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

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 Publication 19

Overview

Students use ice cream glaciers and hot wax lava flows to simulate the interaction of glaciers and lava flows.

continued.....

- 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 (one 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)

Vocabulary: Erosion, glacier, ice ages, lahar, lava, lava flows, pyroclastic flow, striations, vent, volcano, volcanic eruptions

Skills: Interpret, infer, demonstrate, explain, predict, visualize

Benchmarks:

Science:

1 – Understands and uses scientific concepts and principles

1.1 – Use properties to identify, describe, and categorize substances, materials, and objects, and use characteristics to categorize living things

Nature and properties of earth materials–classify rocks and soils into groups based on their chemical and physical properties; describe the processes by which rocks and soils are formed

1.2 – Recognize the components, structure, and organization of systems and the interconnections within and among them

Systems-describe how the parts of a system interact and influence each other

1.3 – Understand how interactions within and among systems cause changes in matter and energy

Processes and interactions in the earth system-describe the processes of constructive and destructive forces and how they continually change landforms on earth

2 – Knows and applies skills and processes of science and technology

2.1 – Develop abilities necessary to do scientific inquiry

Questioning-generate questions that can be answered though scientific investigations

Explanation-use evidence from scientific investigations to think critically and logically to develop descriptions, explanations, and predictions

Geography:

1 – Uses maps, charts, and other geographic tools to understand the spatial arrangement of people, places, resources, and environments on Earth's surface

1.1 – Use and construct maps, charts, and other resources to gather and interpret geographic information

1.1.2b – Uses data and a variety of symbols and colors to create thematic maps, mental maps, and graphs depicting geographic information

1.2 – Recognize spatial patterns on Earth's surface and understand the processes that create these patterns

1.2.2a – Locate physical and human features and events on maps and globes

2 – Understands the complex physical and human characteristics of places and regions

2.1 – Describe the natural characteristics of places and regions and explain the causes of their characteristics

2.1.2 – Use observation, maps, and other tools to identify, compare, and contrast the physical characteristics of places and regions

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 one hundred kilometers (sixty 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 flow 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 (one 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. **<u>Make clay strips that represent previous accumulations of lava rock as ridges that radiate from the volcano.</u>**
   Remove clay from its container and shape into strips 1.5 cm (0.5 inches thick) and approximately 13-17 cm (5-8 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. **<u>Cover volcano model with vanilla ice cream to represent enormous ice-age glaciers.</u>**
   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, (~1/3 inch) of ice cream. When finished, your ice cream-covered volcano model should have a fairly smooth appearance.

5. **<u>Melt the wax.</u>**
   Obtain a stove top heat source and double-boiler system. Place 454 grams (1pound) 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 C (200 degrees F). 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 & 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.

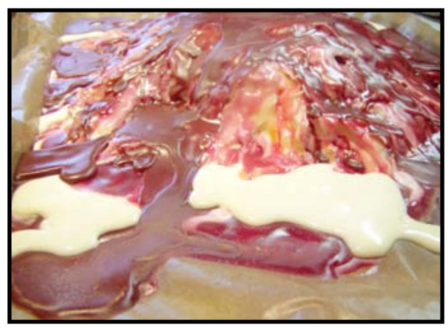
2. Ask students to hypothesize about what happens when hot lava and glacier ice interact. What will happen to the glaciers? To the lava flows?

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. 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. **<u>Instruct student to observe where the lava travels faster.</u>** 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. **<u>Repeat the pouring of wax lava flows and student observations until all wax has been poured.</u>** Use cooling times for discussion of energy transformation that occur when hot lava meets glacier ice.

6. **<u>Instruct students to make additional observations and to relate them to an actual volcano.</u>**
   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. In reality, lava flows on glaciers will break apart, while lava flows that travel off the volcanic cone, and over previous lava flows (represented here as clay ridges) often remain intact.



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

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Extensions

- Instruct students to conduct research projects about glacier-volcano interactions. Students can visit websites 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 flow 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.

Resources

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.

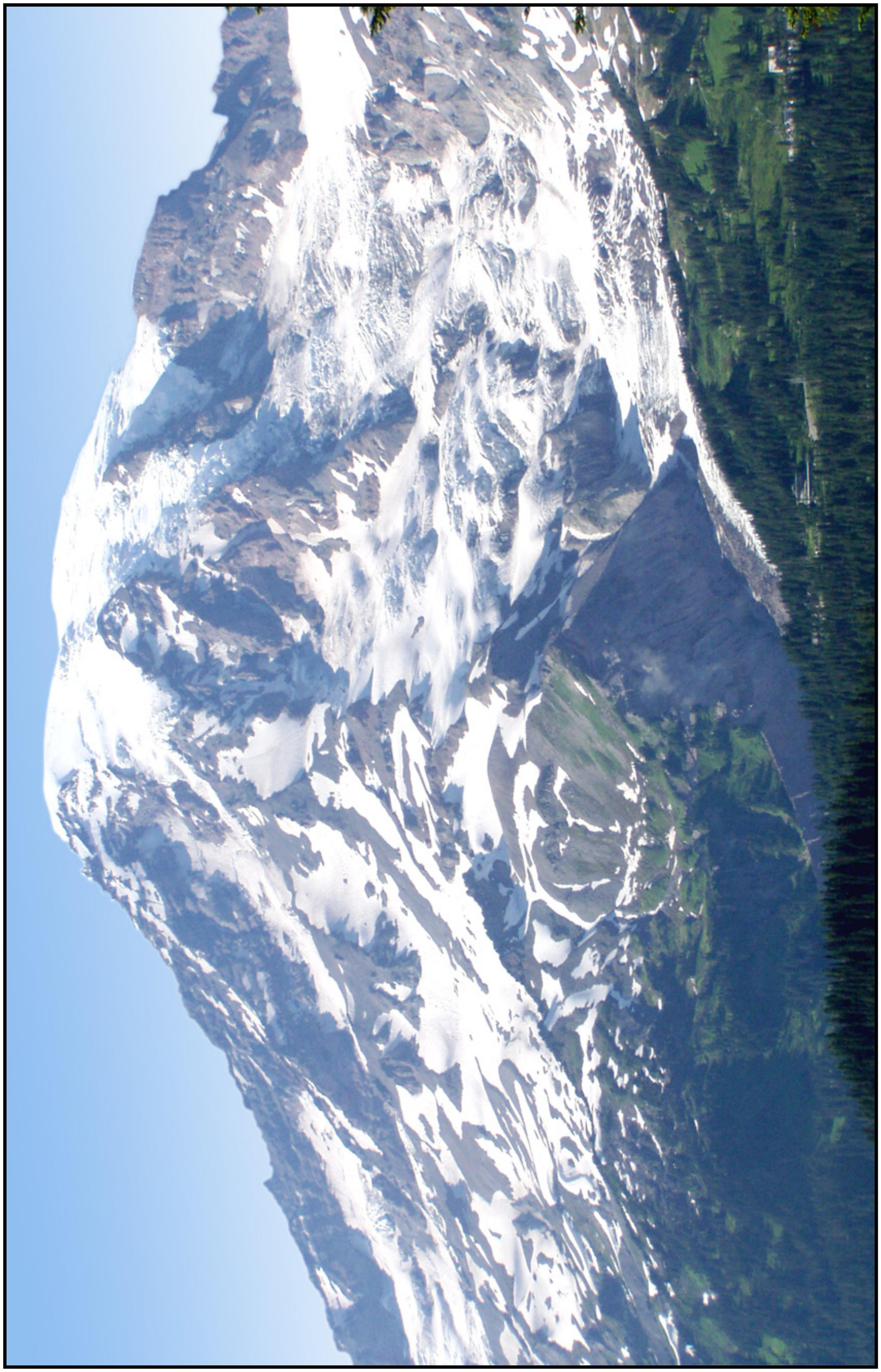
Driedger, C.L., 1993, Glaciers on Mount Rainier, U.S. Geological Survey Fact Sheet, Open-File Report 92-474, 2 p.

Lescinsky, D.T., and Sisson, T.W., 1998, Ridge-forming, ice-bounded lava flows at Mount Rainier, Washington: Geology, 26, p. 351-354.

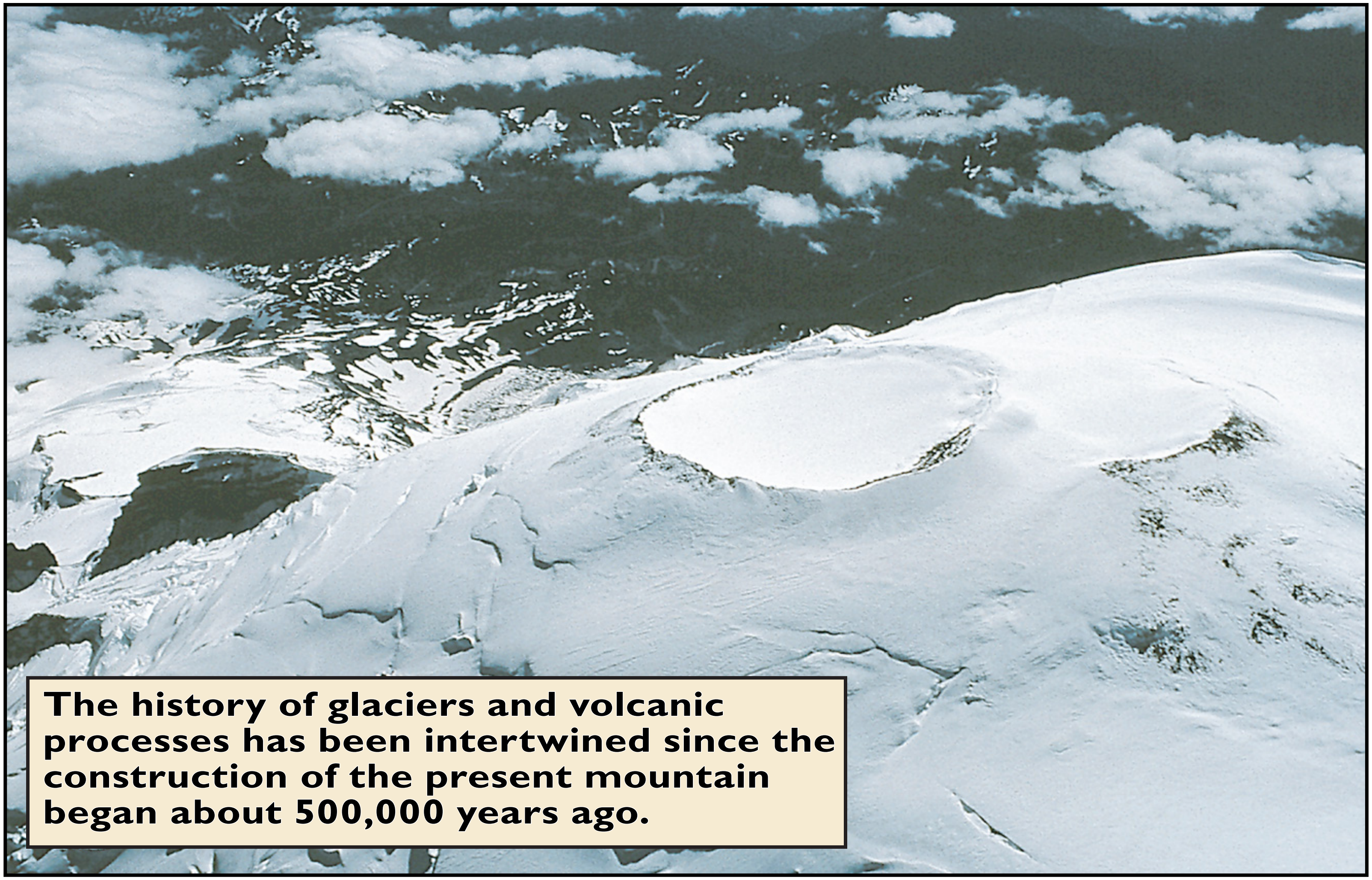
Lescinsky, D.T., and Fink, J.H., 2000, Lava and ice interaction at stratovolcanoes: use of characteristic features to determine past glacial extents and future volcanic hazards: Journal of Geophysical Research, v.105, pages 23, 711-23,726.

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

Glaciers on Mount Rainier

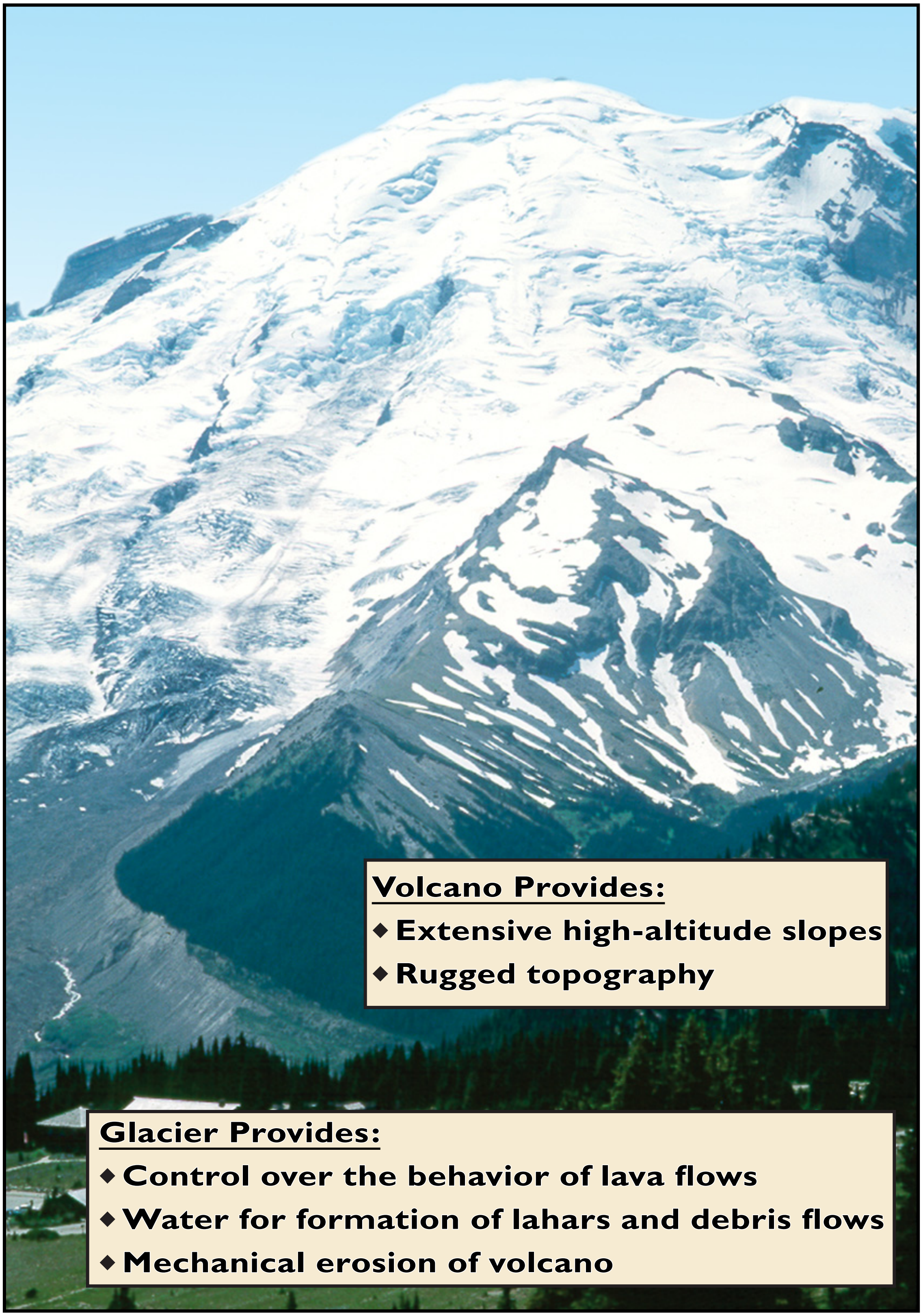


Columbia Crest Summit



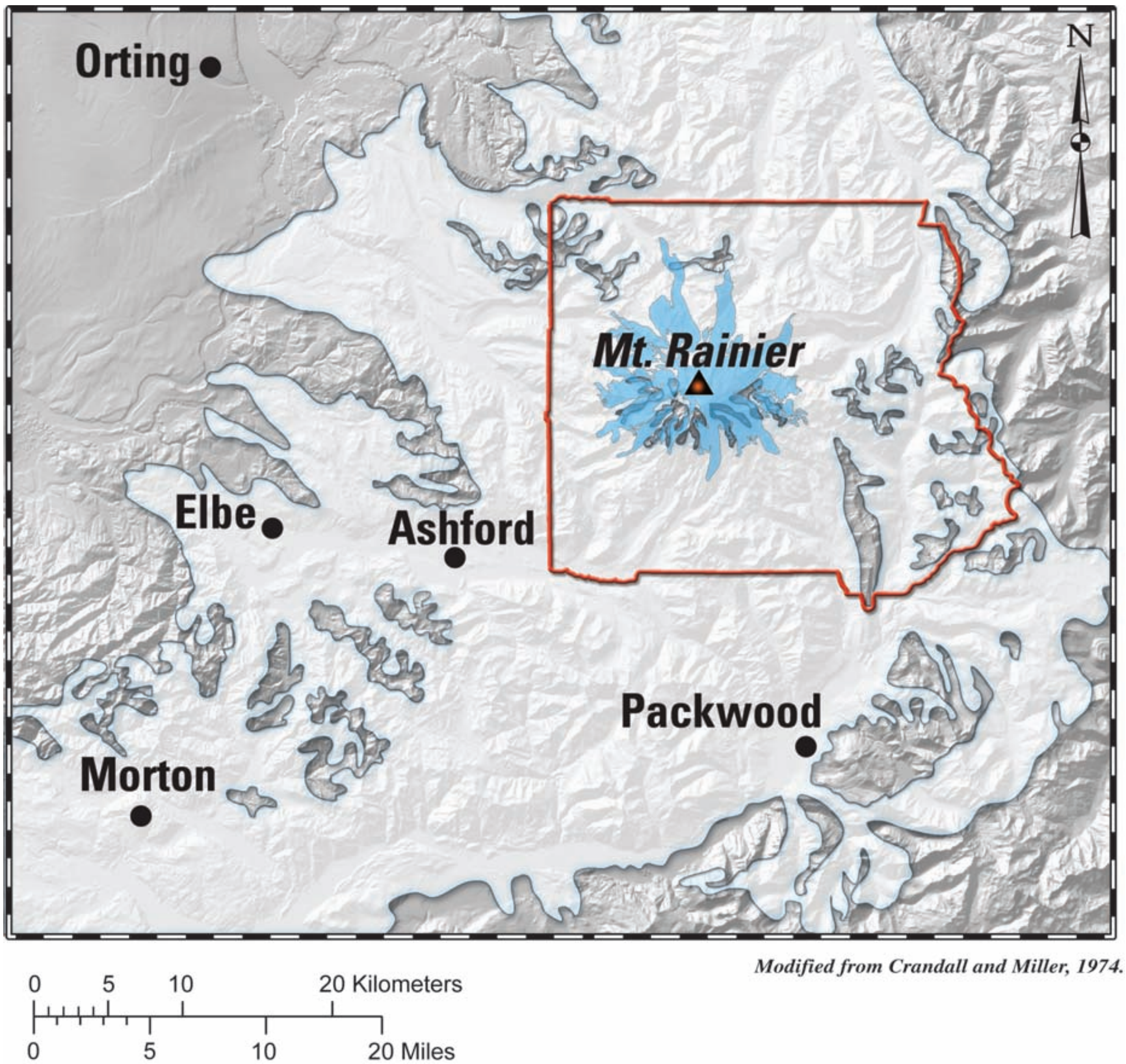
The history of glaciers and volcanic processes has been intertwined since the construction of the present mountain began about 500,000 years ago.

Glacier Volcano Interactions



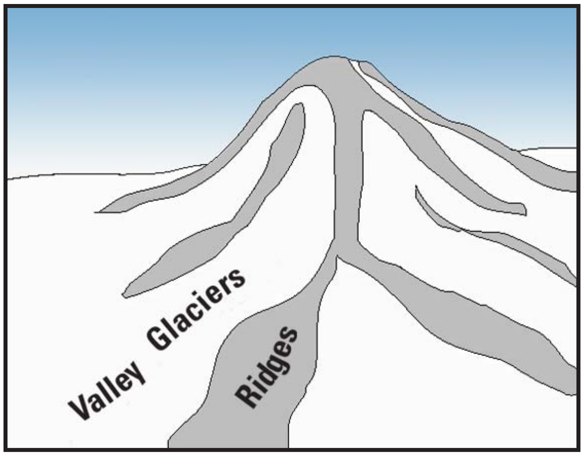
Graphic Page

Maximum Extent of Glaciers on Mount Rainier During the Ice Ages



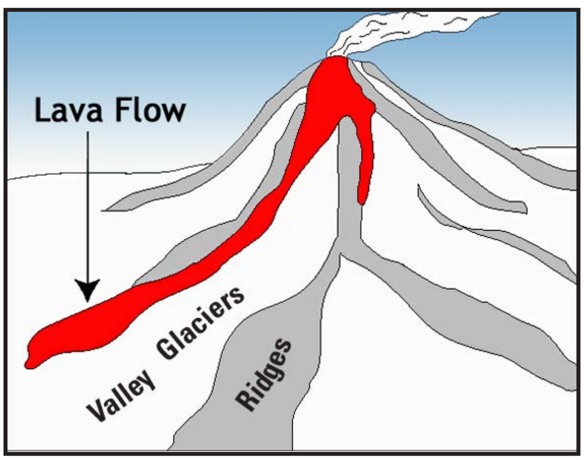
Modified from Crandall and Miller, 1974.

How Lava Ridges are Made



Ice Age glaciation on Mount Rainier

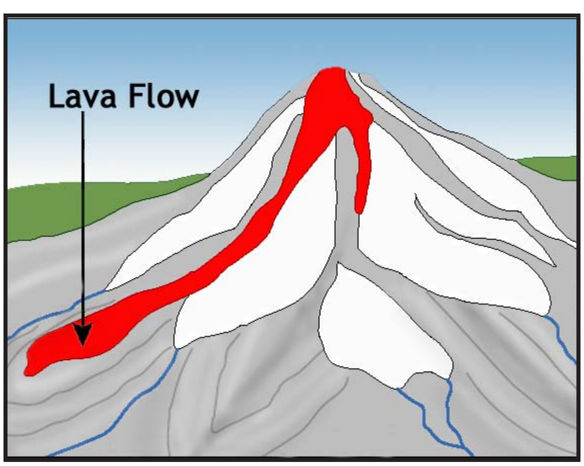
Ice-age glaciers buried much of Mount Rainier. Some rock ridges remained exposed.



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.

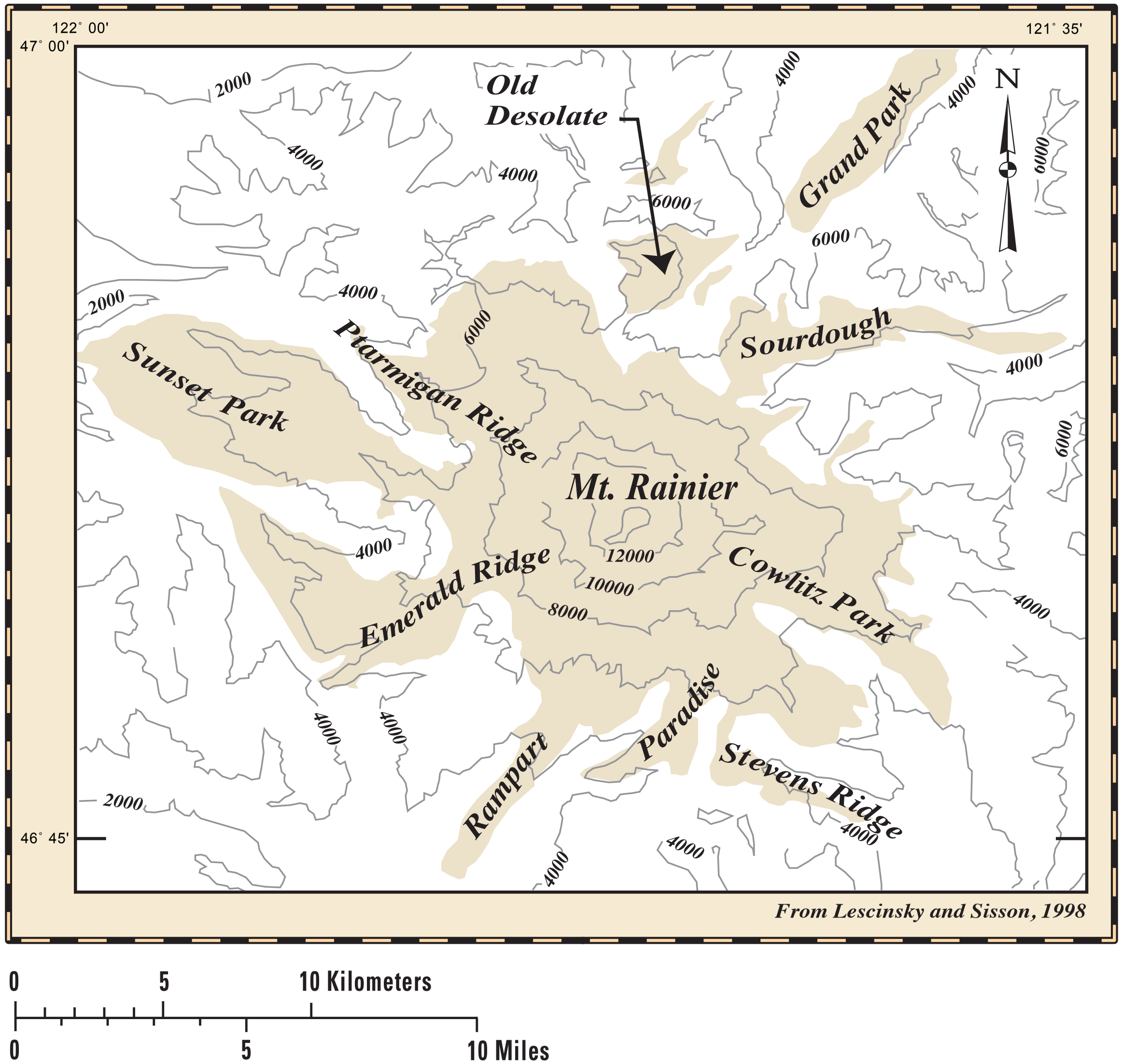


Lava ridges and glaciers today.

Glaciers melted at the end of the ice age. Stack of lava flows remain as ridges.

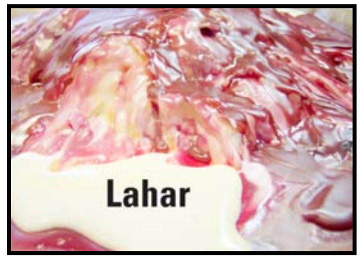
Glacier Scratches (Striations) on Lava Rock At Mount Rainier

Volcanic Rocks of Modern Mount Rainier

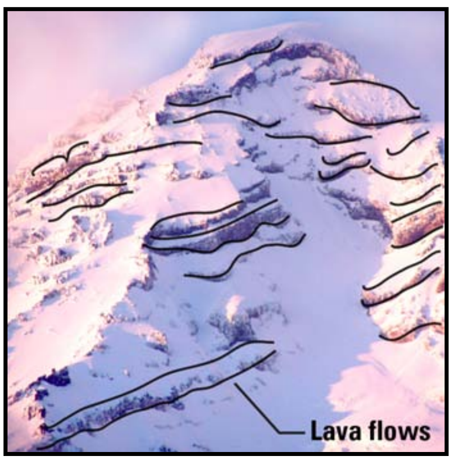


Graphic Page

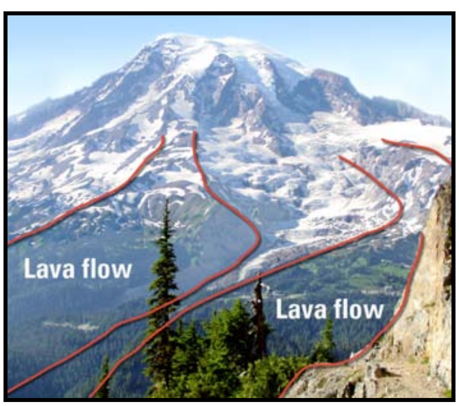
Lava Flows - Experimental and Real World Comparisons

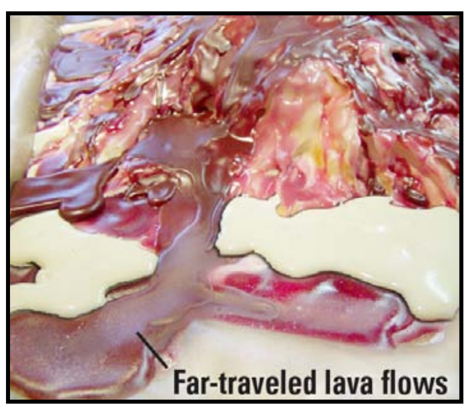


Lahar deposits—*Snow and ice meltwater from pyroclastic flows formed this lahar deposit, which is represented by the flow of melted ice cream in the experiment.*



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.*