fascinating stories to tell.
2. Longmire Museum and transportation exhibit at the historic gas station provide a comprehensive history of visitor use of the park.

Background:

- ***The slice of log outside of Longmire Museum displays a timeline of geologic and historical events.***
  This is an ideal spot to view some of the history of much of Western civilization as chronicled on a slice of log. The tree from which it came stood strong through eruptions, lahars, and human intrusion into the region. Encourage students to read its event labels.

- ***Rocks in path borders and building walls display rocks of local origin.***
  During the 1930s, construction crews collected rounded, smooth-surfaced boulders from the riverbed as construction material for the buildings and path borders. Two rock types are common in the foundations and path liners—the reddish-gray Mount Rainier andesite, which was erupted from the volcano, and the lighter colored salt-and-pepper Tatoosh granodiorite (a variety of granite). About 17 million years ago, magma (hot, molten rock) worked its way upwards through Earth's crust and cooled as granodiorite about 8 to 16

Figure 9—*Tatoosh granodiorite is labeled as shown. The gray and red rock are Mount Rainier andesite. USGS photo by C. Driedger.*

kilometers (5 to 10 miles) below Earth's surface. Movement of Earth's crust forced the entire region upward during formation of the Cascade Range around 10 million years ago. As the mountains rose, erosion stripped away the surface rocks and eventually exposed the harder Tatoosh granodiorite. The Tatoosh granodiorite is visible immediately south and southeast of Longmire as many of the peaks of the Tatoosh Range.

- ***Minerals in some rocks are conspicuous and others less so.***
  The common white crystals in the granodiorite are mostly feldspars with lesser amounts of quartz; the black crystals are hornblende (somewhat elongate) and biotite (shiny dark mica). Feldspar is also conspicuous in the volcanic boulders as scattered white-to-clear crystals, accompanied by lesser pyroxene (brown and green) and sometimes a little hornblende. The darker groundmass in which those crystals are set consists of the same mineral types but are too tiny to distinguish without the aid of a strong magnifying glass or microscope.

- ***Rock origins determine rock appearance.***
  This is an ideal place for students to compare the sizes of crystals in the granodiorite with those in the boulders of Mount Rainier lava. The chemical compositions of the granodiorite and the andesite lava are about the same, indicating that they solidified from similar types of magma. However, the crystals are different sizes because the granodiorite cooled slowly underground giving more time for its crystals to grow ("slowly" means 100,000 to 1 million years to solidify, depending on circumstances). Long times at lower temperatures also account for the presence of quartz, hornblende, and biotite in the granodiorite versus their scarcity in the volcanic rocks. The prominent crystals in the lava also grew underground, but their growth was arrested when the lava erupted and chilled. The dark, fine-grained groundmass was largely or wholly molten at the time of eruption, and rapid posteruptive cooling allowed it to grow only tiny crystals. Some of the lavas cooled quickly and did not have time to crystallize but instead solidified as glass.

Discussion questions for use at pathways and stone buildings:

- **Rocks at Longmire:**
  Many boulders line the paths between the parking area and the meadows and are visible in the walls of Longmire area buildings. What kinds of rocks are these? How did they form? Why are they rounded? ***Boulders are andesite and granodiorite. Andesite formed as Mount Rainier lava flows; granodiorite formed as a mass of rock (pluton) beneath the Earth's surface that cooled and hardened over hundreds of thousands to millions of years. Stream-flow action rounded the boulders.***
- Explain the evidence of this being volcanic terrain. ***Students are close to Mount Rainier and the Rampart Ridge lava flow; warm springs exist nearby; volcanic rocks are found in abundance.***
- Instruct students to examine the rocks and record observations as written notes or in drawings. How many different rock types can they classify? ***Generally, two types of rocks are visible here—andesite and granodiorite. Both are igneous rocks. Most of the andesite boulders came from Mount Rainier, but some students may recognize that there are also brownish andesites that form rock outcrops up the path (north into the woods) in front of the administration building and also at the bridge across the Nisqually River behind the Longmire employee compound. These are older andesites that erupted 30–40 million years ago and form the regional basement into which the Tatoosh granodiorite intruded.***
- Encourage students to make visual observations or use magnifying glasses. Students should note texture, crystal size, and color. Which rocks took longest to cool? ***Rocks with largest crystals—generally granodiorite here.*** Which took the shortest time to cool? ***Andesite—especially those with small crystals.***
- Which rocks cooled inside the Earth (were intrusive)? ***Granodiorite.*** Which rocks cooled on Earth's surface (extrusive)? ***Andesite.***

The small picnic area in front of the flagpole is a good place to conduct the **Magma Mash** activity from the Educator's Guide. This activity illustrates why crystals in some igneous rocks are large and others are small.

Longmire Walk 3—Bridge over the Nisqually River at Longmire

Logistics: 30 minutes

Walk 0.5 kilometer (0.3 mile) through the park residential area to the road bridge that crosses the Nisqually River. Note: If you intend to do the coffee filter experiment for analysis of glacial flour (see page 19), bring materials with you—a bucket, graduated cylinder, funnel, several coffee filters, and a small scale. (Or you may want to collect water now and do the experiment back at school.)

Figure 10— *Nisqually River from Longmire bridge. USGS photo by C. Driedger.*

Features of Interest:

River characteristics:
Rounded river rocks, clear or sediment-laden river water (season dependent), and scouring and aggradation of the riverbed caused by erosion and deposition of river rocks.

Background:

- ***Glaciers ground rock to make glacial flour.***
  The Nisqually River originates 8 kilometers (5 miles) up the valley as melt water from the Nisqually Glacier. The glacier grinds rock against rock and produces an abundance of fine-grained sediment (glacial flour) that is transported by river water (glacial milk). The amount of glacial flour is greatest in summer and, at times, absent during winter. Along the way, glacial waters are diluted by water of nonglacial origin from tributary streams such as Van Trump Creek and the Paradise River. The rocks supporting the ends of the bridge, and visible just upstream along the river, are andesites of the Ohanapecosh Formation that erupted 30 to 40 million years ago from multiple volcanoes much older than Mount Rainier.

- ***The riverbed is routinely modified by natural processes.***
  Floods of 2006 carried boulders to this area, locally filled the channel, and allowed river water to erode the river embankments at Longmire. Park staff later plowed a wide channel

Experiment—Coffee filter analysis of glacial flour—how much glacial flour is in this glacial stream?

Try this experiment with your students at home or during your trip. Determine the amount of glacial flour in a glacial runoff stream by obtaining 10 liters (~2.6 gallons) of river water (obtainable with care at the base of the bridge). Using a standard 1 liter (33.8 fluid ounce) water bottle will require 10 dips and dumps. Weigh a coffee filter on a small scale and then place it in a funnel. Pour the water through the filter so that the glacial flour sticks to the filter. Let the coffee filter dry in the sun. Weigh the whole sample and subtract the original weight of the filter. During summer, you should find that as much as 500 grams (18 ounces) have settled out of 10 liters of water. Try the same experiment with water from different streams, glacial and nonglacial, and in different seasons.

From: Glaciers of North America Field Guide by Sue Ferguson, 1992, Fulcrum Publishing, Golden, Colorado, 176 pages.

Discussion questions for Nisqually River bridge:

Water cycle:

- Encourage students to trace the water cycle of which this river water is a part. ***The water originates as moisture in marine air masses over the Pacific Ocean. As winds blow in from the Pacific, air is forced upward by Mount Rainier, cools, and the moisture within drops as rain or snow. Groundwater and water in the river might have come from rain, melted snow, or melted glacier ice.***
- What processes in the water cycle are taking place during your visit? ***Possibly rain or snowfall, and (or) snowmelt, evaporation, cloud building, and water flowing off the mountain towards the ocean.***
- Explain how the Nisqually River here differs in appearance from rivers in the lowlands near your community. ***It contains a lot of large boulders, and it has seasonal fluctuations in velocity, width and depth, and sediment content.***
- What is the source of this water? ***Nisqually Glacier is the principal water source.***
- Explain how the stream flow fluctuates throughout the year. ***Stream flow is higher in summer and early fall, when snow and ice melt are most intense.***

Rocks in the Nisqually River:

- What type of rocks are found here? ***Mount Rainer volcano (andesite) and rocks from the Tatoosh Range (generally granodiorite).***
- Explain the origin of the downed trees in the riverbed. ***The river embankment was undercut by river water, and the trees fell onto the riverbed.***
- Are the rocks angular or rounded? Why so? ***Rounded because the sharp edges were ground off by collisions with other rocks in the river channel and polished by river flow.***
- Explain the origin of rocks in the riverbed. ***Rocks were eroded upstream and transported here by water and accumulate in the riverbed by a process called deposition or aggradation.***

Flooding:

- Identify evidence of flooding in the Longmire area. ***There are many boulders on the surface adjacent to the riverbed.***
- Explain what actions people have taken to reduce the likelihood of flooding at Longmire. ***People constructed dikes, plowed a deeper channel for the river, and built the bridge high above the river.***
- Explain how changes in river flow can affect human, animal, and plant life. ***Reduction in the amount of stream flow can deprive life forms of water; excess water can flood ecosystems. Flooding can damage or destroy community infrastructure.***
- As changes in climate hasten loss of snow and ice, how will the volume of river water change? ***Water flow could increase in the short term. When the glaciers and snowpack are greatly reduced, the amount of water in the river could decrease. Precipitation that falls as rain instead of snow will be stored as groundwater or flow away in a few days, rather than stored over the course of an entire season or longer.***

Christine Falls and the Tatoosh Pluton Granodiorite Mile 10.8

Logistics: Slow Pass

Safety note: Please do not stop the bus on the bridge over Van Trump Creek, but have the driver slow down and put on emergency flashers. Students get a safe view of upper Christine Falls during a "slow pass" across the highway bridge.

Features of Interest:

1. Granodiorite rock from Tatoosh Pluton
2. Upper Christine Falls

Figure 11— *Granodiorite of the Tatoosh Pluton near Christine Falls (keychain for scale). USGS photo by C. Driedger.*

Background:

- ***Tatoosh granodiorite:***
  This is one place where the 17 million year old Tatoosh granodiorite is visible at the surface. Viewing it along the roadside can be hazardous, so get an armchair view of it through the bus window.

- ***Christine Falls is good example of a hanging-valley waterfall:***
  Van Trump Creek falls off the Rampart Ridge lava flow into the Nisqually River Valley. View Upper Christine Falls in a narrow glen on the north side of the highway bridge (left side as proceeding from Longmire to Paradise). The bridge conveys you directly above Christine Falls. Observe it from a viewpoint adjacent to the parking lot.

- ***Debris Flows in Van Trump Creek:***
  On numerous occasions in recent years, stream water picked up and transported loose rock as debris flows, which swept down the valley of Van Trump Creek.

Glacier Bridge

Mile 11.6

Logistics:

Safety note: Please do not stop the bus on Glacier Bridge, but have the driver slow down and put on emergency flashers. Students get a safe view of the Nisqually River during a "slow pass" along the highway bridge.

Figure 12— *Nisqually River valley as seen from Glacier Bridge. USGS photo by C. Driedger.*

Features of Interest:

1. Nisqually River and Glacier
2. Evidence of glacier retreat

Background:

- ***Valley of the Nisqually River:***
  The Nisqually River originates at the terminus (lower end) of Nisqually Glacier, marginally visible 1.9 kilometers (1.2 miles) upvalley. Nisqually River is a "braided stream." For information about braided streams, see page 24.

- ***Road up the side of Ricksecker Point lava flow:***
  On the east side of the bridge, the road turns to the south and clings to the cliff of the Ricksecker Point lava flow.

Figure 13— *Nisqually Glacier terminus at river crossing in 1908. Photo by A. Curtis, Courtesy of Washington State History Museum.*

- ***Imagine yourself face-to-face with Nisqually Glacier.***
  In 1840, the terminus of the Nisqually Glacier lay just downstream of the present bridge. Now imagine it was in the 1880s, and you are accompanying early entrepreneur James Longmire on a hike up the riverbed to obtain glacier ice for his hotel's ice house. Longmire complains that he is forced to travel farther each year as the glacier terminus retreats up valley. Longmire's complaint became one of the first written records to document Nisqually Glacier's recession.

  Over the next 120 years, the glacier thinned and receded beyond the curve in the valley wall. Since that time, the glacier terminus has made small advances and recessions but never regained its former position in the vicinity of the Glacier Bridge. Read more about Nisqually Glacier in the descriptions for the next stop and in the background notes for Paradise.

Ricksecker Point Loop Road—North

Mile 12.7

Logistics: 15 minutes

Turn right on the Ricksecker Point Loop Road and park into the first lot on the right.

Features of Interest:

1. View of Mount Rainier's inner structure
2. Ricksecker Point lava flows
3. Nisqually Glacier and River
4. Evidence of rock and water cycles

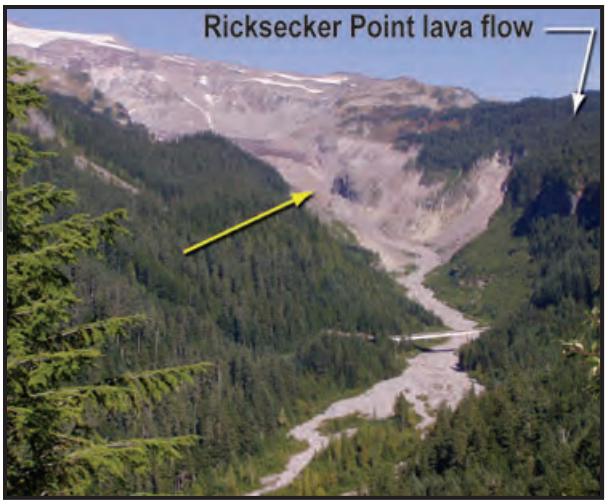


Figure 14— *Nisqually Valley from Ricksecker Point North. White arrow indicates location of Ricksecker Point lava flow, and yellow arrow indicates terminus of Nisqually Glacier. USGS photo by C. Driedger.*

Background:

- ***Ricksecker Point lava flow:*** Chances are that you are familiar with red hot lava flows from seeing them on TV shows. But now, here you are standing on top of lava flows that cooled and hardened. The Ricksecker Point lava flow on which you stand flowed into place about 40,000 years ago. This lava flow towers above the Nisqually River, as does the high-perched Rampart Ridge lava flow (380,000 years old) lava flow across the valley. It is a good place to contemplate why the lava flows exist so high above the present valley floor. As you drive towards the parking lot at Ricksecker Point South, be aware of the rubbly lava rocks that might have toppled onto the road surface.

Figure 15— *Loose rock rubble from top of the 40,000-year-old Ricksecker Point lava flow. USGS photo by C. Driedger.*

- ***View of Mount Rainier's inner structure:*** In clear weather, this stunning vista presents opportunities for discussion about Mount Rainier's inner structure. Glaciers and rock fall have stripped away overlying rocks to expose hundreds of lava layers, each 15 meters (50 feet) thick or more. The steep cliff bands are the dense flow interiors, whereas the intervening rubble slopes are the rubbly flow tops. The layering of hard lava and loose rocks creates a cliff-and-slope appearance, and preservation of the rubbly flow tops shows that the successive lava flows erupted in rapid succession. Such bursts of volcanic activity, separated by longer periods of few eruptions,

typify Mount Rainier's history, as well as that of the other active Cascade volcanoes. Some of the rubble slopes are deposits of pyroclastic flows (fast avalanches of hot lava fragments), but these cannot be distinguished from the more abundant rubbly tops of lava flows at this distance.

- ***Viewing Nisqually Glacier:***
  Ricksecker Point North is a grand place to observe Nisqually Glacier and evidence of its advances and retreats. The glacier's maximum position during the Little Ice Age (a period of global cooling from A.D. 1300 to 1850) was about 0.2 kilometer (0.1 mile) downstream of Glacier Bridge. About 2 kilometers (1.2 miles) of recession has occurred since the mid-nineteenth century. Moraines of the later part of the Little Ice Age hang on the valley walls and are a source of frequent rock fall. The interpretive sign illustrates the location of the glacier terminus through time. Nisqually Glacier is confined within steep valley walls, and through the course of glacier motion over many millennia, erosion by ice-bound rocks has deepened and widened the valley into the U-shape characteristic of glacier valleys. Learn more about Nisqually Glacier in the Nisqually Vista Trail section of this guide.

- ***Nisqually River—A braided stream:***
  During the summer months, rivers are swollen with snow and ice meltwater and heavily laden with boulders, gravel, and glacial flour, the fine-grained rock milled at the glacier bed. When the river level subsides, the boulders and gravel are deposited to form channels and bars. The water flows in a braided pattern around the islands and bars. The view from Ricksecker Point North shows several braids on the valley floor.

- ***Evidence of the rock and water cycles:***
  From this spectacular vantage point, several stages of the rock cycle are in evidence—some rocks that are intact within Mount Rainier, rock fall onto the glacier surface, rocks in the riverbed, and fine-grained sediment carried in river water. These are evidence of mountain building, weathering, and erosion. Phases of the water cycle are seen as clouds, precipitation, snow and ice, river water, moist forest soils, and vegetation.

Discussion questions for Ricksecker Point North Viewpoint:

Nisqually Glacier:

- Ask students to point out the summit of Mount Rainier and the head of Nisqually Glacier on its southern flank. Ask them to look for evidence that Nisqually Glacier was formerly present downvalley of its current location. ***U-shaped valley and erosionally smoothed surfaces on rocks.***

River width:

- Explain why the riverbed is so wide and with so little water flowing across it. ***The volume of stream flow is changeable and depends on precipitation and snowmelt and the presence of glacier outburst floods. In addition, the heavy load of rocks deposited on the valley floor over the years has caused the river to shift position.***

Water cycle:

- From this viewpoint, view water in a variety of forms. Identify the various stages of the water cycle that are visible from here. ***Water exists in the clouds, glaciers, snow, river, and in the moist forest soils.***

Rock cycle:

- From this viewpoint, students can observe rocks in a variety of phases in the rock cycle. Ask students to identify the various stages of the rock cycle that are in view from here. ***Several stages of the rock cycle are in evidence—rocks intact within the face of Mount Rainier, rock fall on the glacier surface, rocks in the riverbed, and fine-grained sediment carried in river water.*** Ask students where the river will carry and deposit the fine-grained material that it carries downstream. ***Some of the fine-grained rock will be deposited in Alder Reservoir and ulimately in the Pacific Ocean. Pieces of these rocks might become part of sedimentary rocks; these rocks might be metamorphosed, or melt and form magma to be erupted again.***

Rocks in the manmade walls of the parking lot:

- What color are the rocks in the manmade walls of the parking lot? ***Salt-and-pepper.*** Are they alike or different from rocks in the valley wall? ***Rocks in the valley walls are darker in color because they consist of lava erupted from Mount Rainier. The salt-and-pepper granodiorite was eroded from cliffs of the Tatoosh Pluton located upstream from Glacier Bridge (and under the lava flows).***

Ricksecker Point Loop Road—South

Logistics: 15 minutes

Note: Ricksecker Point loop road is closed in winter.
Drive approximately 0.6 kilometer (0.4 mile) to the Ricksecker Point parking lot located at the switchback in the road. This viewpoint is located at the tip of the lava flow.

Figure 16— *Mount Rainier from Ricksecker Point South. USGS photo by C. Driedger.*

Features of Interest:

1. Panoramic view of Mount Rainier
2. Interactions between lava flows and glaciers
3. Top and toe of Ricksecker Point lava flow
4. Tatoosh Range (pluton of pre-Mount Rainier rocks)
5. Paradise Lahar

Background:

- ***The toe of this lava flow was constrained at the juncture of two massive ice-age glaciers.*** Ricksecker Point lava erupted during a period of extensive glaciation. The present overlook is close to the level of the glaciers' surface, during the Ice Age, when one could have walked across the ice to Rampart Ridge above the chasm now occupied by the Nisqually River or across to Eagle Peak and the Tatoosh Range above the present Paradise River valley. During repeated eruptions, lava streamed down the south side of Mount Rainier and flowed along the margin of the approximately 240 meter (800 foot) thick ancestral Nisqually River Glacier to the west and the ancestral Paradise River Glacier to the east. Lava probably advanced along the crest of an ice-buried ridge between the flanking major ice streams because the ice was thinnest along that route. At the confluence of the two glaciers near the present location of Ricksecker Point, much or perhaps all of the lava pooled, cooled, and hardened. After the glaciers retreated, the Ricksecker Point lava flow remained stranded high above the surrounding terrain. The down-valley toe of the lava flow supports the present roadway at Ricksecker Point. See the activity Fire and Ice in the Educator's Guide for more information about how this phenomenon was important in the shaping of Mount Rainier.

- ***Rubbly top of Ricksecker Point lava flow.***
  This feature is visible in the toe of the lava flow—the outcrop northeast of the parking lot. Andesite lava flows typically consist of a dense interior with elongate columns in which pasty lava cooled slowly, shrank, and cracked, overlain by a carapace of loose rubble. This rubbly flow top forms because the upper surface of the lava flow cools quickly and hardens as the flow continues to move. The rocks of the flow top are jostled and broken and grind against one another forming a rubbly carapace. Note the lava "squeeze-ups" (ridges and spines of solid rock) where molten lava from the hot interior of the flow intruded into the rubbly top of the flow. These rubbly flow tops erode quickly and are preserved only if the flow is relatively young or early on is buried by succeeding lava flows. The Ricksecker Point lava flow is about 40,000 years in age—one of the younger of the large ridge-producing flows in Mount Rainier National Park (the youngest known lava flows from Mount Rainier erupted about 2,800 years ago, are exposed along the rim of the summit crater and underlie the Emmons and Winthrop Glaciers on the opposite side of the volcano). The flow top rubble is quite unstable and produces frequent rock fall onto the roadway.

- ***Other rocks identifiable from Ricksecker Point South.***
  This location offers a view of pre-Mount Rainier rocks (Tatoosh granodiorite) in the Tatoosh Range to the south and in the roadway guard walls constructed around the periphery of the parking lot.

Discussion questions for Ricksecker Point South Viewpoint:

Origin of the valley:

- Develop a hypothesis about the origin of the valley. ***Glacial ice flowed down the valleys of Paradise Creek and the Nisqually River and joined here. Lava flowed from Mount Rainier and was confined between the confluence of these two glaciers. The lava cooled and hardened. When the glacier melted, the lava flow was stranded high above the valley floor.***
- Near this point, elevation of the Nisqually River Valley floor is approximately 1,040 meters (3,400 feet). You are standing at elevation 1,280 meters (4,200 feet). Calculate a minimum ice thickness when the lava flow formed (erosion rates in hard granodiorite are slow, so the valley floor was almost exactly the same elevation 40,000 years ago). ***Answer is approximately 240 meters (800 feet).***

Volcanic processes:

- While viewing Mount Rainier, name the processes that formed the multiple layers (seen in profile) on the volcano. ***Lava formed the solid rock layers; pyroclastic flows and loose rock from lava flow tops formed the intervening loose rock layers.***
- List the geologic processes that formed the landscape. ***Volcanism, glaciation, and erosion by water flow.***
- List some evidence for repeated volcanism at Mount Rainier National Park. ***Hundreds of lava flows erupted through time built the ridges that radiate from Mount Rainier.***
- Explain how volcanic activity at Mount Rainier differs from activity at other types of volcanoes, such as Hawaiian volcanoes. ***Lava here is more viscous than at Hawaiian volcanoes and capable of accumulating as a steep-sided pile—that is, as a stratovolcano.***

Paradise Visitor Facilities — Mile 17.6

Logistics: 30 minutes to 5 hours

Note: Obtain the most recent map of trails at the visitor center. Consider one or more options:

Option 1—View the Paradise Jackson Visitor Center exhibits and theater (30 to 60 minutes+). Note: Cafeteria and gift shop also are located in the visitor center.

Option 2—Hike the Nisqually Vista trail 1.9 kilometers (1.2 miles) roundtrip (1.5 hour). ***Note: Group snowshoe walks are available by prior arrangement in winter.***

Figure 17*— The Paradise Jackson Visitor Center. USGS photo by C. Driedger.*

Option 3—Make longer hikes to Alta Vista 2.8 kilometers (1.75 miles) round trip, Glacier Vista (3.2 kilometers or 2.0 miles round trip), and Panorama Point (6.4 kilometers or 4.0 miles round trip). Allow about 5 hours for the Panorama Point trip. A 1.2 kilometers (1 mile) short hike leads to Myrtle Falls. Trails begin just outside the north doors of the visitor center. ***Note: Option 3 trails are snowbound in winter and travel there is not appropriate for school groups.***

Note: If you intend to conduct the bug string experiment (page 35), choose hike options 2 or 3. If you intend to do the glacial striations experiment (page 43), choose option 3. Consult those sections for a list of equipment required.

Features of Interest:

1. Alpine meadows and views of other volcanic features and landforms (Mounts Rainier, Adams and St. Helens, and the Goat Rocks, the Tatoosh Range, and basalt flows to the east)
2. Visitor Center, location on the Ricksecker Point lava flow
3. Tephra layers (material ejected from a volcano that falls to the ground; when less than 2 millimeters (0.08 inch), it is called volcanic ash)
4. Paradise Lahar
5. Glaciation

Figure 18*— Boulders from the 5,600-year-old Paradise Lahar protrude at the surface over much of Paradise Ridge. Sandy layers of volcanic ash from eruptions of Mount Rainier and Mount St. Helens overlie and underlie boulders of the Paradise Lahar. USGS photo by C. Driedger.*

Paradise Area Trails—Mount Rainier National Park

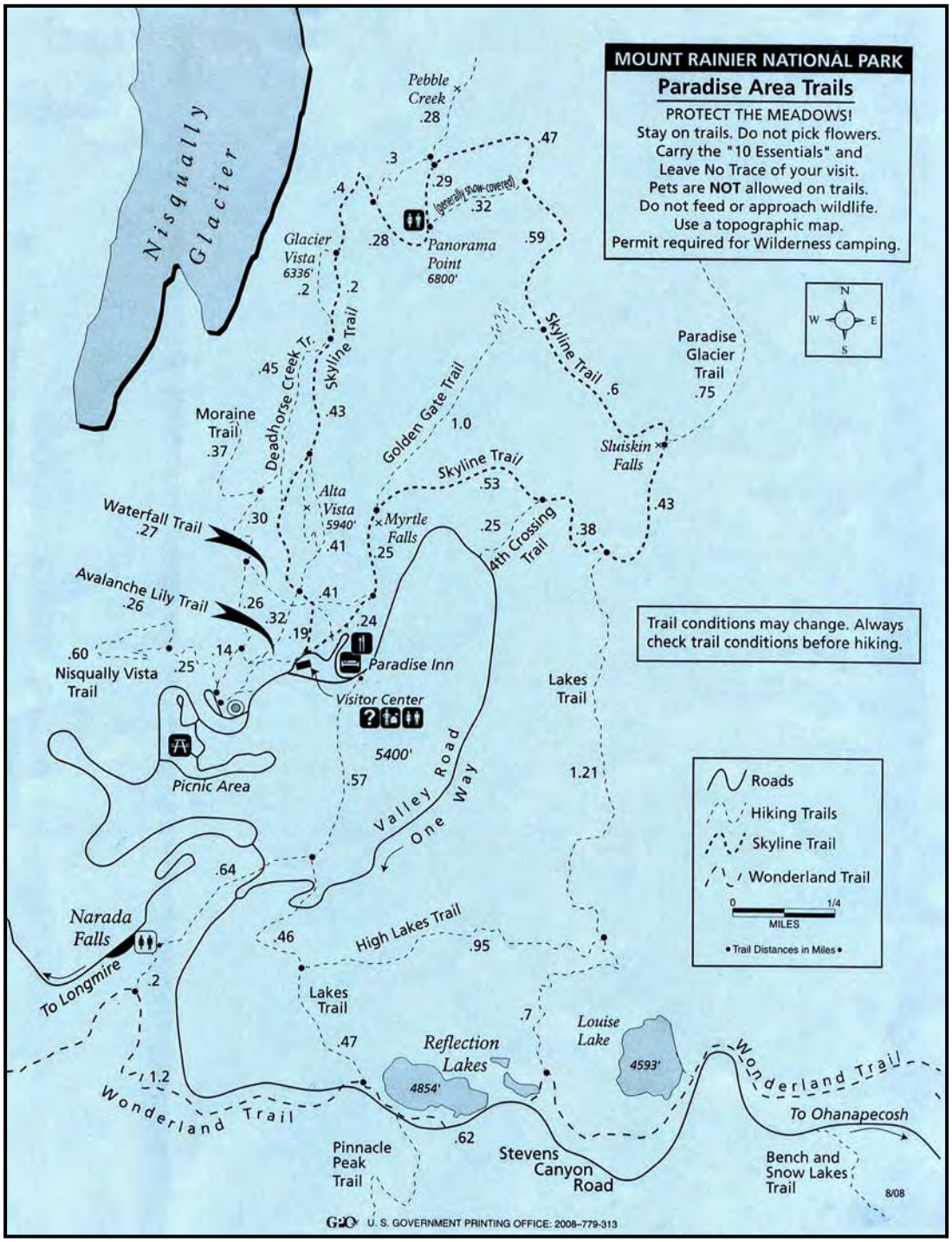


Figure 19— *National Park Service map of Paradise Area Trails, available at Mount Rainier National Park facilities.*

Background:

- ***The Paradise visitor facilities are built on a thick stack of lava flows that are overlain by lahar deposits and tephra layers.***
  In the vicinity of the Paradise visitor facilities, the 40,000-year-old Ricksecker Point lava flow (which sits on a stack of older lava flows) is covered with an undulating surface of rock debris left there by several lahars, most notably the 5,600-year-old Paradise Lahar and the 7,200-to 7,400-year-old Reflection Lakes Lahar. The Paradise Lahar formed by collapse of rock near the summit of Mount Rainier. It swept down the southeast side at about the same time that the Osceola Mudflow swept down the mountain's northeast side. Most of the Paradise Lahar descended the valley of the Nisqually Glacier and River, but rocky deposits on valley walls show that the Paradise Lahar also swept over Paradise and Mazama Ridges and filled the valley between Ricksecker Point and the Tatoosh Range—a thickness that temporarily may have exceeded 250 meters (820 feet). When the more liquid part of the lahars drained away, they left behind large boulders on the surface. These boulders are easily identifiable along the trails around Paradise as isolated blocks and by their light brown and yellowish brown colors that result from hydrothermal alteration by hot gases near the volcano's summit. The Reflection Lakes Lahar was one of many collapses that have occurred on Mount Rainier. The undulating surface left behind by these and other lahars are responsible for the numerous small hills and ponds, such as Reflection Lakes southeast of Paradise.

Figure 20— *Layer Yn erupted from Mount St. Helens in A.D. 1479 and found near the surface around the south side of Mount Rainier. Lens cap shown for scale. USGS photo by C. Driedger.*

- ***Tephra layers at Paradise:***
  The sandy layers evident in many road and trail embankments are layers of tephra. Wind blew volcanic ash and larger pieces of pumice here from eruptions at Mount Rainier, Mount St. Helens, and ancient Mount Mazama (present-day Crater Lake, Oregon). Material from tephra eruptions of Mount Rainier are poorly represented at Paradise because most of the volcano's ash was blown to the eastern flank. The tephra layers have been distorted or removed entirely in most outcrops by the action of burrowing animals, plant roots, surface water movement, and long-term slope creep. These actions leave us with an imperfect and minimal record of eruptions.

Common Tephras found in the vicinity of Paradise:

Layer Wn	Layer Yn	Layer D	Layer O
Mount St. Helens	Mount St. Helens	Mount Rainier	Mount Mazama
A.D. 1479	about 3,700 years ago	about 7,000 years ago	about 7,700 years ago
• white to gray and brown • sand-size ash	• yellow to brown • coarse particles	• yellowish - to reddish brown • coarse pumice and scoria	• yellow-orange to pale-brown • silt-size ash

- ***Ice ages:***
  The past 2 million years of Earth's history were typified by the development of extensive glaciers in high mountains and also covering large areas of northern North America, Europe and Asia, alternating with nonglacial times. This time is known as the Pleistocene or in popular literature as the Ice Age. Worldwide, ice advanced and retreated. Over the 500,000 year existence of Mount Rainier, periods of widespread glaciers have each lasted from 90,000 to 120,000 years, separated by intervals of thousands to a few tens of thousands of years when climate was more like that of today. Smaller fluctuations in ice extent were superimposed on these major advances and retreats. The last period of extensive glaciation ended about 11,000 years ago. Between the fourteenth century and A.D. 1850, many of the glaciers on Mount Rainier advanced to their farthest extent downvalley since the last ice age. This period when glacier advances occurred worldwide became known as the Little Ice Age.

- ***Nisqually Glacier history:***
  On at least two occasions (about 150,000 years ago and then again about 20,000 years ago) Nisqually Glacier extended as far as approximately 60 kilometers (37 miles) from Mount Rainier to the site of Alder Lake Dam, west of the town of Elbe. During the past period of regional glaciation that peaked about 22,000 years ago, ice from the ancestral Nisqually River Glacier extended as far as the community of Ashford, approximately 32 kilometers (20 miles) from the foot of the mountain. During the Little Ice Age, Nisqually Glacier terminated 240 meters (800 feet) downvalley from the present site of Glacier Bridge (Highway 706) over the Nisqually River. After 1850, retreat of the Nisqually Glacier was slow until about 1920 when it hastened. Between the peak of the Little Ice Age and 1950, Nisqually Glacier and other large valley glaciers on Mount Rainier retreated about 1.6 kilometers (1 mile) up valley. Beginning in 1950 and continuing through the early 1980s, however, Nisqually Glacier and many other major glaciers advanced slightly in response to several years of relatively cooler temperatures. Since the early 1980s, Nisqually Glacier and most other glaciers on the mountain have been thinning and retreating. At the time of this writing (2014), the active terminus of Nisqually Glacier is located near the 1951 terminus position. As climate continues to change, at times making conditions less favorable for glacier growth, it is unlikely that Nisqually Glacier will disappear completely, but it will thin and become a much smaller glacier, residing higher on the slopes of Mount Rainier.

Logistics: 30 to 60 minutes+

Open daily in summer and on selected days during winter. Call or check the Mount Rainier National Park Web site for specific information. The parking lot fills by midday during summer weekends, less quickly at other times. In the visitor center, visit the Mount Rainier movie in the theater, and the large relief map on the first floor, and the exhibit area on the second floor. A gift shop and cafeteria are located in the same building. ***Obtain a current map of trails at the visitor center.***

Option 1 Paradise Jackson Visitor Center

Figure 21— *Interactive displays about natural and human history are located on the second floor of the Jackson Visitor Center at Paradise. USGS photo by C. Driedger.*

Discussion questions for Geology Exhibits:

After viewing the exhibits, students should be able to answer these basic questions about the area.

- What are the other volcanoes of the Cascade Range between northern Washington and northern California? ***Mount Baker, Glacier Peak, Mount Adams, Mount St. Helens, Mount Hood, Three Sisters, Newberry Volcano, Mount Jefferson, Crater Lake, Medicine Lake volcano, Mount Shasta, and Lassen Peak.***
- Explain how precipitation is important to glaciers, rivers, and living things at Mount Rainier National Park. ***Fresh snow and rainfall feed glaciers and rivers and provide abundant moisture for plants and animals.***
- What is a glacier, and how does a glacier form? ***A glacier is a mass of ice formed from snow falling and accumulating over the years and moving in response to gravity.***
- Name some geologic processes that have shaped the area. ***Lava flows, volcanic ash fall, pyroclastic flows, lahars, glaciers, and rivers.***
- Name the principal hazards to people and structures on valley floors surrounding Mount Rainier. ***Lahars and debris flows.***

Logistics: 1.5 hours

Consider walking the 1.9 kilometer (1.2 mile) paved Nisqually Vista Loop Trail, which can be reached at the north side of the westernmost parking lot. Numerous paths lead to this trailhead, so seek advice from staff about the easiest way to reach it. This walk can be done in athletic shoes in summer through early fall; in hiking boots on compacted snow (June through mid-July); or with snowshoes (November through May). The National Park Service requires that hikers remain on the trails at all times, and if the trail is snow covered, that they follow trail flags carefully. Check hiking conditions before your trip. Hiking at high elevation can be tiring. Early summer hiking on this trail may be slippery and hazardous.

Option 2 Nisqually Vista Hike

Figure 22— *The Nisqually Vista Loop Trail, paved and well marked, is suitable for hiking during summer and fall and for snowshoe walks during winter and spring. USGS photo by C. Driedger.*

Note to Teachers:
Before making this hike, read the materials carefully and plan to ask the discussion questions at each stop described. For the bug-string measurement (see page 35), you will need at least 1 hour between setting up and returning to the stakes.

Features of Interest:

1. Mount Rainier
2. Nisqually Glacier
3. Glacial moraines
4. Cross-section of the volcano
5. U-shaped glacial valley
6. Boulders left behind by lahars
7. Volcanic ash

Figure 23— *Tephra, reworked by water and by the actions of plants and animals is visible along many trails around Paradise. USGS photo by C. Driedger.*

Teacher background and guiding questions:

- ***Tephra layers:***
  Trail embankments are ideal locations to view volcanic ash as it erodes and falls into the path. Rock fragments called

tephra erupted from a volcano; pieces of tephra less than 2 millimeters diameter are called volcanic ash. Geologists designated the yellow-colored ash as layer Yn. It was erupted from Mount St. Helens about 3,700 years ago. In some places along this trail, find layer Wn (Mount St. Helens in A.D. 1479), and layer O (Mount Mazama, 7,700 years ago). See in-depth descriptions of these tephras on page 31. Reworking of the ash by water and by plants and animals has disturbed and mixed the layers and in many places made them indistinguishable.

Discussion questions for along trail where tephra is visible:

- What are the layers of sandy unconsolidated material? ***Tephra.***
- Where did these layers come from? ***Eruptions at Mount St. Helens, ancient Mount Mazama (present-day Crater Lake, Oregon). Most tephra from eruptions at Mount Rainier fell on the eastern flanks of the volcano.***
- In what ways is tephra important to plants and animals? ***The soft texture of tephra allows easy penetration by plant roots and burrowing by animals.***

- ***Weather station:***
  This pole-mounted station is a great place to talk about Mount Rainier's weather. The station contains instruments for measurement of air temperature, solar radiation, wind direction and speed, humidity, and precipitation, including a device that measures the depth of snow on the ground throughout winter. The record for snowfall at Mount Rainier was 8 meters (93 feet) set in the winter of 1971–72.

Figure 24—*The Paradise weather station, perched high above winter snowpack, is the source of weather data used by visitors and researchers. USGS photo by C. Driedger.*

Discussion questions for weather station area:

- Ask about the importance of this weather station to people. ***Information on snowfall helps us to quantify yearly water supplies for hydropower, drinking, and irrigation. The long-term weather record is used to identify climate changes. Current conditions reported from this station can help visitors make suitable plans for their visit to Mount Rainier.***
- Do you have the same weather station components at your school or community weather station? Why or why not? ***Answers will vary.***
- Challenge students to do a Web search when they return to the classroom and to find the current weather conditions at Paradise. ***Hint: Current conditions from this site are posted at the Northwest Weather and Avalanche Center.***

Experiment—Bug-string measurements of snow melt rate. How fast is the snow melting?

1. For the bug-string measurement of snowmelt, you will need to allow at least one hour after setting up the stakes to see measurable snowmelt in the repeat measurement (more on hot and sunny days; on some days no melt will occur).
2. Beside the trail, on untouched snow, pound two wooden garden stakes securely into snow about 2 meters (6 feet) apart, taking care not to disturb the snow surface between them.
3. Connect the stakes with a string, 1 stretch the string taut, and then tie string to wooden garden stakes at height of approximately 8 centimeters (3 inches) above the snow surface.
4. Use a permanent marker to mark "bugs" (tick marks) approximately every 15 centimeters (6 inches) along the string.
5. Use a ruler to measure the vertical distance between snow surface and each bug on the string.
6. Record your measurements.
7. Return 1 hour or more later to repeat the measurements of the distances between the bug string and now surface.
8. Take an average of the original and repeat measurements, subtract values, and calculate melt rate per hour.

- ***Gas bubble boulder and other boulders left stranded by lahars of centuries ago:*** As you descend the hill towards the edge of the ridge, the trail passes one particularly large boulder that contains an enormous gas bubble. Expanding gases inflated the magma, which later cooled and hardened. Most of the large rocks on the surface were transported here by lahars that swept over the ridge. This is a good place to talk about the rock cycle and the processes that formed the rock and transported it. Look for other boulders along the trailside. The undulating ground surface is another legacy of lahars.

Figure 25— *Rock along the side of the Nisqually Vista Loop Trail, probably transported here by the 5,600-year-old Paradise Lahar, contains a large gas bubble. USGS photo by C. Driedger.*

Trail junction.

Take the trail on the right. In winter, the trail is snow covered; follow the flags carefully.

- ***Flower fields, twisted trees, and tadpoles:*** In summer, wildflowers fill the meadow with color. They sink their roots into the soft tephra from eruptions at Mounts Rainier and St. Helens. Tadpoles swim in small ponds during late summer and fall. The trail descends through trees. Note that heavy snow has bent and distorted the tops of many trees. If you are here in summer, observe that these trees, which have spent more than half the year surviving under snow, are badly misshapen.

Figure 26— *Flowering meadows are dependable attractions along the Nisqually Vista Loop Trail in summer, even during poor weather conditions. USGS photo by C. Driedger.*

- ***Nisqually Glacier viewpoints:*** Nisqually Glacier is evident from four viewpoints along the trail. The last viewpoint provides the best view and can accommodate an average-size class safely. An interpretive sign describes the glacier and its parts. ***Visitors should not climb on or beyond the rock retaining wall.*** The viewpoints are ideal locations to rest and discuss concepts and features noted in the bullets below.

Figure 27— *The terminus, or snout, of Nisqually Glacier is visible as a gray diamond-shaped feature in the lower center of the photograph. Rocks cover much of the lower glacier and make the glacier difficult to discern to the untrained eye. Red line indicates postion of glacier terminus. USGS photo by C. Driedger.*

- ***Nisqually Glacier is one of the most easily accessible and most studied glaciers on Mount Rainier.*** The glacier begins at the south edge of the summit crater and flows as much as 1 meter (3 feet) per day down a series of ice falls and then slows in the region 2.6 kilometers (1.6 mile) upvalley from the terminus, where it is joined from the west by the Wilson Glacier (left looking uphill). Nisqually Glacier is the fourth largest glacier by area on Mount Rainier. Scientists used radar devices to measure the ice and found it to be at its thickest about 1 kilometer (0.6 mile) up valley from the terminus—about 120 meters (400 feet) deep. Height of the terminus is approximately 30 meters (100 feet).

- ***Moraines and trimlines:*** Moraines are the sharp-crested ridges of unconsolidated rocks visible along the glacier's margins. Rocks fall off of cliffs onto glaciers, are transported, and then deposited along the glacier margins. Moraines can grow large when the glacier position remains stable over a

period of years and are good indicators of a glacier's former dimensions. At Nisqually Glacier, the highest lateral (side) moraines record elevation of the ice during the 1840 advance (arrow on figure 28). Some of the roughly linear rock patches visible below the 1840 moraine are part of moraines formed during later ice advances in the latter part of the 19th century and during a brief advance in 1900. Look for trimlines, the distinct boundaries between older forest and younger pioneering vegetation that are visible above moraines on the glacier's west margin. Geologists determined the former extent of Nisqually Glacier and other glaciers by mapping the outline of glacial moraines and noting the position and ages of trimlines.

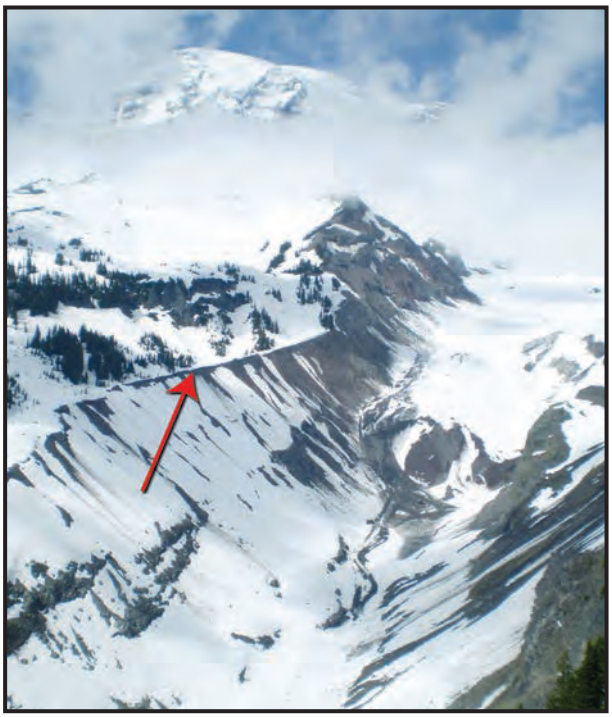


Figure 28— *Moraines from glacial advances in the nineteenth century are visible from the Nisqually Vista Loop Trail as sharp lines on the west valley wall at upper right of this photograph (red arrow) and in figure 27. USGS photo by C. Driedger.*

- ***Crevasses:***
  Glaciers flow faster near their surface and at centerline and slower near their bed and margins. The unequal flow rate causes the ice to tear and form crevasses. The ice also cracks as it rides over the crests of bulges in its rock bed. Most crevasses on Nisqually Glacier do not exceed 30 meters (100 feet) in depth.

- ***Origin of rock on the surface of Nisqually Glacier:***
  The glacier begins as a thick accumulation of snow and ice at the south edge of the summit crater. Avalanches fall from nearby rock walls and supply additional snow and rock to the glacier. In summer the ice melts on the lower mountain, but the rocks are left behind and accumulate on the surface, year after year. At thicknesses less than 2.5 centimeters (1 inch), small rock debris on the glacier enhances ice melt; rock debris at greater thicknesses slows the melting. The result of this action is a rocky and uneven glacier surface that by late summer is brown to black in color.

- ***Glacier advance and retreat:***
  Climatic conditions control the amount of snowfall and melt and, thus, the dimensions of a glacier. When summer melt exceeds winter snowfall over a period of years, the terminus retreats. When snowfall over a period of years exceeds summer melt, the terminus advances. A convex terminus indicates ongoing advance, while a concave terminus indicates terminus retreat. At Mount Rainier, changes in glaciers' terminus positions typically take about one decade to become apparent. Because of this relationship between climate and terminus behavior, glaciers are indicators of climate change.

- ***The Nisqually River begins beneath the ice of Nisqually Glacier and becomes visible at the cave-like opening glacier terminus.***
  River water carries a substantial load of glacial flour, the fine-grained rock eroded from the glacier's bed. In winter, the glacier melts less and flows more slowly, resulting in a reduced rate of erosion. This causes noticeable differences in the cloudiness of the water between winter and summer.

Figure 29—*During summer, Nisqually River rapidly conveys melt water from glacier and winter snowpack. The flow diminishes in winter. USGS photo by C. Driedger.*

Discussion questions for Nisqually Vista viewpoint:

General observations of Nisqually Glacier:

- List some features visible at Nisqually Glacier. ***Glacier terminus, cave where Nisqually River begins, rock cover on glacier, crevasses, glacier moraines, vegetative trimlines, snowline and U-shaped valley. If you visit during summer or fall, observe that the snowline is now at a higher-elevation than in winter. Snow that remains on the surface at the end of the summer melt season might eventually transform into ice.***

Water and rock cycles:

- Encourage discussion of the water and rock cycles. Name processes in each that are visible from here. ***Rock Cycle—results of volcanism notable as lava flows, pyroclastic flows, and volcanic ash; erosion by rock fall and glacier; moraine building; and transport of rocks and sediment downstream. Water Cycle—cloud formation and potential precipitation during your visit, glacier formation, long-term storage of water as snow and ice, glacier melt, and river flow.***

Rock on the glacier surface:

- What is the origin of rocks that cover the glacier surface? ***Much of the rock debris originates as rock fall. Successive layers of snow bury the rocks. The snow metamorphoses to ice and flows to lower elevations. In the warmer temperatures of lower elevations, the ice melts and the rocks accumulate on the glacier surface.***
- Why is there a large amount of rock fall at Mount Rainier? ***Volcanic and glacial processes have produced large amounts of loose rock by tephra fall, pyroclastic flows, erosion from the rubbly tops of lava flows, and glacial action. The freezing and thawing of water in fractures within the rock causes additional rock breakage.***
- What effect will the rock have on the melting of the glacier? ***Rock insulates the ice when it exists at a thickness greater than 2.5 centimeters (1 inch) and enhances melt at lesser thicknesses. When ice melts, rock from within is left to cover the glacier surface.***

Glacier advance and retreat:

- What natural processes cause glaciers to lose mass? ***Melting, sublimation (from solid to gas), evaporation, and avalanching.***
- Explain how the glacier can flow continuously downhill and at the same time lose length by melting. ***The position of the glacier terminus advances down valley when, over a period of years, flow rate exceeds melt rate. The position of the glacier terminus retreats up valley when, over a period of years, the glacier melt rate exceeds its flow rate.***
- What evidence is visible of the present status of the glacier? ***At this writing in 2014, the glacier terminus is retreating, and the terminus has a characteristic concave shape, as compared to a convex shape during advance.***
- What evidence suggests that the glacier has been larger in the past? ***Moraines and trimlines show former heights of ice, and glacial striations (scratches) are found atop flanking rock ridges.***
- How can knowledge of former glacier dimensions help us understand past climatic conditions? ***Glaciers enlarge or shrink in size as a result of climate conditions and thus are sensitive indicators of the climate over a period of years.***

Nisqually River:

- What causes the cloudiness in the water that exits the glacier? ***Glacial flour.***
- Which substance is harder—glacial ice or rock? ***Rock.***
- Can glacial ice cut rock, or is there another mechanism which allows for the cutting of rock beneath a glacier? Explain your reasoning. ***Ice is softer than rock and will not scratch it. Rock that is encased within glacial ice scratches rocks at the bed of a glacier.***
- Explain how glaciers can help and hinder the growth of vegetation. ***Glaciers store water as ice and then release it as stream flow. Plants and animals use this water for survival. Areas that are recently deglaciated are not conducive to growth of vegetation because they lack favorable soil and environmental conditions. In the long-term absence of glacier ice, soils form and vegetation can flourish.***

Establishing a photo record:

- Ask students about what a photo record can reveal about glacier change. ***Changes in glacier dimensions.***
- Encourage students to begin their own photo record, and give them the opportunity to start a long-erm photo record at this viewpoint. Ask what methodology will provide the most consistency with repeat photography. ***During each visit, take photos from same location (GPS can help you maintain your photo stations); include landmarks in photographs; use same or similar camera lenses; make photographs in clear weather; keep your photograph collection well labeled and organized.***

Figure 30— *Alternating layers of lava and loose rock rubble are visible in eroded slopes of Mount Rainier. Some of the loose rock layers were emplaced by pyroclastic flows and others from the broken shards of rock from lava-flow tops. USGS photo by C. Driedger.*

Internal structure of Mount Rainier:

- Nisqually Vista is a grand place to observe lava layers that protrude from within Mount Rainier. Nearly every cliff is the formerly pasty interior of a lava flow that hardened into dense rock, and the overlying slope is its rubbly flow top. Glacial erosion and rockslides have cut into the stacks of lava, exposing them in cross section. The lava layers slope away from Mount Rainier's summit, showing that nearly all lava flows erupted from high on the volcano, and that successive flows built up the volcano. Preservation of the loose rubble bands and the parallel layering show that the lava flows erupted in quick succession. In some places, careful observers may see places where higher layers cut across and terminate lower ones. These situations represent erosional breaks during which lava either did not erupt from the volcano or flowed to other parts of the volcano long enough that erosion could incise its slopes. Subsequent eruptions then buried those eroded surfaces.

End your field trip by completing the loop trail.

- During an in-class review of your hike, analyze any data collected and look at the photographs. Post-field trip review will promote retention of the material covered during this trip.

Option 3 Alta Vista/Glacier Vista, Panorama Point, Myrtle Falls Hikes:

Logistics: 5 hours for complete trip

See hike options below. If departing from the main (upper) parking lot next to the Jackson Visitor Center, use the central trailhead (the grand granite staircase engraved with the John Muir quote) for access to these trails and nearby Myrtle Falls. For rubbings of glacial striations, bring a compass, tracing paper and pencils.

Note to teachers about trail safety:
Speak with staff at the visitor center to obtain an accurate assessment of current trail and weather conditions before embarking on a trip to Glacier Vista or Panorama Point. The trail offers dramatic vistas of subalpine wildflowers, a close-up view of Mount Rainier and Nisqually Glacier, and, on a clear day, views of Mounts St. Helens, Adams, and Hood. All hikers must remain on established trails.

Figure 31— *Visitors hike the Skyline Trail with Mount Rainier and Nisqually Glacier as a backdrop. USGS photo by C. Driedger.*

Features of Interest—(described thematically on pages 42 and 47)

1. Nisqually Glacier
2. Glacial geology
3. Lava and pyroclastic flow layers
4. Regional sources of volcanism

Hike Options

These trails offer dramatic vistas of subalpine wildflowers, a close-up view of Mount Rainier and Nisqually glacier, and, on clear days, Panorama Point and the Skyline Trail offer views of Mounts St. Helens and Adams as well as Rainier. Rather than a stop-by-stop description, this guide provides general information about features visible along all the trails noted. Refer also to the map in figure 19.

A. Alta Vista:

Alta Vista offers a view of Mount Rainier, rocks of Paradise Lahar, and tephra layers. Hike 2.7 kilometers round trip (1.7 mile) to Alta Vista for a regional view of Mount Rainier and the Paradise Ridge area.
1.25 hours—Average hiking time
Relevant descriptions in this field trip guide: general descriptions in the Nisqually Vista Loop Trail section.

B. Glacier Vista:

Glacier Vista offers a picturesque view of Mount Rainier, Nisqually Glacier, lava layers and fragmental volcanic deposits, boulders from lahars on ridge, and tephra layers. Round-trip distance from visitor center is approximately 4 kilometers (2.5 miles).
2 hours—Average hiking time
Relevant descriptions in this field-trip guide: general descriptions in the Nisqually Vista Trail section.

C. Panorama Point:

For hikers with proven ability to walk safely in challenging conditions, continue on to Panorama Point, 6.5 kilometers (4 miles) round trip from Paradise with 520 meters (1,700 feet) elevation gain. Enjoy a grand panorama of Mount Rainier and surrounding terrain.
3 hours—Average hiking time
See descriptions in A and B, plus glacier description in the Nisqually Vista Trail section.

D. Skyline Loop/Golden Gate Trail options:

Make a loop via the Skyline and Golden Gate trails (round trip of 6 kilometers or 4 miles). For a longer loop, hike the entire Skyline Trail, at 9 kilometers (5.5 miles) round trip.
3 hours—Average hiking time on Skyline and Golden Gate trails
4.5 hours—Average hiking time on Skyline Loop trail
See descriptions in A and B, plus the Nisqually Glacier description in the Nisqually Vista Trail section.

E. *Myrtle Falls:*

Consider taking the paved trail to picturesque Myrtle Falls. This trail (round trip 1.6 kilometers or 1 mile), leads the hiker over terrain underlain by deposits of two lahars and volcanic ash from Mount Rainier and Mount St. Helens. Elevation gain is 60 meters or 200 feet.
45 minutes—Estimated hiking time
Relevant description: Myrtle Falls

Background—features on Paradise Trail:

- ***All of the trails listed in the above options traverse Paradise Ridge, where early lava flows were confined by ice-age glaciers, then overrun by younger glaciers and lahars.*** Around 40,000 years ago, the Ricksecker Point and Muir Snowfield, and earlier lava flows advanced down the broad crest of a rock ridge, confined by the flanking ancestral Nisqually and Paradise River Glaciers. Later, the glaciers enlarged, overtopped the ridge, and scoured away the lava's original rubbly top. The present Nisqually and Paradise Glaciers are now dwarfed by lava flows they had once confined. We know these lava flows as Paradise, Rampart, and Mazama Ridges. Along the trail the surface of the lava flow is widely mantled and concealed by tan, gray, and black boulders and sandy sediment of the Paradise lahar.

Background—lava layers:

- ***All trail options offer views of lava flow and pyroclastic flow layers.***

The layered rock cliff directly across the Nisqually Glacier from Glacier Vista at 1,930 meters (6,340 feet) elevation affords a close view of lava flows and their rubbly tops (figure 32), as well as a small pyroclastic flow that was so hot when it came to rest that its ash and rock particles sintered or welded together and produced hard rock. Pyroclastic flows are fast moving avalanches of hot volcanic ash, lava fragments, and sometimes pumice that usually form during explosive phases of eruptions. On glacier-clad volcanoes like Mount Rainier, most pyroclastic flows traverse and melt snow and glacial ice. This both cools the pyroclastic flow and adds water, thereby transforming it into a lahar that can then travel long distances from the volcano. The pyroclastic flow across the Nisqually Glacier at least partly escaped this fate and is exposed about three-quarters of the way up the rock buttress as a low cliff band that slopes down to the left (south). This cliff has a sandy, brownish hue, distinct from the grayer and more closely fractured lava flows, and is overlain and underlain by sandy slopes that are parts of the pyroclastic flow that were insufficiently hot to weld when the flow came to rest. This pyroclastic flow erupted about 90,000 years ago immediately before an eruption of a large lava flow that caps Mazama Ridge and descends into Stevens Canyon to the southeast of Paradise.

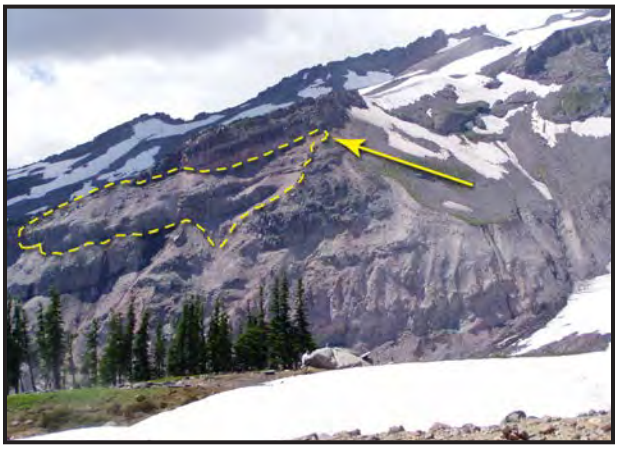


Figure 32— *Alternating layers of lava and loose rock rubble from pyroclastic flows are visible on the west side of Nisqually Glacier. Arrow shows welded pyroclastic flows. USGS photo by C. Driedger.*

Background—glacial striations:

- ***Glacial striations along the trail near Glacier Vista indicate the passage of ice.*** This is an ideal location to observe evidence of past glacier movement over Paradise Ridge. Glaciers commonly polish bedrock and boulders that face uphill, and break the rock on the downhill side. Coarse rocks that moved over the bedrock gouged scratches that are called striations. Finer grained rock carried by subglacial water polishes the bedrock and gives it a lustrous finish called glacial polish.

Figure 33— *Glacial striations are visible on bedrock surfaces along the trail between Paradise and Panorama Point. USGS photo by C. Driedger.*

Discussion questions where glacier striations are visible:

- Explain how the ice contributes to the development of these striations. ***Ice alone is too soft to scratch rock. Rocks embedded in moving ice at the base of the glacier scratch the bedrock.***
- Why does some rock appear rounded and polished? ***Finergrained rock debris carried in subglacial water can polish the bedrock and make a lustrous finish called glacial polish.***
- Use the striations to determine the direction of ice movement. ***In most locations, ice moved in a generally southwesterly direction.***

Experiment—mapping glacial striations:

Watch for glacial striations along your route. Use a compass to determine the direction of glacier movement at each location. Record the directions that ice traveled on a map. Do a pencil-and-paper rubbing of the striations at each mapped location. Are the striations the same everywhere? This can be done without leaving the trail.

Background: Skyline Trail

- ***Skyline Trail ascends on to 250,000-year-old lava flows.***
  Just above Glacier Vista the trail ascends steeply, commonly across snow, and then cuts back and up across a fractured lava outcrop. This outcrop is lava that erupted about 250,000 years ago during a period when Mount Rainier was especially active. This and similar aged lava flows form the substrate over which the Ricksecker Point and Muir Snowfield lava flows descended. This lava flow also forms Panorama Point, as well as the broad basin below Pebble Creek.

Figure 34— *Blasted rock outcrop in 250,000 year-old lava flow on the Skyline Trail. USGS photo by C. Driedger.*

Background: Panorama Point

- ***Panorama Point is a prime viewpoint on the Skyline Trail.***
  Panorama Point offers a grand vista of volcanic terrain of a variety of ages and origins. You stand on a 250,000-year-old lava flow from Mount Rainier, which is flanked on the downhill side by the 40,000-year-old Ricksecker Point lava flow. Upturned layers of the Columbia River Basalts that erupted from fissures starting about 17 million years ago form some of the horizon to the east. At middle distance and to the south rises the Tatoosh Range, the roughly 17-million-year-old mass of magma that rose into Earth's crust and cooled slowly. In the distance to the southeast, the eroded volcanic rocks of the 2-million-year-old Goat Rocks volcano appear as high terrain. On the horizon on a clear day, you can see the young stratovolcanoes—Mounts Adams, Hood, and St. Helens. Behind you to the north soars Mount Rainier. While at Panorama Point view the sign which points out additional features.

  Return to the visitor facilities by retracing your steps or by completing the loop trail, either by the eastern leg of the Skyline Trail or the shorter Golden Gate Trail.

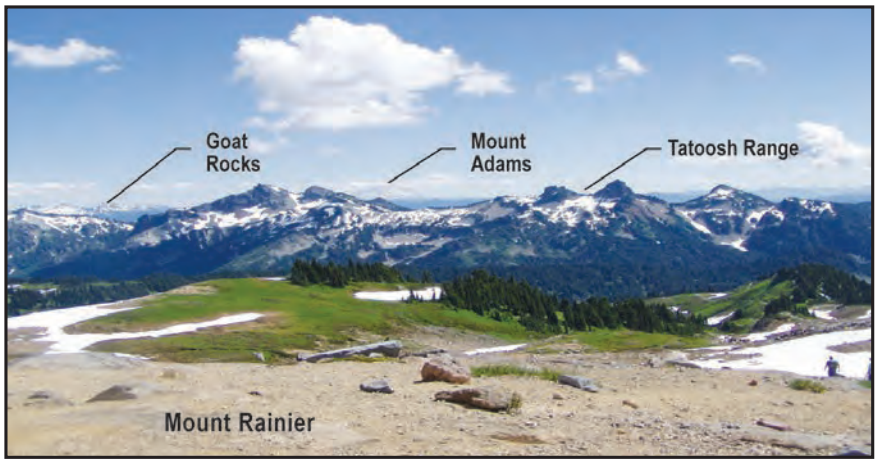


Figure 35 *—The view southward from Panorama Point. USGS photo by C. Driedger.*

Discussion questions for Panorama Point:

- At this viewpoint, name some of the visible geographic features that contain igneous rocks. ***Mounts Rainier, Adams, Hood, and St. Helens and Goat Rocks, Tatoosh Range, and Columbia River Basalts on the eastern horizon.***
- Indicate to students that volcanoes have erupted many times in this region. Ask them what this fact suggests about potential for future eruptions. ***Volcanism has modified the landscape of this region for millions of years, and there is every reason to believe that volcanism will continue into the future.***
- Investigate the rock cycle with your students. Choose one of the features noted above—one of the large volcanoes, the Tatoosh Range, or the Columbia River Basalts. Ask students to trace the path of the rocks that now comprise that feature. Invite them to hypothesize about the eventual destination of the rocks over geologic time. ***For the large volcanoes and for the Columbia River Basalts, rock originated as magma within the Earth, and then erupted and flowed on to Earth's surface. For rocks of the Tatoosh Range, magma rose into the crust but never reached Earth's surface. The rocks cooled slowly and eventually were exposed by weathering and erosion. Today, weathering and erosion by stream water, ice, and mass movements are wearing down the slopes of these features and transporting rock fragments towards the Pacific Ocean.***
- Snow patches can persist throughout the summer on Paradise Ridge. Discuss with students how long-lasting snow patches can affect the lives of animals and plants. ***Snow patches slow the seasonal growth of plants, but their melting provides water for plants and animals throughout the summer. Where snow patches remain throughout the summer, no plants grow.***

Discussion questions about water and rock cycles:

- Consider a stop at several points along the trail and listen. Can you hear the sound of running water? Where does the water originate? ***Water originates from the melting of snow and ice. What is the water's destination? The Nisqually River to the west, Paradise River to the east (which flows into the Nisqually River), and eventually to Puget Sound at Nisqually Reach.***

- List the processes of the rock and water cycles that are notable here. ***Rock cycle—results of volcanism are notable as lava flows, pyroclastic flows, volcanic ash, and lahars; and erosion can be seen as rock fall, moraine building, and transport of rocks and sediment downstream by the river. Water cycle—snowfall, long term storage of water as snow and ice, glacier melt, river flow, and cloud formation and potential precipitation during your visit.***

Background: Skyline Trail

- ***The Skyline Trail east of Panorama Point leads you across slabs of lava rock from the interior of a lava flow.*** Thousands of years ago, glaciers over-topped the ridge and scoured away the rubbly top of the Muir Snowfield lava flow, exposing this lava from the interior of the flow. The lava cooled, hardened and fractured into distinctive slate-like slabs.

Figure 36— *Lava flows fractured into plates are common in the vicinity of Panorama Point. USGS photo by C. Driedger.*

- ***The deglaciated area once covered by Paradise Glacier is visible to the east.*** From Panorama Point the hiker gets a distant view of recently deglaciated and barren terrain formerly covered by Paradise Glacier. Our generation is not the first to appreciate the Paradise Glacier area. Historically the Paradise Glacier ice caves were the principal visitor attraction on this side of the mountain. Early twentieth century visitors watched in dismay as the Paradise Glacier separated into upper and lower sections and the lower section became no more than an isolated stagnant ice mass. The once famous ice caves exist now only in memories and photographs, but a visit to the deglaciated area reveals a fascinating landscape of abandoned stream channels, glacial polish, striations, and chatter marks—the small curved fractures in the bedrock akin to marks made by a carpenter as their chisel slips along a piece of wood.

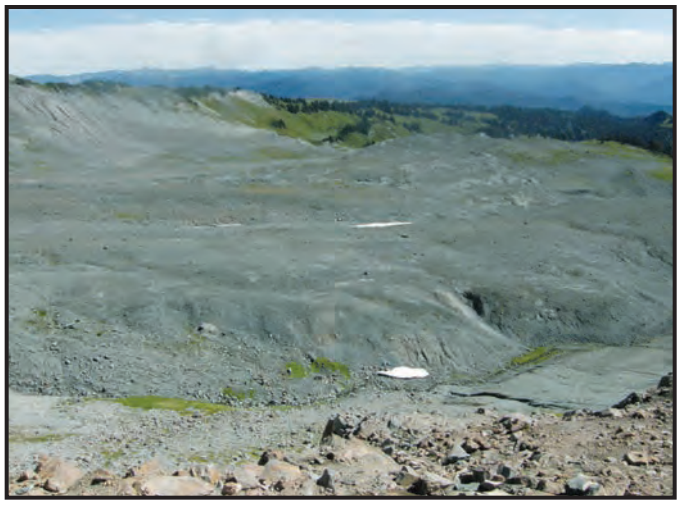


Figure 37— *An impressive display of glacial features exists where Paradise Glacier once flowed. USGS photo by C. Driedger.*

- ***Skyline Trail loops to the east above a persistent steep snowfield in the headwaters of Edith Creek and then descends onto the crest of upper Mazama Ridge.***

The 90,000-year-old Mazama Ridge lava flow caps the ridge down to the area around Reflection Lakes and then drops into Stevens Canyon where it supports Bench Lake and a long ridge on the southwest canyon wall. Several routes can be taken back to Paradise from upper Mazama Ridge, the shortest being the trail into Edith Creek from the Golden Gate (2.4 kilometers, 1.5 mile) return to Paradise. Further down Mazama Ridge, a side trip up the trail to the former Paradise Glacier ice caves region (2.4 kilometers (1.5 mile) roundtrip) affords close up views of the glassy ice-chilled edge of the Mazama Ridge lava flow (black shiny columns) and the terrain recently exposed by melting of the lower Paradise Glacier. This side trail departs from the Stevens-Van Trump historical monument near Sluiskin Falls.

Tephra from Mount St. Helens and Mount Rainier is visible in outcrops along the Skyline and Golden Gate Trails.

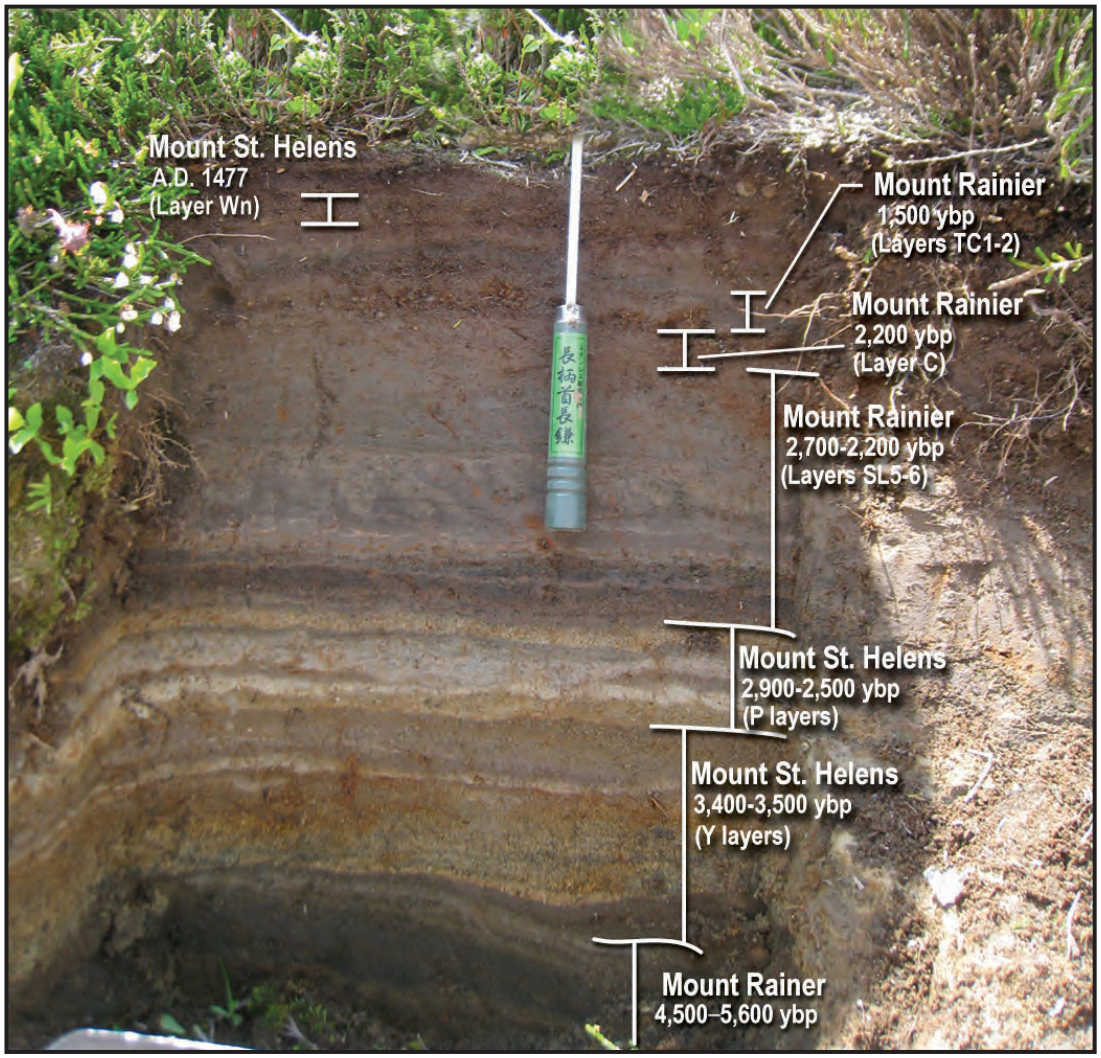


Figure 38*— Tephra layers identified by geologists are visible in trail cuts along the Skyline and Golden Gate Trails. USGS photo by J. Vallance.*

- ***Myrtle Falls offers a short walk and a picturesque view.***
  Walk on the side trail toward the base of the falls for a spectacular view of Edith Creek as it tumbles off the eastern edge of a cliff of Tatoosh granodiorite, with Mount Rainier as backdrop. The trail is underlain by rocky layers from two lahars and crumbly volcanic ash from Mount Rainier and Mount St. Helens.

Figure 39— *Myrtle Falls with Mount Rainier in the background. USGS photo by C. Driedger.*

References

Driedger, C.L., 1993, Glaciers on Mount Rainier, U.S. Geological Open-File Report 92–474, 2 p.

Lescinsky, D.T., and Sisson, T.W., 1998, Ridge-forming, ice-bounded lava flows at Mount Rainier, Washington: Geology, v. 26, no. 4, p. 351–354.

Pringle, P.T., 2008, Roadside geology of Mount Rainier National Park and vicinity: Washington State Department of Natural Resources Information Circular 107, 190 p.

Scott, K.M., Vallance, J.W., and Pringle, P.T., 1995, Sedimentology, behavior, and hazards of debris flows at Mount Rainier, Washington: U.S. Geological Survey Professional Paper 1547, 56 p.

Sisson, T.W., Vallance, J.W., and Pringle, P.T., 2001, Progress made in understanding Mount Rainier's hazards: EOS, Transactions of the American Geophysical Union, v. 82, p. 116–120.

Sisson, T.W., and Vallance, J.W., 2008, Frequent Eruptions at Mount Rainier over the last ~2,600 years: Bulletin of Volcanology, v. 71, no. 6, p. 595.

Vallance, J., Driedger, C., and Scott, W., 2002, Diversion of melt water from Kautz Glacier initiates small debris flows near Van Trump Park, Mount Rainier, Washington: Washington Geology, v. 30, no. 1/2, July 2002, p. 17–19.

Walder, J.S., and Driedger, C.L., 1994, Geomorphic change caused by outburst floods and debris flows at Mount Rainier, WA: U.S. Geological Survey Water Resources Investigation Open-File Report 93–4093, 93 p.

Walder, J.S., and Driedger, C.L., 1994, Rapid Geomorphic change caused by glacial outburst floods and debris flows along Tahoma Creek, Mount Rainier, WA, USA: Arctic and Alpine Research, v. 26, no. 4, p. 319–327.

APPENDIX IV

INTERNET RESOURCES

The Internet Resource List provides guidance for acquisition of additional resources that pertain to the subjects in this educator guide. The parent Internet address is listed as well as some specific links to educational resources. The list consists of selected government and organization Web sites. Authors do not intend this list to be comprehensive.

General topics covered on the following pages:

Plate Tectonics
Cascades Volcanoes General Information
How Volcanoes Work
Glaciers
Topographic Maps
Monitoring Volcanoes
Community Preparedness
Visiting Mount Rainier
Other Teacher Resources

PLATE TECTONICS

Obtain additional information that is germane to the following activities:

Surrounded by Volcanoes
Riding the Magma Elevator
Cascade Volcano Timeline

U.S. Geological Survey (USGS) This Dynamic Earth: The Story of Plate Tectonics

http://pubs.usgs.gov/gip/dynamic

This publication provides an overview of the concept of plate tectonics and the scientific studies that led to our understanding of the concept. Originally published in hard copy, it is now available in .pdf and .html versions on-line. The publication is the source of many commonly published graphics about plate tectonics, and can be a resource for individual educators.

Smithsonian Global Volcanism Program

http://www.volcano.si.edu/

This Web site lists the volcanoes of the world that have been active during the past 10,000 years, and tabulates their eruption histories. Also found are regional volcano maps; global maps of tectonic plates; volcanoes and earthquakes; volcanic activity reports and special announcements; photo examples of volcano types and processes; frequently asked questions; and products for sale. Educators should take particular note of items in Mapping and Products pages, such as the interactive version of This Dynamic Planet—World Map of Volcanoes, Earthquakes, Impact Craters and Plate Tectonics, and the Earthquake and Eruptions CD-ROM. These and other products are available for purchase by mail at the Products Web page.

Activity last modified: September 7, 2014

Pacific Northwest Seismic Network (PNSN)

http://www.pnsn.org
This Web site posts real-time data and statistics about earthquakes in Washington and Oregon including: latest earthquakes; earthquakes specific to volcanoes; hazards from earthquakes; emergency preparations; research and operations projects; and links to educational products and services. Find webicorders that display real-time earthquake signatures at Cascade volcanoes, links to the USGS World Earthquakes map, and entry to the Did You Feel It? Web page at: **http://earthquake.usgs.gov/**

National Oceanic and Atmospheric Administration (NOAA) Pacific Marine Environmental Laboratory (PMEL)

http://www.pmel.noaa.gov/
Visit these Web pages for information about submarine volcanism off the coast of the Pacific Northwest. See *NOAA's New Millennium Observatory (NeMO)*, **http://www.pmel.noaa.gov/vents/**, a seafloor observatory at Axial volcano, located 450 kilometers (250 miles) off Oregon's coast and 1.6 kilometers (1 mile) underwater on the Juan de Fuca Ridge. Educators should note curriculum materials on the *NeMO* pages; interactive dives to a submarine volcano; expedition results; text and photographs about tools and technology and underwater volcanic features.

Incorporated Research Institutions for Seismology (IRIS)

http://www.iris.edu/
This Web site contains animations, explanations and lectures about earth movements, and a Teachable Moments page to help you teach about recent earthquakes.

CASCADE VOLCANOES GENERAL INFORMATION

Obtain additional information that is germane to the following activities:

- ***Fire, Flood and Fury***
- ***Cascade Volcano Timeline***
- ***Volcano Hall of Fame***
- ***Planning your Trip to Mount Rainier***
- ***Living Well with a Volcano in Your Backyard***
- ***Nineteenth-Century Newspaper Accounts of an Eruption at Mount Rainier***
- ***Cascade Volcano Timeline***
- ***A String of Volcanoes***
- ***Perilous Beauty***
- ***The Next Eruption of Mount Rainier***
- ***A Volcano Tussle***

U.S. Geological Survey (USGS) Volcano Hazards Program

http://volcanoes.usgs.gov

The USGS-Volcano Hazards Program Web site provides news reports about volcanic unrest within the United States and its territories, and describes the work of volcanologists in the USGS Volcano Hazards Program. Find detailed descriptions of volcano hazard types, volcano monitoring, methods to reduce volcanic risk, and warning schemes. Educators should visit the Web pages about volcanic ash and the photoglossary. Look for publications and other materials highlighted for educators.

U.S. Geological Survey (USGS) Cascades Volcano Observatory

http://volcanoes.usgs.gov/observatories/cvo/

This Web site contains Cascade Range histories, hazards and current activity updates, hazards assessment reports and maps, information about glaciers on volcanoes, volcano monitoring techniques, maps, photographs, movies, and educational outreach materials. Teachers and students who wish to stay appraised of current volcanic unrest in the Cascades can view the *Cascade Range Weekly Update.* Of particular interest to educators will be the comprehensive background material, geologic timelines, maps, and photographs. Under Mount Rainier Publications find a variety of scientific reports about Mount Rainier. **http://volcanoes.usgs.gov/volcanoes/mount_rainier/**.

Smithsonian Global Volcanism Program

http://www.volcano.si.edu/

This Web site, described in detail in the Plate Tectonics section of this list, includes information about Cascade volcanoes, as well as volcanoes and current volcanic activity around the world.

HOW VOLCANOES WORK

Obtain additional information that is germane to the following activities:

- *Magma Mash*
- *Riding the Magma Elevator*
- *Volcanic Processes*
- *Tephra Explorer*
- *Rock Stars, Lahar in a Jar*
- *Fire and Ice*
- *Earth Blocks*
- *Soda Bottle Volcano*
- *Understanding Volcanic Hazards*
- *Tephra Popcorn*
- *Volcano Fan Club*
- *Rock Rubble Review*
- *Shoebox Geologist*
- *Lava—Building Blocks of Mount of Mount Rainier*

Volcano World

http://volcano.Oregonstate.edu/

This Web site contains interviews with volcanologists, general information about volcanoes, FAQ's, simple earth science lessons, and links to current eruption Web pages and blogs.

U.S. Geological Survey (USGS) Volcano Hazards Program

http://volcanoes.usgs.gov

See information about volcano processes and hazards with in-depth descriptions, photographs, case studies, discussions of effects on communities, and links to other pertinent Internet sites.

San Diego State University—How Volcanoes Work

http://www.geology.sdsu.edu/how_volcanoes_work/

Educational resources at describe the science behind volcanoes and volcanic processes. It is appropriate for university-level geology students and Earth science teachers. Each menu section builds upon previous segments. For users who lack fundamental knowledge of volcanological principles and terms, it is best to make a stepped progression through the Web site material. More advanced users will find each section self-contained and can navigate the Web site readily. The site is sponsored by NASA and maintained under the auspices of *Project ALERT (Augmented Learning Environment and Renewable Teaching).*

GLACIERS

Obtain additional information that is germane to the following activities:

Fire and Ice *Lahar in a Jar*

Mount Rainier National Park

http://www.nps.gov/mora/naturescience/glaciers.htm
Find information about glaciers and glacier change at this site and its linked Web pages.

Portland State University—Glaciers of the American West

http://glaciers.research.pdx.edu/
This Web site contains maps, information and diagrams about glacier dynamics, facts and statistics, and comparative photographs of glaciers throughout the 20th and early 21st centuries.

TOPOGRAPHIC MAPS

Obtain additional information that is germane to the following activities:

Planning Your Trip to Mount Rainier *Topographic Maps at Mount Rainier*
Play-dough Topo

U.S. Geological Survey (USGS) Map Information

http://www.usgs.gov/pubprod/maps.html
Order topographic maps, find locations of local map dealers, learn about different types of maps, view maps and images on line. Download the four-page color booklet Topographic Map Symbols, which provides a key to symbols published on topographic maps, such as buildings, streams, streets and woods. http://pubs.usgs.gov/gip/TopographicMapSymbols/topomapsymbols.pdf

MONITORING VOLCANOES

Obtain additional information that is germane to the following activities:

Perilous Beauty—Video *The Next Eruption of Mount Rainier*
Reducing Volcanic Risk—Video *Don't Be Scared—Be Prepared*
A Volcano Tussle *Volcano Fan Club*

American Meteorological Society (AMS) (Use for Volcano Fan Club activity extension)

http://www.ametsoc.org/
This Web site contains weekly weather and climate news, weather maps and summaries, weather data, and weather education information. To obtain real-time data for the Volcano Fan Club activity extension, visit **http://www.ametsoc.org/amsedu/dstreme** and click the *Upper Air* box to obtain maps that indicate wind barbs and the chosen pressure in millibars (850, 700 or 500) in height above the surface.

U.S. Geological Survey (USGS) Volcano Hazards Program

http://volcanoes.usgs.gov
In addition to earlier mentioned material about volcanic processes and hazards, the Web site contains information about hazards, monitoring strategies, alert levels, warning schemes and general strategies for reducing volcanic risk. Visit the U.S. Geological Survey's technical report that describes aerial and satellite monitoring of Mount Rainier at **http://pubs.usgs.gov/of/2000/ofr-00-0027,** and a more general publication about volcano monitoring at **http://pubs.usgs.gov/gip/monitor/conclusions.html**

COMMUNITY PREPAREDNESS

Obtain additional information that is germane to the following activities:

The Next Eruption of Mount Rainier
Volcano Tussle
Don't Be Scared—Be Prepared
Living Well with a Volcano in Your Backyard

American Red Cross (ARC)

http://www.redcross.org/
See *Plan and Prepare* for general information about personal and community disaster preparedness, emergency preparedness kits and how to help children cope with disasters.

Federal Emergency Management Agency (FEMA)

http://www.fema.gov/
The FEMA Web site contains general information about hazard preparedness.

Pierce County Department of Emergency Management (PCDEM)

http://www.co.pierce.wa.us
See *Emergency Plans,* for the Mount Rainier Volcanic Hazards Response Plan, hazard and also for vulnerability assessments, lahar evacuation plan and other links.

U.S. Geological Survey (USGS) Cascades Volcano Observatory

http://volcanoes.usgs.gov/observatories/cvo/
See *Prepare,* for information on *How to Prepare, Action During Unrest, Accessing Volcano Info* and *Links to Preparedness Resources.*

U.S. Geological Survey (USGS) Volcano Hazards Program

http://volcanoes.usgs.gov/ash
See *Volcanic Ash—What it can Do and How to Prevent Damage* for practical information about living with volcanic ash.These Web pages contain detailed information about the effects of volcanic ash on human health, agriculture, buildings, communication systems, power supplies, transportation, water supply, and wastewater facilities.It describes actions to be taken for preparedness and recommended methods for ash cleanup.

Washington Military Department Emergency Management Division (WaEMD)

http://www.emd.wa.gov
See *Government Departments, Emergency Management* pages. Find emergency response plans for people at risk in the vicinity of volcanoes, volcano educational publications and volcanic ash cleanup brochures. See recommendations for school, community and home preparedness.

VISITING MOUNT RAINIER

Obtain additional information that is germane to the following activities:

Rock Stars

Journey Back in Time

Planning Your Trip to Mount Rainier

Living Well with a Volcano in Your Backyard

National Park Service (NPS) Mount Rainier National Park

http://nature.nps.gov/geology/tour/
Visit *Park Geology Tours* for a complete list of geologic landforms within the National Park Service system and general geology information about each location. Obtain general information, such as regulations and current road and trail conditions at the Mount Rainier National Park Mount Web site **http://www.nps.gov/mora.** Educators should take note of recommendations for field trips, teacher workshops and curriculum, and information about the Junior Ranger Program. For a virtual visit, view the multimedia gallery.

OTHER TEACHER RESOURCES

Obtain additional information that is germane to all of the activities.

U.S. Geological Survey (USGS) homepage

http://www.usgs.gov

See Education to obtain earth science news and information, online geology curriculum, and the USGS Store. See Maps, Products and Publications to reach the Publications Warehouse, where thousands of agency publications are posted. Search for Mount Rainier scientific publications, fact sheets, and volcano hazards assessments.

U.S. Geological Survey (USGS) Cascades Volcano Observatory

http://volcanoes.usgs.gov/observatories/cvo/education.html

See *CVO Education* for educational resources.

Digital Library for Earth Science Information (DLESE)

http://www.dlese.org

DLESE is a National Science Foundation digital online library of earth science educational materials. The Web site serves as a resource for information, teaching boxes, curriculum links, digital models and other products useful for teaching of earth sciences. Guided inquiry is used throughout, and where possible, authors seek to have students replicate the discoveries of science that have led to our understanding of geologic processes.

International Association for Volcanology and Chemistry of the Earth's Interior (IAVCEI)

http://www.iavcei.org

IAVCEI is a primary international volcano science organization for volcanologists and serious volcano enthusiasts. The Web site provides information about upcoming meetings, commission activities, and publications. The *About Volcanoes* pages connect you to Web sites that contain education resources, and information about volcano observatories and data centers, professional associations, research groups, image databases, photo/slide sets, online journals and upcoming events designed for educators.

APPENDIX V

GLOSSARY

Absolute age – The date of an event usually expressed in years and related to a specific time scale; also referred to as a "numerical age." Absolute ages are most commonly obtained using radiometric dating methods.

Active volcano – A volcano that is currently erupting or has erupted during recorded history and has potential to erupt again.

Amphibole – A mineral group composed of complex silicates, the most common variety being hornblende which is usually dark green to black in color. Amphiboles are found in igneous and metamorphic rocks.

Andesite – A gray extrusive volcanic rock containing 58 to 63 percent silica with a moderate viscosity (resistance to flow) when in a molten state. Intermediate in color, composition, and eruptive character between basalt and dacite. It is fine-grained and sometimes displays bubbles (vesicles).

Ash – (see volcanic ash)

Ash cloud – Cloud of ash formed by volcanic explosions or derived from a pyroclastic flow. It is sometimes called an eruption cloud.

Ash (volcanic) – Fragments less than 2 millimeters (0.1 inch) in diameter of lava or rock blasted into the air by volcanic eruptions.

Ash fall – Ash falling from an eruption column or ash cloud.

Asthenosphere – (also spelled aesthenosphere) A ductile layer of the Earth's upper mantle just below the lithosphere. This layer is composed of rock that can flow slowly because it is at high temperature and pressure. The rigid lithosphere is thought to "float" or move around atop the slowly flowing asthenosphere. The asthenosphere is about 180 kilometers (110 miles) thick.

Bar – The bar and the millibar are units of pressure. They are not SI units (International System), but they are accepted for use with the SI. The bar is still widely used in descriptions of pressure because it is about the same as atmospheric pressure. 1 bar = 105 Pascals = 14.52 pounds per square inch. 1 atmosphere = 1.013 bars.

Basalt – Hard, gray to black extrusive volcanic rock. Contains 45 to 52 percent silica, is mafic, rich in iron and magnesium, fine-grained, often displays "frozen" gas bubbles (vesicles) and sometimes contains phenocrysts of feldspar, olivine, pyroxene, and iron titanium oxides. Because of low silica content, basalt has a low viscosity (resistance to flow).

Therefore, basaltic lava often can flow with ease, equivalent first to the pace of a run, then as it cools, at the speed of a fast walk. Basaltic lava frequently flows 20 kilometers (12 miles) or more from the vent. The low viscosity typically allows volcanic gases to escape nonexplosively.

Basaltic andesite – A volcanic rock that contains 52 to 57 percent silica, dark gray to black; a subcategory of andesite.

Last modified: September 7, 2014

Beaker – A container for liquids that is straight sided and cylindrical in shape, commonly used in laboratories.

Benchmark – A permanent metal tablet or other metal marker firmly embedded in rock indicating a precisely determined latitude, longitude, and elevation above sea level.

Blocks – Solid rock fragments greater than 64 millimeters (2.5 inches) in diameter that are ejected from a volcano during an explosive eruption. Blocks commonly consist of pieces of old lava flows that were torn away from conduit walls.

Bomb (volcanic) – Tephra larger than about 64 millimeters (2.5 inches) that are in a semisolid or plastic condition. Volcanic bombs undergo widely varying degrees of aerodynamic shaping, which depends on their fluidity during flight through the atmosphere. Based on their shapes after they hit the ground, bombs are described as "spindle or fusiform," "ribbon," or "cowdung."

Bread-crust bomb – A type of volcanic bomb characterized by a network of opened cracks on its surface, due to continued expansion of the interior after solidification of the crust.

Breccia – A coarse-grained rock composed of angular broken rock fragments in a finer matrix that is commonly found on the margins of lava flows, especially top and bottom.

Caldera – A large volcanic depression, commonly circular or elliptical in shape. Formed by collapse during withdrawal or ejection of a large volume of magma that leaves the roof of the magma reservoir unsupported.

Cascadia Subduction Zone – A long fault that stretches from mid-Vancouver Island to Northern California. It separates the oceanic Juan de Fuca and Gorda Plates from the continental North American Plate. New ocean floor is being created offshore of Washington and Oregon. As material wells up along the ocean ridge, the ocean floor is pushed toward and beneath the continent.

Chemical elements – (see elements)

Cinder cone – A steep-sided volcanic cone generally basaltic in composition and formed by accumulation of scoria and bombs around a volcanic vent during explosive eruptions.

Columbia River Basalt Group – One of the largest series of flood basalts ever to appear on Earth's surface engulfed about 160,000 square kilometers (63,000 square miles) of eastern Washington, Oregon and western Idaho. During the late Miocene and early Pliocene (between 17 and 6 million years), lava accumulated to a thickness of more than 3 kilometers (2 miles) in places. Numerous linear vents, some more than 145 kilometers (90 miles) long, show where lava erupted near the eastern edge of the Columbia River Basalts.

Composite volcano – A long-lived and steep-sided volcano composed of many layers of volcanic rocks, usually of high-viscosity lava and fragmented debris such as lahar and pyroclastic deposits. Also called a stratovolcano. Examples include the major edifices of the Cascades, such as Mounts Rainier, St. Helens, Shasta, Hood, and others.

Conduit – A subterranean passage through which magma reaches the surface to drive volcanic eruptions.

Cone – (see volcanic cone)

Continental crust – The part of Earth's crust that includes the continents and the continental shelves. (see crust)

Contour line – A line on a map or chart that connects points of equal elevation.

Contour interval – The difference in elevation between two adjacent contours.

Convergent plate boundary – The boundary between two tectonic plates that are moving toward each other. One plate may be dragged down (or subducted) beneath the other, or they may collide and force the uplift of a mountain range.

Core – The innermost layer of the Earth made mostly of iron and nickel. The core, divided into a liquid outer core and a solid inner core by its internal properties, has a thickness of 3,500 kilometers (2,200 miles). The core is the most dense of the Earth's layers. It is the source of Earth's magnetic field.

Crater – The typically circular depression containing a volcanic vent, commonly less than 2 kilometers (1.2 miles) across. Formed by volcanic explosions and usually involving the accumulation of erupted material around the vent rather than by subsidence of the crater floor.

Crust – The outermost layer of the Earth. Oceanic crust is 5 to 10 kilometers (3 to 6 miles) thick and is composed mostly of basalt. Continental crust is 20 to 70 kilometers (12 to 40 miles) thick and is composed mostly of granitic and sedimentary rock.

Crystal – A solid compound composed of ordered, three-dimensional array of atoms chemically bonded together.

Dacite – An extrusive igneous rock most often light gray but can be dark gray to black. Dacite lava consists of about 63 to 70 percent silica (SiO_2). The principal minerals that make up dacite are feldspar, pyroxene and (or). hornblende. Dacite generally erupts at temperatures between 800 and 1000 degrees Celcius (1470 to 1830 degrees Farenheit), and is one of the most common rock types associated with eruptions with large eruption columns. Dacitic lavas tend to erupt explosively, thereby ejecting abundant tephra into the atmosphere.

Deadman Flats assemblage – An assemblage of lahar deposits in the White River Valley formed during an eruption(s) between 800 to 1,260 years ago.

Debris avalanche – A gravity-driven rapid mass movement of unsorted rock and soil. Debris avalanches commonly originate as large rockslides that, during movement, disintegrate into fragments ranging in size from small particles to blocks hundreds of meters across. If the avalanche has a high water content, parts of it may continue to flow down valley as a lahar after some of its coarser parts have come to rest.

Debris flow – A flowing mixture of water and solid debris that moves down a river channel under the force of gravity. A debris flow is sometimes referred to as a lahar (if originating at a volcano) or a mudflow, and when moving, resembles flowing concrete. Debris flows are can be initiated by numerous processes—landslides of water-saturated debris; heavy rainfall eroding volcanic deposits; rapid melting of snow and ice; or breakout of water from glaciers, crater lakes, or lakes dammed by volcanic eruptions. At Mount Rainier, the U.S. Geological Survey uses the term solely for small non-eruptive events related to slope failure, rainfall or glacier outbursts, which travel only a few kilometers (miles) and do not affect large human populations.

Density – Density is equal to the mass of an object divided by its volume.

Deposit – Earth material of any type that has accumulated by any natural process or agent.

Deposition – The laying, placing, or accumulating of material onto Earth's surface. In geology it refers to the accumulation of rocks or sediment.

Diapir – A domed rock formation where a core of rock has moved upward and pierced through more brittle overlying strata, as with an intrusive diapir of rising magma.

Dike – A tabular body of igneous rock that fills a rock fracture.

Diorite – An intrusive igneous rock formed from magma deep within the Earth and made of plagioclase feldspar and a small amount of quartz, biotite, and amphibole or pyroxene. It is called "salt and pepper" rock because of its nearly equal proportions of light-colored minerals (mostly plagioclase feldspar and quartz) and dark-colored minerals (amphibole, pyroxene, and biotite). Diorite is the intrusive equivalent of andesite

Disaster supplies kit – Items stored in case of emergency to help residents endure long periods without electrical power, heat, or running water.

Divergent plate boundary – A linear zone along which two tectonic plates move away from each other, allowing magma from the mantle to rise up and solidify as new crust.

Dormant volcano – A volcano that has not erupted within historical time but is capable of erupting again.

Earthquake – The shaking of the ground caused by an abrupt shift of rock along a fault in the Earth.

Electron Mudflow – A lahar that occurred on the west flank of Mount Rainier approximately 500 years ago and flowed down both branches of the Puyallup River. This lahar, which presumably began as a debris avalanche, has not been correlated with any eruptive activity at Mount Rainier; thus it may have occurred without precursory eruptive phenomena. The Electron Mudflow was about 30 meters (100 feet) deep as it exited the Cascade mountain front (about 36 kilometers, 22 miles, west of Mount Rainier), and flowed onto the Puget Lowland.

Elements – A substance composed of a single type of atom. Examples include hydrogen, helium, carbon, oxygen, and others. Elements are defined by the number of protons in each nucleus.

Elevation – Height of a geographic location above a fixed reference point, often mean sea level.

Emergency contact information – A list of telephone and other contact information (relatives, doctors, schools, work) for each family member. Information can be stored on wallet cards, cell phones, or spreadsheets and should be readily available in the event of an emergency.

Emergency plan – A plan assembled prior to an emergency that identifies courses of actions to be taken during an emergency.

Epigraph – An engraved inscription on a statue, tablet, or building.

Erosion – The removal and transport of Earth materials by gravity, running water, glaciation, wind, or chemical dissolution.

Eruption – The ejection of lava and other eruptive products from a volcano or a fissure onto Earth's surface.

Eruption cloud – A cloud of tephra and gases that travels downwind of an eruption column.

Eruption column – The vertical column of tephra and gases rising above a volcanic vent.

Eruptive period – A timespan during which a volcano erupts multiple times.

Explosion – A sudden and energetic release of lava or debris from a volcanic vent due to the expansion of materials during pressure release.

Explosive eruption – An eruption or phase of an eruption characterized by the forceful ejection of tephra and volcanic gases into the atmosphere.

Exsolution – The separation of an initially homogeneous solid solution into distinct crystalline phases. This process generally takes place during cooling.

Extinct volcano – A volcano that is not now erupting and is not expected to erupt again.

Extrusive rock – An igneous rock produced when magma cools at or very near Earth's surface. Crystals do not have much time to grow, so these rocks have a fine-grained or even glassy texture. Gas bubbles are often trapped in the solidified lava, forming a bubbly, vesicular texture. Pumice, obsidian, and lava are all extrusive igneous rocks. (see volcanic rock).

Family emergency preparedness plan – (see emergency plan).

Fault – A rock fracture or zone along which one side of a fracture has moved relative to the other side.

Fife's Peak Formation – Layers of volcanic rocks formed between 26 and 22 million years ago by eruptions of volcanoes east of present day Mount Rainier.

Flank collapse – Massive catastrophic collapse of a volcano's flank that causes a debris avalanche. They are often triggered by magma intrusion and also, perhaps, by large earthquakes.

Flood basalt – Extensive lava flow fields tens or hundreds of thousands of cubic kilometers (hundreds of thousands of cubic miles) in volume that issue from fissures. The most famous U.S. example of a flood basalt is the Columbia River Basalt, which originated in northwestern Idaho and covers most of southeastern Washington and northern Oregon, extending all the way to the Pacific Ocean.

Folding – The bending of layers of rock.

Fracture – A crack in a rock. A fracture has no relative movement of its walls whereas the walls of a fault have relative motion.

Freezing point – The temperature at which a substance solidifies.

Fumarole – A vent that releases volcanic gases, including water vapor (steam).

Gabbro – A coarse-grained igneous intrusive rock that has cooled slowly from magma deep within the Earth. It is a crystalline mass of feldspars, pyroxene, and olivine, typically dark gray, greenish gray, to black in color. Gabbro's chemistry is approximately equivalent to that of basalt.

Gases – (see volcanic gases)

Geologic time – The period of time covering the physical formation and development of the Earth. Geologic time is divided into eons lasting hundreds of millions to several billion years, eras lasting tens of millions to hundreds of million years, periods lasting millions to tens of millions years, and epochs lasting thousands to millions of years.

Geothermal – Pertaining to the heat of the interior of the Earth.

Glacial moraine – A landform composed mainly of accumulated and unsorted rock debris that has been deposited by a glacier.

Glacier – A mass of ice that shows evidence of flow over a period of years as indicated by the presence of flow lines, crevasses, and other geologic evidence.

Glacier outburst flood – The sudden release of water stored at the base of or within a glacier, or from a glacier-dammed lake, sometimes referred to by the Icelandic term jökulhlaup.

Glaciation – A term for the collective processes of glacial activity, including erosion and deposition, and the resulting effects of such action on Earth's surface.

Graduated cylinder – A piece of laboratory plastic or glassware, which is cylindrical in shape with markings indicating increments of volume.

Granite – A coarse-grained intrusive igneous rock that typically contains minerals such as quartz, feldspar, mica, and usually hornblende. Granite forms as magma cools far beneath Earth's surface. Because it hardens deep underground it cools very slowly. This allows crystals to grow large enough to be seen easily by the naked eye.

Granodiorite – A coarse-grained intrusive igneous rock intermediate in composition between granite and diorite. It is principal rock type of the Tatoosh Range at Mount Rainier.

Hazard – Any physical process that can cause damage, harm or adverse effects. (see volcanic hazards).

Hazard zone, Volcano Hazard Zone – Area potentially at risk from volcanic hazards.

Holocene Epoch – The time between 10,000 years ago and the present.

Hot ash flow (pyroclastic flow) – A turbulent mixture of extremely hot gases and unsorted pyroclastic material (volcanic fragments, crystals, ash, pumice, and glass shards) that can move as rapidly as a few hundred kilometers per hour (about 100 miles an hour).

Hot spot – An area in a tectonic plate where magma rises persistently from the mantle and erupts at the Earth's surface. As the plate moves over the hot spot, a chain of volcanoes sometimes forms, such as the Hawaiian Islands.

Hydrothermal alteration – Chemical alteration of rocks and minerals by reaction with hot acidic groundwater.

Hydrothermally altered rock – Rock that has been altered by long-term immersion in hot acidic gases or groundwater.

Ice age – A period of long-term reduction in the temperature of Earth's climate, resulting in an expansion of ice sheets and mountain glaciers. The most recent global ice age ended about 10,000 years ago.

Igneous rocks – Rocks solidified from a magma.

Infrastructure – The basic facilities and services needed for the functioning of a community or society such as transportation and communications systems, water and power lines, hospitals, schools, post offices, and prisons.

Intrusive – Pertains to magma emplaced in preexisting rock below Earth's surface.

Isopach – Lines of equal thickness similar to elevation contours on a topographic map, typically used to map tephra deposits.

Juan de Fuca Plate – The oceanic plate that is subducting under the North American continental plate offshore of Oregon and Washington and southern British Columbia.

Juan de Fuca Ridge – A submarine ridge or spreading center offshore of British Columbia, Washington, and Oregon. The eastward side of the ridge is called the Juan de Fuca Plate and the westward side is the Pacific Plate.

Klickitat – Traditional Native American name for Mount Adams, also Pahto (Pah'to, Patu, and Patoe).

Kulshan – An early name given to Mount Baker by Native Americans was "Koma Kulshan." Various translations include "broken or damaged," "blown off," "to shoot," or "Great White One."

Lahar – A flowing mixture of water-saturated rock debris that moves under the force of gravity down the slopes of a volcano. Lahars are sometimes referred to as debris flows or mudflows. Lahars can originate as landslides but most often are triggered by the production of meltwater during volcanic eruptions or by the release of stored water.

Landslide (volcanic) – The rapid downslope movement of soil, rock debris, and sometimes glacial ice, with or without water, from the flank of a volcano.

Lava – Magma that erupts onto the Earth's surface.

Lava dome – Rounded, steep-sided mounds built by the extrusion of viscous magma, usually either dacite or rhyolite but sometimes of andesite. Such magmas are typically too viscous (resistant to flow) to move far from the vent before cooling and crystallizing. Domes may consist of one or more individual lava lobes.

Lava flow – The outpouring from a vent or fissure of molten lava, which flows downhill and cools on the surface as a mass of solidified rock.

Lava fountain – A jet of lava sprayed into the air. Lava fountains typically involve low-viscosity lavas such as basalt.

Lava tube – A tubular subterranean passageway formed by the crusting over of lava channels in some fluid lava flows, especially basalt.

Law of Superposition – A general geologic principle stating that in any sequence of layered rocks that has not been overturned, the youngest layer is at the top and the oldest is at the base.

Lithic – A rock or volcanic deposit containing abundant fragments of previously formed rocks.

Lithosphere – Earth's solid and outermost shell. It includes the crust and the uppermost mantle that overlies the hotter and more ductile rock of the asthenosphere. The lithosphere thickness varies greatly, ranging from less than 15 kilometers (9 miles) for young oceanic lithosphere to approximately 200 kilometers (120 miles) or more for ancient continental lithosphere, such as under the interior areas of the continents.

Loowit – A traditional Native American name for Mount St. Helens meaning "firekeeper," sometimes called Lawe'latla, or La-wa-la-clough ("smoking mountain") and Loowitlatkla, meaning "Lady of Fire."

Mafic – Igneous rock rich in dark-colored minerals containing abundant magnesium and iron. In volcanoes, it is chiefly basalt and basaltic andesite.

Magma – Molten rock containing crystals and dissolved gases that forms within the upper part of the Earth's mantle and crust. When erupted onto the Earth's surface, it is called lava.

Magma chamber – A subsurface reservoir of magma.

Magmatic eruption – An eruption of magma, as opposed to a phreatic eruption, which blasts only fragments of preexisting rock into the atmosphere.

Mantle – A solid but plastic zone of Earth's interior between the crust and the core that is approximately 2,900 kilometers (1,740 miles) thick.

Map scale – A scale that defines how many units on the Earth's surface are equal to one unit on the map. It can be expressed as 1/100,000 or 1:100,000. In this example, 1 centimeter on the map equals 100,000 centimeters (1 kilometer) on the Earth.

Mazama – Native American name for the high mountain that became Crater Lake; means "mountain goat" in the local native language. Mount Mazama first erupted 420,000 years ago and activity continued until about 40,000 years ago. A violent eruption 7,700 years ago led to the collapse of the entire upper half of the edifice to form a caldera that, with time, filled with water to form Crater Lake.

Metamorphic rock – Rock that has been subjected to high pressures or heat and is changed from it's initial form. Metamorphism does not melt rocks but instead transforms them into denser, more compact rocks.

Metaphor – A figure of speech in which an expression is used to refer to something that it does not literally denote in order to suggest a similarity.

Mid-ocean ridge – Where tectonic plates move away from each other (divergent plate boundaries), magma from the mantle rises and accumulates as a chain of volcanoes called a mid-ocean ridge.

Mineral – A naturally occurring homogeneous inorganic element or compound.

Miocene – An epoch of geologic time between the Oligocene and Pliocene, occurring from about 23 million to 5.3 million years ago.

Mitigation (hazard) – Any action taken to permanently eliminate or reduce the long-term risk to human life, property, and functions of a society.

Modoc War – An armed conflict between the Native American Modoc tribe and the U.S. Army in southern Oregon and northern California during 1872 and 1873.

Molten – Reduced to liquid by heating.

Monitor – (see monitoring volcano).

Monitoring (volcano) – Actions taken to detect and measure changes in the state of a volcano. It generally entails the detection of earthquake swarms and other types of seismic events, swelling or subsidence of a volcano's summit or flanks, and the release of volcanic gases from the ground and vents. Monitoring may also include systems to detect and warn about volcanic ash clouds, lahars, and changes in water chemistry around volcanoes.

Mudflow – General term for a predominantly fine-grained and rapidly moving flow of mud, rocks and debris that possesses a high degree of fluidity during movement. It is sometimes used as a general term that includes lahars and debris flows.

National Lahar – Melting of snow and ice during an eruption between 2,200 and 500 years ago provided water for initiation of National Lahar. This lahar inundated the Nisqually River Valley to depths of 10 to 40 meters (30 to 120 feet) and flowed to Puget Sound.

North American Plate – Tectonic plate consisting mainly of lithosphere underlying North America and the western Atlantic Ocean.

Observation – The act of deliberately sensing an event or item and noting the details.

Obsidian – Obsidian is dense volcanic glass formed when lava cools so fast that crystals don't have time to grow extensively or at all. Very tiny crystals of iron oxide cause its dark color.

Oceanic crust – Part of Earth's crust that generally underlies the ocean basins. It is thinner than continental crust, generally less than 10 kilometers (6 miles) thick, but it is more dense and is composed primarily of basalt and gabbro.

Oceanic plate – A tectonic plate whose crustal portion is composed mainly of oceanic crust.

Oceanic ridge – See mid-ocean ridge.

Osceola Mudflow – A large lahar that initiated with collapse of the hydrothermally altered summit and northeast flank of Mount Rainier approximately 5,600 years ago. The collapse, triggered by an intrusion of magma into the volcano, caused a lahar which covered at least 400 square kilometers (150 square miles) and had a volume of almost 3.8 cubic kilometers (almost 1-cubic mile).

Ohanapecosh Formation – Widely exposed volcanic and sedimentary rocks in southern Washington related to volcanism between 38 and 24 million years ago. Several of the vents that produced the volcanic rocks of the Ohanapecosh Formation are found within Mount Rainier National Park.

Pacific Plate – The oceanic tectonic plate beneath most of the Pacific Ocean. Interactions with other plates along its margin cause very large earthquake and volcanic activity in a zone dubbed the Pacific Rim of Fire.

Pahto – (see Klickitat).

Pascal – A unit of pressure or stress in the International System of Units (SI). One pascal is equivalent to one newton (1 N) of force applied over an area of 1 meter squared (1 m^2).

Pele's Hair – Thin strands of volcanic glass formed during explosive eruptions of basaltic lava. Named for Pele, the Hawaiian goddess of volcanoes. A single strand with a diameter of less than 0.5 millimeters (0.02 inch) may be as long as 2 meters (6 feet).

Phenocryst – The larger crystals surrounded by finer grained material or glass within an igneous rock.

Phreatic eruption – An explosion of steam, mud, or other material that is not incandescent. It is caused by the heating and expansion of groundwater due to an underlying igneous heat source.

Phreatomagmatic eruption – An explosive eruption caused by interaction of magma with groundwater or shallow surface water.

Plagioclase feldspars –A group of minerals that contain sodium, calcium, and aluminum silicate in varying amounts and with different properties. Color is in shades of gray, white, greenish, yellowish, or bluish with an iridescent.

Plate tectonics – A scientific theory that describes the motion of the lithosphere (Earth's crust and upper mantle), which is divided into a number of rigid plates that are in motion and interact with one another.

Pleistocene Epoch – This term refers to the segment of time extending roughly from 2 million to 10,000 years ago. During the Pleistocene Epoch, Earth's temperate zones were alternately covered by glaciers during cool periods (ice ages) and uncovered in warmer times, when glaciers retreated (interglacials).

Pliocene – An epoch of geologic time between the Miocene and Pleistocene, occurring from about 5.3 million to 2.6 million years ago.

Plutonic rock – An intrusive igneous rock that solidified from magma at great depth, as opposed to at shallow depth, and is typically coarse grained.

Pumice – A light-colored, low-density, frothy volcanic rock, usually of dacite or rhyolite composition, formed by the expansion of gas bubbles in erupting lava.

Pyroclastic flow (or hot ash flow) – An avalanche of hot ash, pumice, rock fragments, and volcanic gas that rushes down the side of a volcano as fast as a few hundred kilometers per hour (about 100 miles an hour).

Pyroxene – A group of silicate minerals that contain oxides of magnesium, iron, calcium, sodium or aluminum, in combination with silica, manganese, and chromium. Pyroxenes are a common constituent of igneous rocks and, based on their chemical composition, range in color from white to dark green or black, although they are typically found in dark-colored igneous rocks.

Reflection Lakes Lahar – A lahar caused by landslide that covered much of Paradise Ridge with boulders and hilly terrain approximately 7,400 to 7,200 years ago. Modern Reflection Lakes fills a depression within the lahar deposit.

Relative age – The age of a rock, geologic feature, or event defined relative to other rocks, geologic features, or events rather than in terms of years.

Rhyolite – An extrusive rock similar in composition to granite but with much smaller crystals. Rhyolite is rich in silica and aluminum and sometimes contains phenocrysts of feldspar (Sodium (Na)- rich varieties), quartz, hornblende, and biotite. Rhyolite's silica (SiO_2) content is between 69 and 77 percent.

Ring of Fire – The name of the extensive area of volcanic and seismic activity that roughly coincides with the edges of the Pacific Ocean.

Risk – The chance or probability that people or property will be harmed or experience an adverse effect if exposed to a hazardous event.

Rock fall – Free falling of rock from a cliff or steep slope.

Rock rubble – A loose mass of angular rock fragments, commonly found on the tops of lava flows.

Round Pass Mudflow – A lahar caused by a collapse on the west flank of Mount Rainier approximately 2,600 years ago. The lahar traveled a short distance in the Tahoma Creek Valley, and in the Puyallup River Valley for a longer distance, probably as far as the Puget Sound lowland.

Rubble – (see rock rubble)

Sandstone – A sedimentary rock formed by the consolidation and compaction of sand and held together by a natural cement, such as silica.

Scoria – A vesicular (bubbly) glassy lava rock of basaltic to andesitic composition ejected from a vent during an explosive eruption. The bubbly nature of scoria is due to the escape of volcanic gases during eruption. Scoria is typically dark gray to black or red in color, mostly due to its high iron content.

Seafloor spreading – A process whereby new oceanic crust is formed by upwelling of magma at the mid-ocean ridges as two plates move away from the ridge at a rate of 1 to 10 centimeters (0.4 to 4 inches) per year.

Seamount – An underwater mountain rising from the ocean floor and having a peaked or flat-topped summit below the surface of the sea.

Sediment – Unconsolidated particles, ranging from clay-size to boulders, produced by the weathering of rocks and transported by natural agents such as wind, water, and ice.

Sedimentary rocks – Rock resulting from the consolidation of sediment.

Seismologist – A scientist who studies earthquakes and the structure of the Earth through the study of seismic waves.

Seismograph – A scientific instrument that detects and records vibrations (seismic waves) produced by earthquakes.

Shield volcano – A volcano that has the shape of an inverted warrior's shield. It has long gentle slopes produced by multiple eruptions of fluid lava flows.

Silica – Silicon dioxide (SiO_2), a basic constituent of volcanic rocks and the most important factor controlling the fluidity of magma. The higher a magma's silica content, the greater its viscosity or resistance to flow.

Solidus – The temperature boundary above which solids and liquids exist in equilibrium and below which no liquid phase exists.

Spindle-shaped bomb – (see bomb)

Spreading ridges – Linear ridges on the ocean floor where tectonic plates separate and magma erupts. About 80 percent of the Earth's volcanic activity occurs on the ocean floor.

Steam explosion – A violent expansion of steam, occurring when water or water vapor is abruptly exposed to low pressure.

Steam vent – A vent from which steam is expelled.

Stevens Ridge Formation – Discontinuous layers of volcanic rocks formed around the same time as the Fife's Peak Formation (between 26 and 22 million years ago), which consist chiefly of pyroclastic flow deposits. These rocks are visible in numerous areas within Mount Rainier National Park.

Stratigraphic column – A diagram that shows in a single column all rock and sediment layers, from older layers at the base to younger ones at the top.

Stratigraphy – The study of rock and sediment layers aimed at understanding geologic history and Earth-surface processes.

Stratovolcano – A steep-sided volcano composed of many layers of volcanic rocks, usually of high-viscosity lava and fragmental debris such as lahar and pyroclastic deposits. Also called a composite volcano.

Striations – Scratches or minute lines, generally parallel, that are inscribed into a rock surface by a geologic agent, such as a glacier.

Subduction – The process whereby two tectonic plates converge and one sinks beneath the other.

Subduction zone – Where two tectonic plates converge and one descends beneath the other. Magma generated just above the descending plate at a depth of about 80 to 100 kilometers (50 to 60 miles) feeds volcanoes on the overriding plate.

Tahoma – One of several traditional Native American names for Mount Rainier, also Taxo'ma, Ta-co-bet, Takhoma, Taqomen, and Dah-ko-bed and meaning "place where the waters begin."

Tatoosh pluton – A solidified magma body that formed the roots of earlier volcanoes between 18 and 14 million years ago and now stands, in part, as a granodiorite mountain range along the southern margin of Mount Rainier National Park.

Tectonic plates – A patchwork of rigid slabs (16 major ones identified at present) that make up Earth's lithosphere. These plates float on top of a softer, more plastic layer in the asthenosphere. The plates are in motion and interact with each other to produce earthquakes and volcanoes and to fold and fault the Earth's crust.

Tehama – Traditional Native American name now applied to an extinct large stratovolcano southeast of Lassen Peak, California, that is mostly eroded away. Authorities disagree on the exact meaning, which has been reported as "high water," "low land," "salmon" or "shallow."

Tephra – The general term for volcanic ejecta of any size. Other terms are used to describe ejecta of specific ranges. Fragmental volcanic products between 2 to 64 millimeters (0.1 to about 2.0 inches) in diameter are called lapilli; material finer than 2.0 millimeters (0.1 inch) is called ash. Fragments larger than about 64 millimeters (2.5 inches) are called blocks if they were ejected in a solid state and volcanic bombs if ejected in semisolid, or plastic, condition.

Throat – (see conduit)

Topographic map – A map depicting landscape, usually through use of contour lines. The map shows the horizontal and vertical positions of the natural features.

Topography – General configuration of the land surface, including its relief and the position of its natural and man-made features.

Transform fault – The fault zone between two tectonic plates (or two parts of a single plate), where pieces are sliding horizontally past one another.

Transform plate boundary – Zone where tectonic plates slide horizontally past each other.

Transverse fault – (see transform fault)

Trench – A narrow, elongate depression of the deep-sea floor associated with a subduction zone.

Tsunami – A large, rapidly moving ocean wave triggered by a major disturbance of the ocean floor, which is usually caused by an earthquake but sometimes produced by a submarine landslide or a volcanic eruption.

Twin Creeks assemblage – An assemblage of lahar deposits in the White River Valley, thought to have formed between 1,350–1700 years ago. In some literature, considered part of the Deadman Flats assemblage.

Vent – An opening at the Earth's surface through which volcanic materials (lava, tephra, and gases) erupt. Vents can be at a volcano's summit or on its slopes; they can be circular (craters) or linear (fissures).

Vesicles – Bubbles in volcanic rock caused by the entrapment of gas.

Viscosity – Measure of the physical resistance to flow of a fluid. As an example, taffy and molasses are more viscous than water.

Viscous – Possesses a notable physical resistance to flow.

Volcanic ash – Fragments less than 2 millimeters (0.1 inch) in diameter of lava or rock blasted into the air by volcanic explosions or rising upwards from moving pyroclastic flows.

Volcanic unrest – Changes in earthquake activity, ground deformation, gas emission, or geologic features that exceed day-to-day variability and can signal a change of physical conditions within a volcano. Not all unrest leads to a volcanic eruption.

Volcanic gas – Gas of volcanic origin that consists mainly of steam (water), carbon dioxide, sulfur dioxide, and hydrogen sulfide.

Volcanic mudflows – (see mudflows, lahars).

Volcanic rocks – Rocks formed by the cooling of lava.

Volcanism – Any of the processes by which magma and its associated gases rise to the crust from the Earth's interior and are discharged onto the surface or into the atmosphere.

Volcano – A vent (opening) in the surface of the Earth through which magma erupts; a landform that is constructed by the erupted material.

Volcanic cone – Conical mound of lava and pyroclastic debris that builds up around a vent.

Volcanic hazards – Sources of potential danger associated with a volcano. Some more common volcanic hazards include volcanic ashfall, lava flows, pyroclastic flows, lahars, volcanic gases, debris avalanches, and volcanogenic tsunamis.

Volcano hazard map – A map that displays the areas likely to be affected by volcanic processes.

Volcanologist – A scientist who studies volcanoes and volcanic events.

Wy'east – Native American name for Mount Hood and named for a chief of the Multnomah tribe.

Activity last modified: December 12, 2009

This page left intentionally blank

ISSN 2332-0345X (online)

http://dx.doi.org/10.3133/gip19