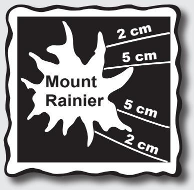
Tephra Explorer



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 one class session)

Materials:

- Copies of *"Make Your Own Tephra Isopach map"* student page
- Graphic of *"Exploring Tephra Layers at Mount Rainier"–Tephra Maps 1-6"*
- Projection copy or student copies of *"Exploring Tephra Layers at Mount Rainier"*
- Map of Cascades Volcanoes

USGS
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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:

Science:

1 – Understands and uses scientific concepts and principles

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

Components and patterns of the earth system–describe the components and relationships of the earth system, including the solid earth (crust, hot convecting mantle and dense metallic core)

2 – Analyze the different ways people use the environment, identify the consequences of use, and consider possible alternatives

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

Activity last modified: January 3, 2008

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

1.1.2a – 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 constrast the physical characteristics of places and regions

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 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 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 didn't 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

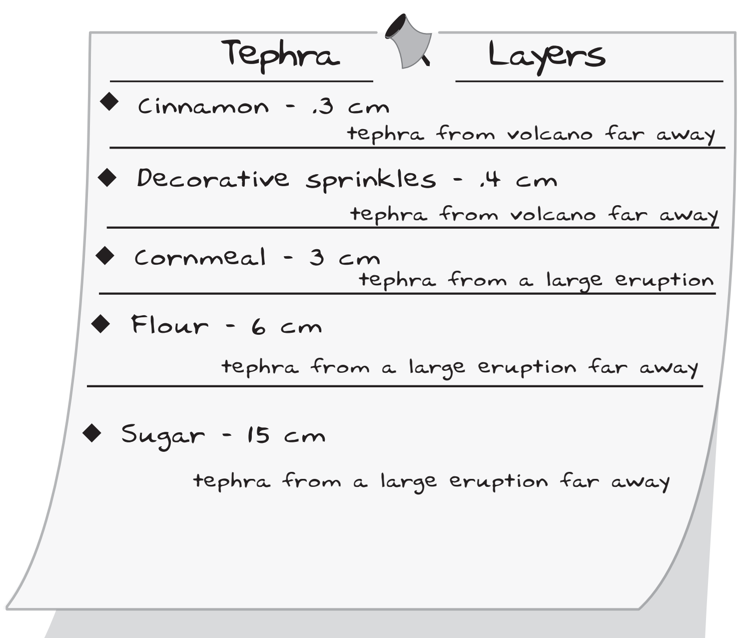
- ***Use protractors with your study of tephra layers.*** Provide students with protractors and instruct them to determine precise compass directions of tephra fall for the ***"Tephra Maps,"*** 1 through 6. For the student page ***"Make Your Own Tephra Isopach Map,"*** choose some compass directions 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.

Resources

Mullineaux, D.R., 1974, Pumice and other pyroclastics in deposits at Mount Rainier National Park: U.S. Geological Survey Bulletin 1326, 83p.

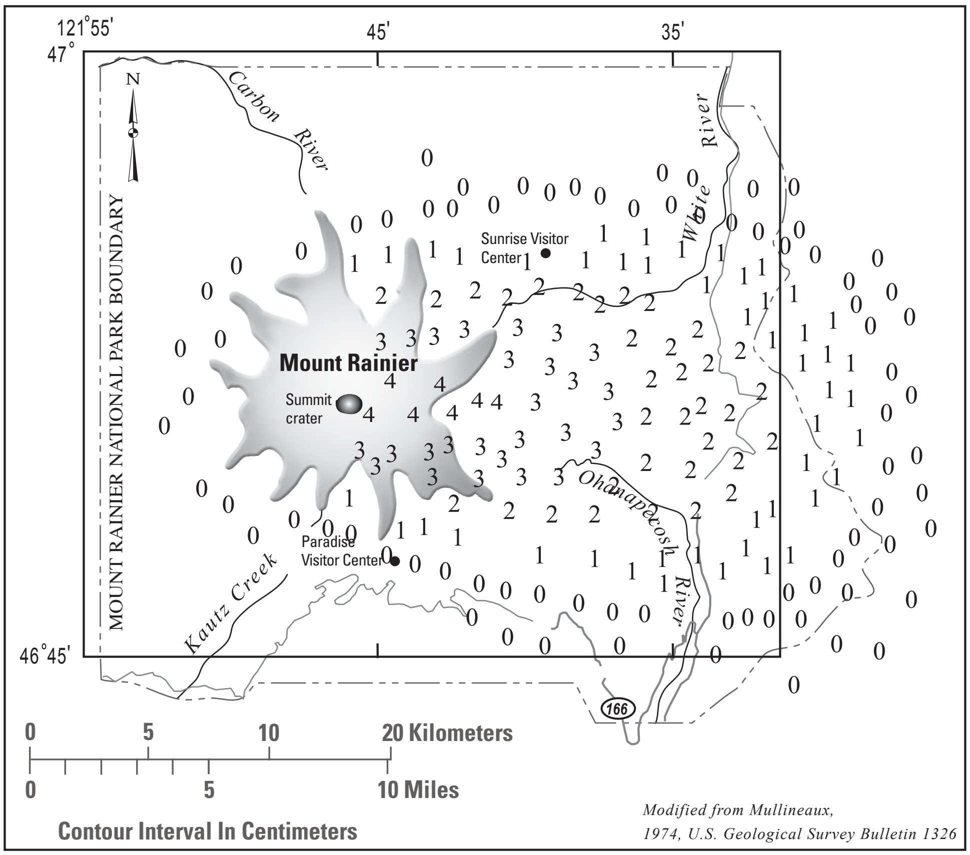
Crandell, D.R., 1969, Surficial geology of Mount Rainier National Park Washington: U.S. Geological Survey Bulletin 1288, 41p.

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

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.



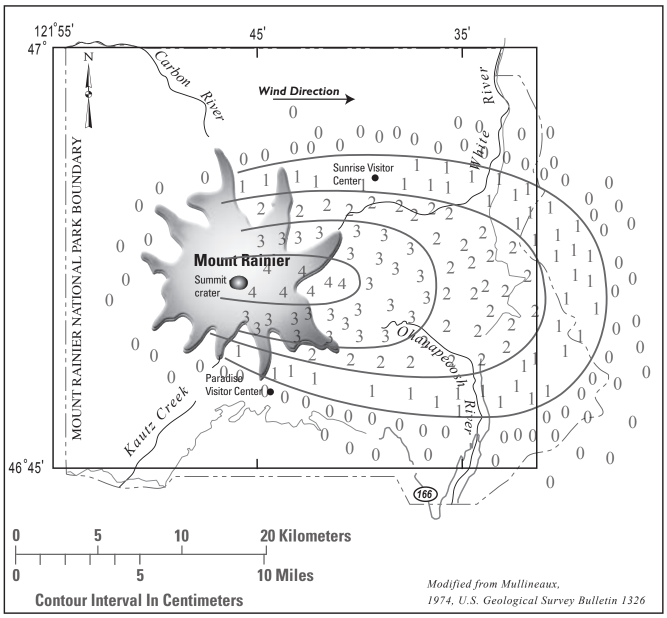
1. Develop an hypothesis that explains how the thickness of tephra fall will vary with increasing distance from the volcano.

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 see example on teacher page, 10. 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.



1. Develop a hypothesis that explains how ash thickness will vary with increasing distance from the volcano.

ANSWER:
The deposit will be thickest close to the volcano and thinner farther 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 see example on teacher page, 10. These contours indicate areas of equal tephra thickness and are known as isopachs.

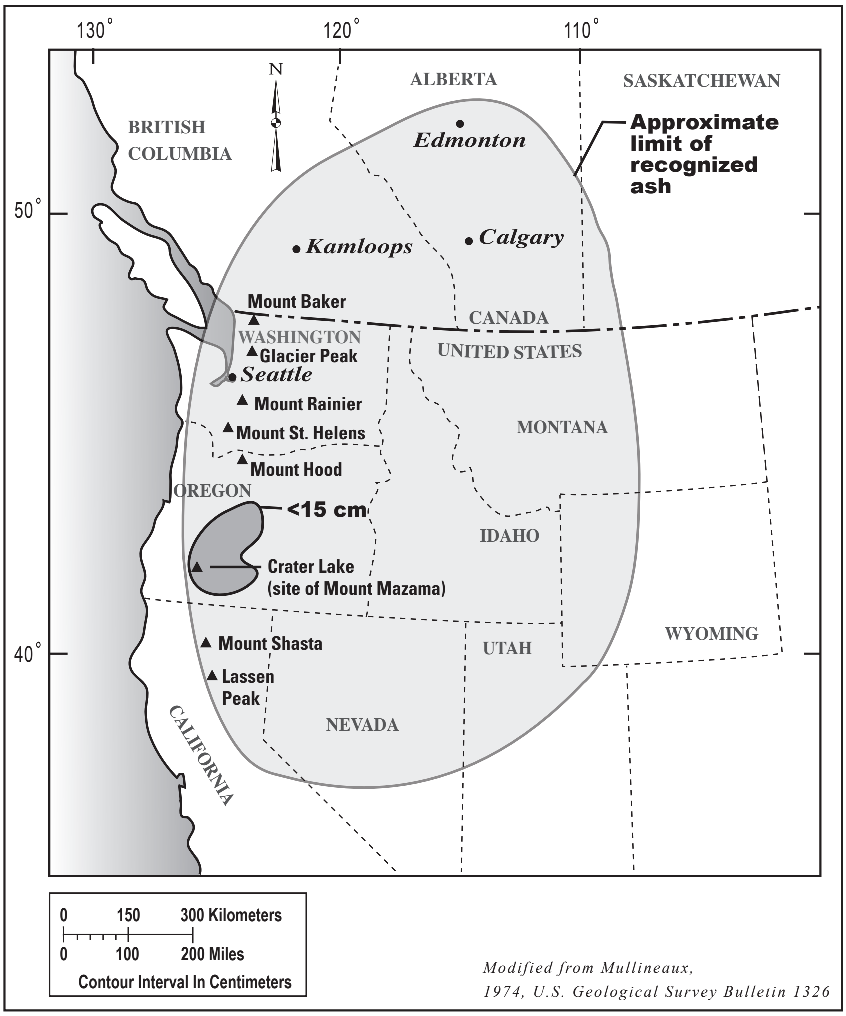
ANSWER:
(see map above)

Student Page

Name ____________________________

Exploring Tephra Layers at Mount Rainier

Instructions: *On Tephra maps 1-6, identify the wind direction at the time of the tephra eruption and the probable source volcano.*



Tephra Map 1

*Wind Direction:*______________

*Source Volcano:*______________

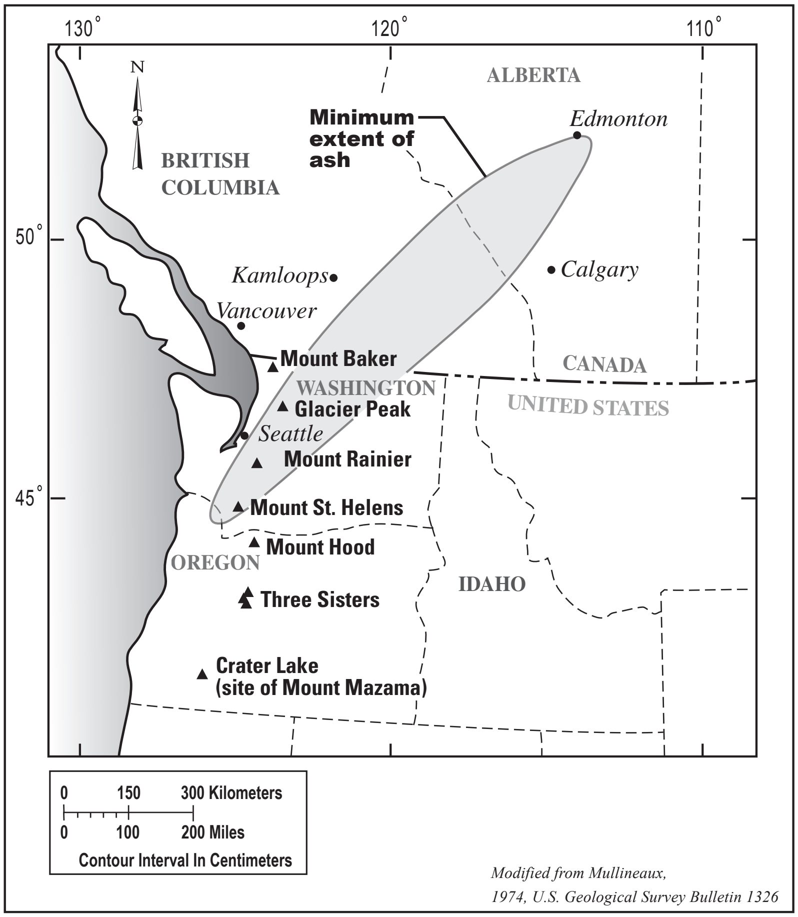
Explain your answer below:

Student Page

Name ______________________

Exploring Tephra Layers at Mount Rainier

Instructions: *On Tephra maps 1-6, 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:*____________

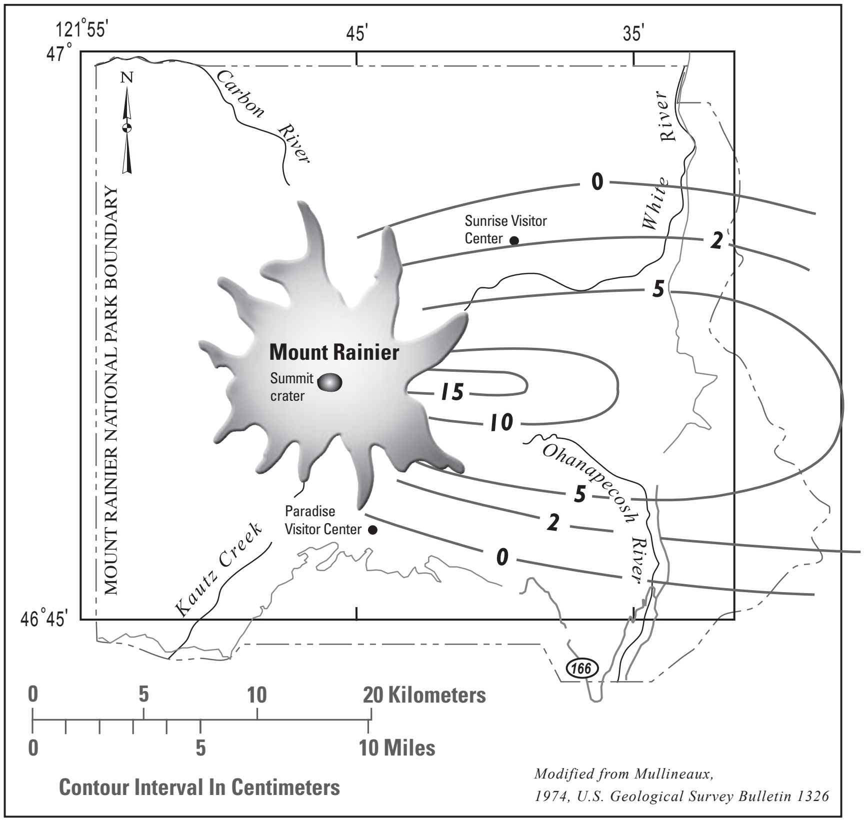
*Source Volcano:*____________

Explain your answer below:

Name ___________________________

Exploring Tephra Layers at Mount Rainier

Instructions: *On Tephra maps 1-6, identify the wind direction at the time of the tephra eruption and the probable source volcano.*



Tephra Map 3

*Wind Direction:*______________

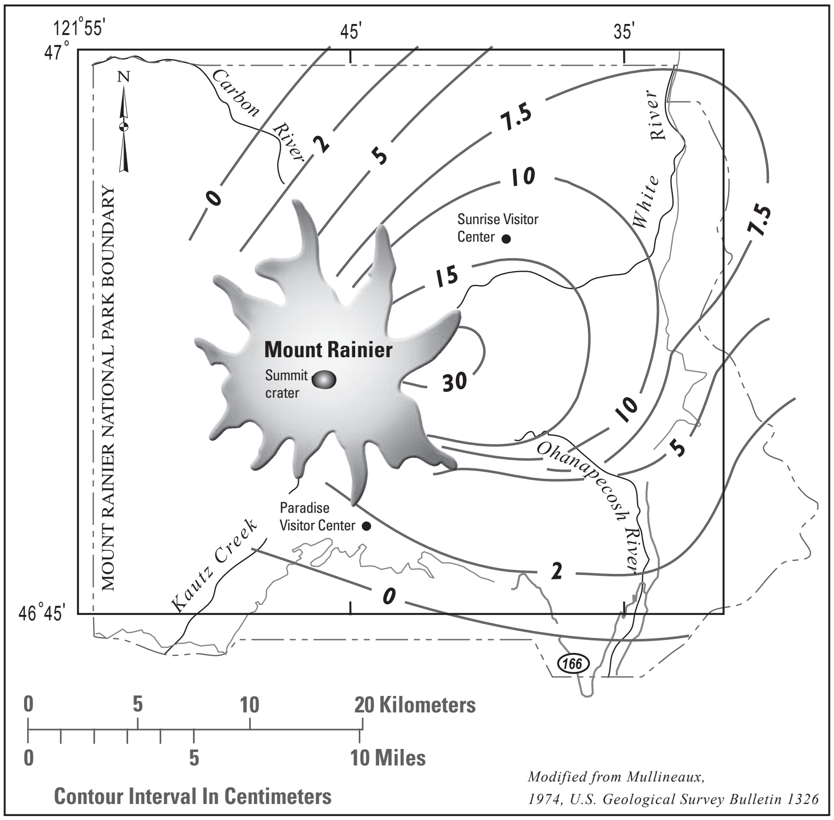
*Source Volcano:*______________

Explain your answer below:

Name ____________________________

Exploring Tephra Layers at Mount Rainier

Instructions: *On Tephra maps 1-6, identify the wind direction at the time of the tephra eruption and the probable source volcano.*



Tephra Map 4

*Wind Direction:*______________

*Source Volcano:*______________

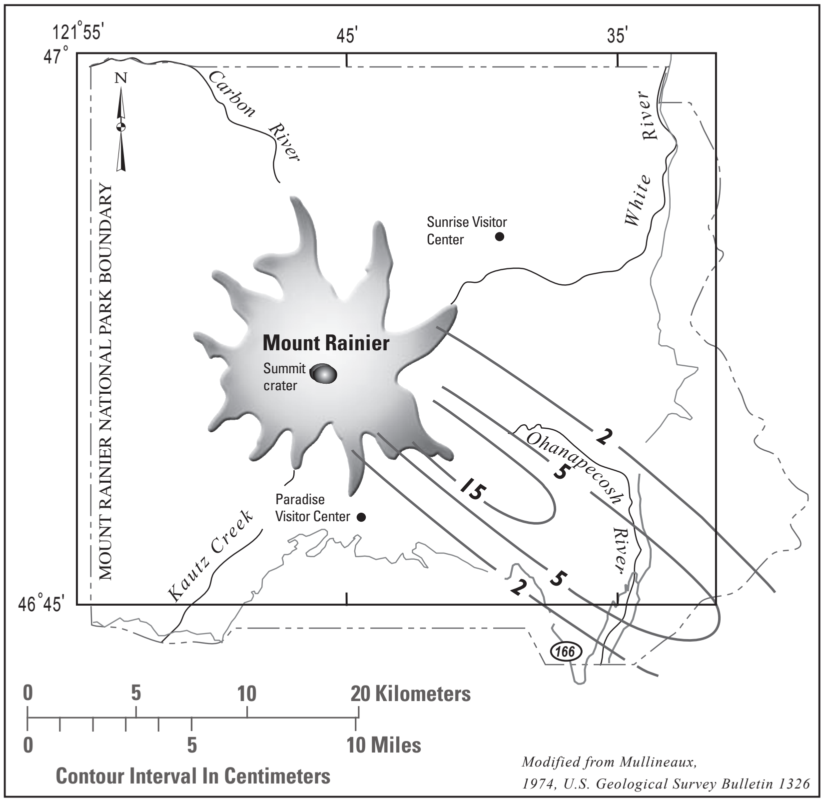
Explain your answer below:

Student Page

Name ______________________

Exploring Tephra Layers at Mount Rainier

Instructions: *On Tephra maps 1-6, identify the wind direction at the time of the tephra eruption and the probable source volcano.*



Tephra Map 5

*Wind Direction:*______________

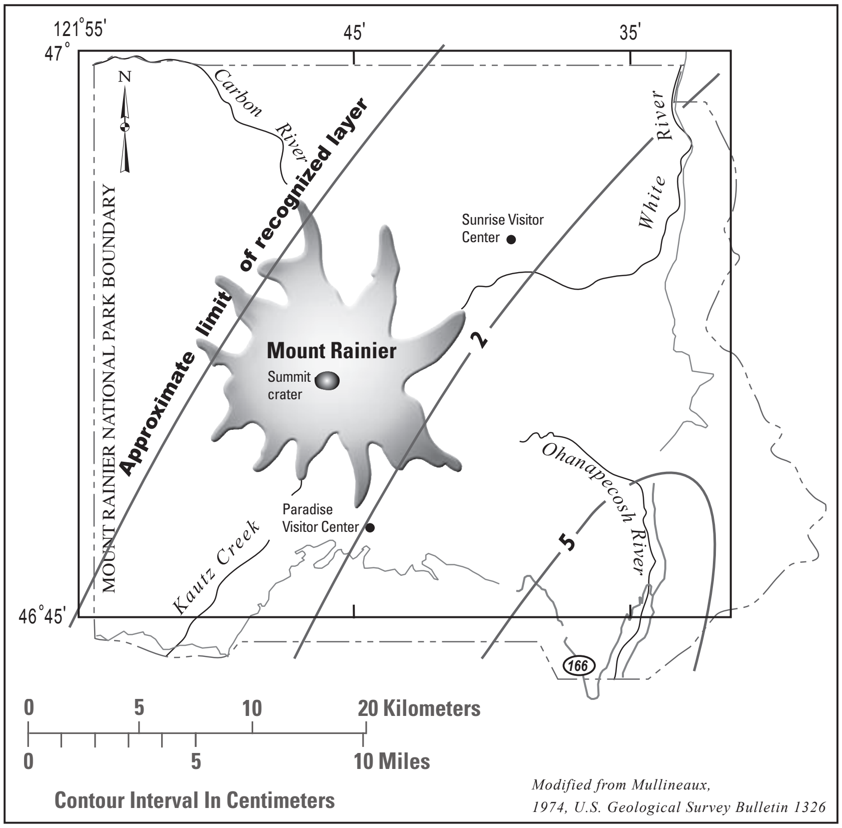
*Source Volcano:*______________

Explain your answer below:

Name ___________________________

Exploring Tephra Layers at Mount Rainier

Instructions: *On Tephra maps 1-6, identify the wind direction at the time of the tephra eruption and the probable source volcano.*



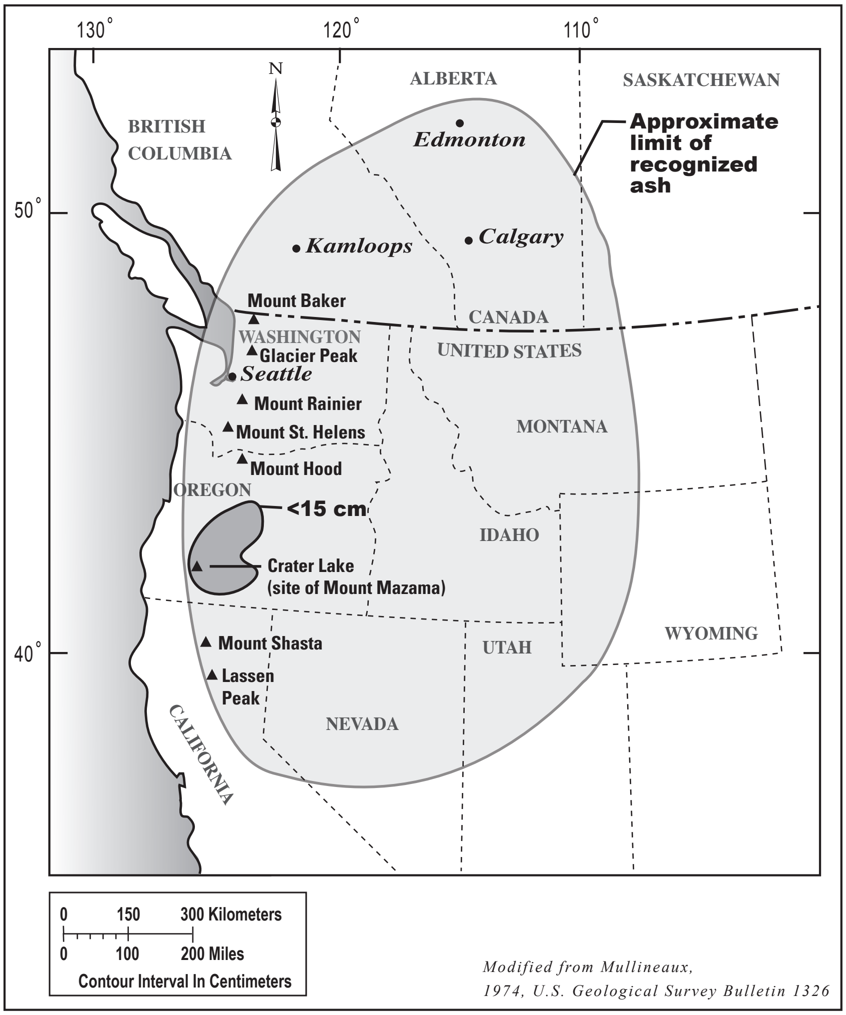
Tephra Map 6

*Wind Direction:*_____________

*Source Volcano:*_____________

Explain your answer below:

Exploring Tephra Layers at Mount Rainier



Tephra Map 1

Wind Direction:______________

Source Volcano:______________

Tephra O:

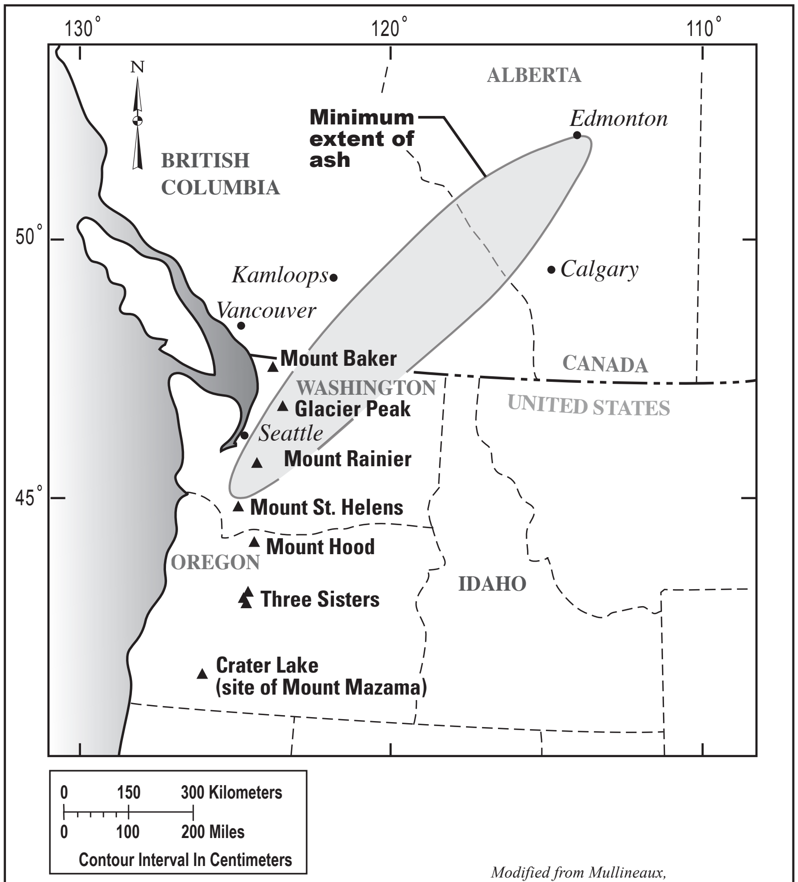
Wind Direction: ***From Southwest***

Source Volcano: ***Mount Mazama (Crater Lake)***

Age: ***7,700 years ago***

Description: Tephra layer O originated from 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 U.S. and southwest Canada. At Mount Rainier, tephra layer O is generally about five centimeters thick (two inches). Layer O is recognizable in road and trail cuts by its flourlike texture and commonly yellow-orange color.

Exploring Tephra Layers at Mount Rainier



Modified from Mullineaux, 1974, U.S. Geological Survey Bulletin 1326

Tephra Map 2

Wind Direction:_______________

Source Volcano:_______________

Tephra Yn:

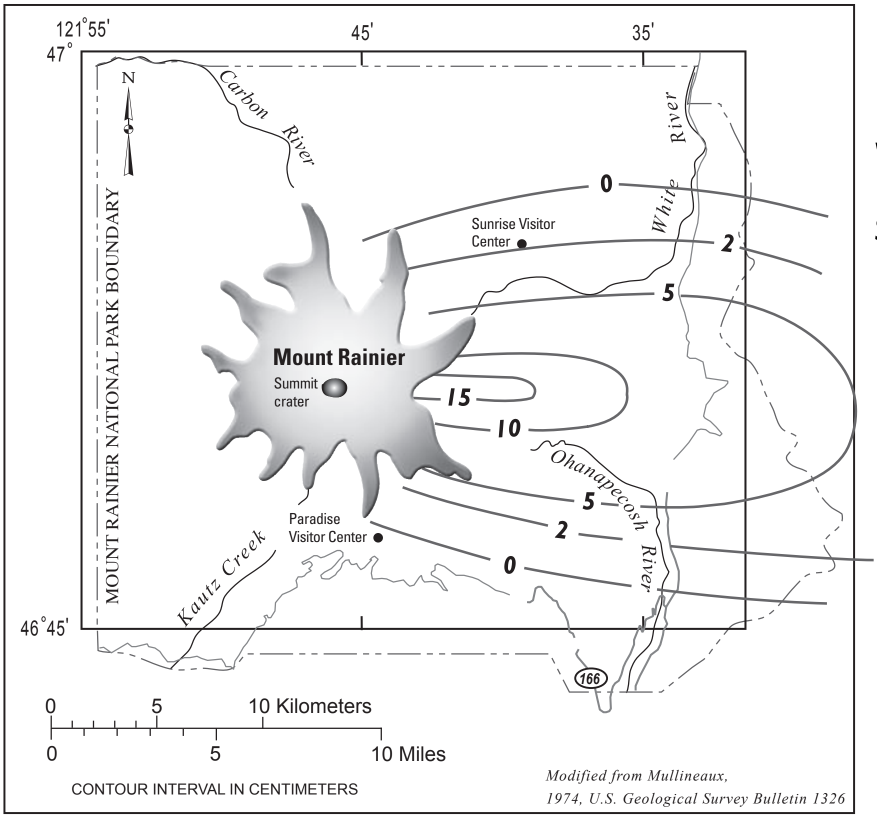
Wind Direction: ***From Southwest***

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, and in addition to tephra, produced pyroclastic flows and lahars. 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.

Exploring Tephra Layers at Mount Rainier



Tephra Map 3

*Wind Direction:*______________

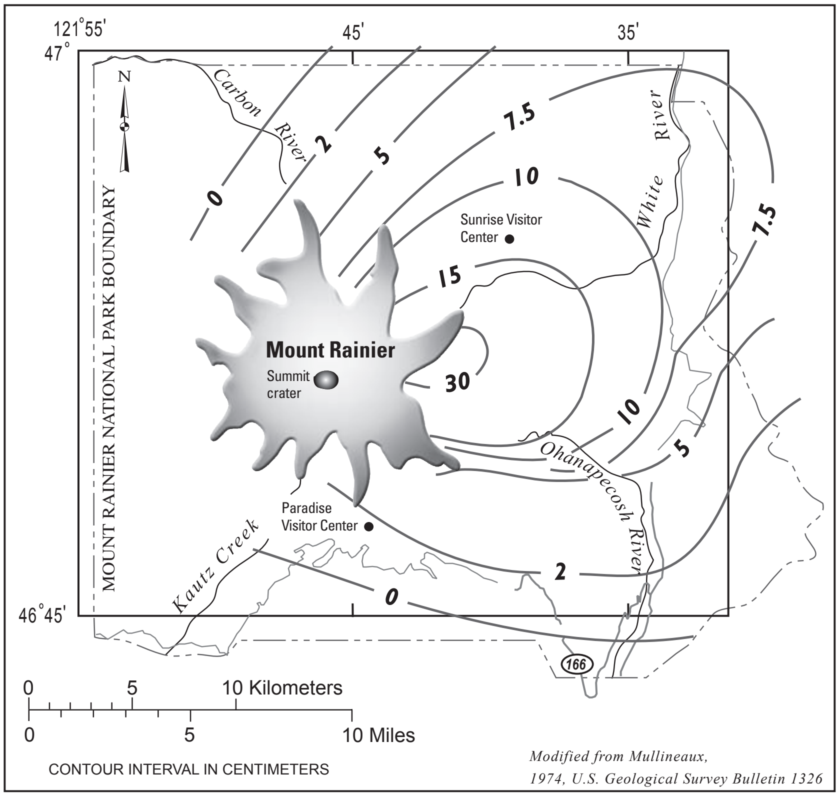
*Source Volcano:*______________

Tephra D:

Wind Direction: ***From West***
Source Volcano: ***Mount Rainier***
Age: ***6,700 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



Tephra Map 4

*Wind Direction:*______________

*Source Volcano:*______________

Tephra C:

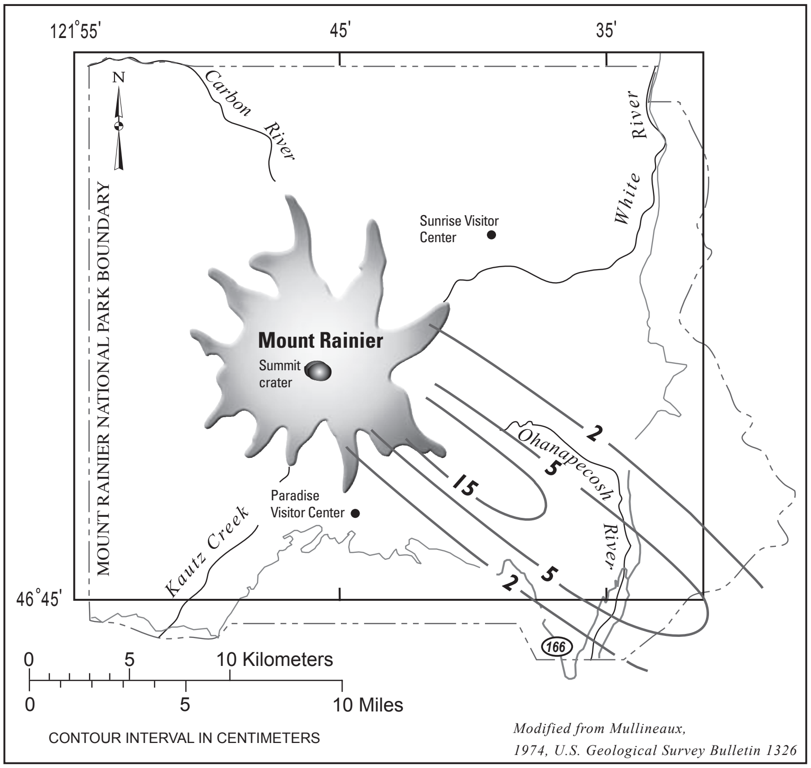
Wind Direction: ***From West/Southwest***

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 km (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.

Exploring Tephra Layers at Mount Rainier



Tephra Map 5

Wind Direction:______________

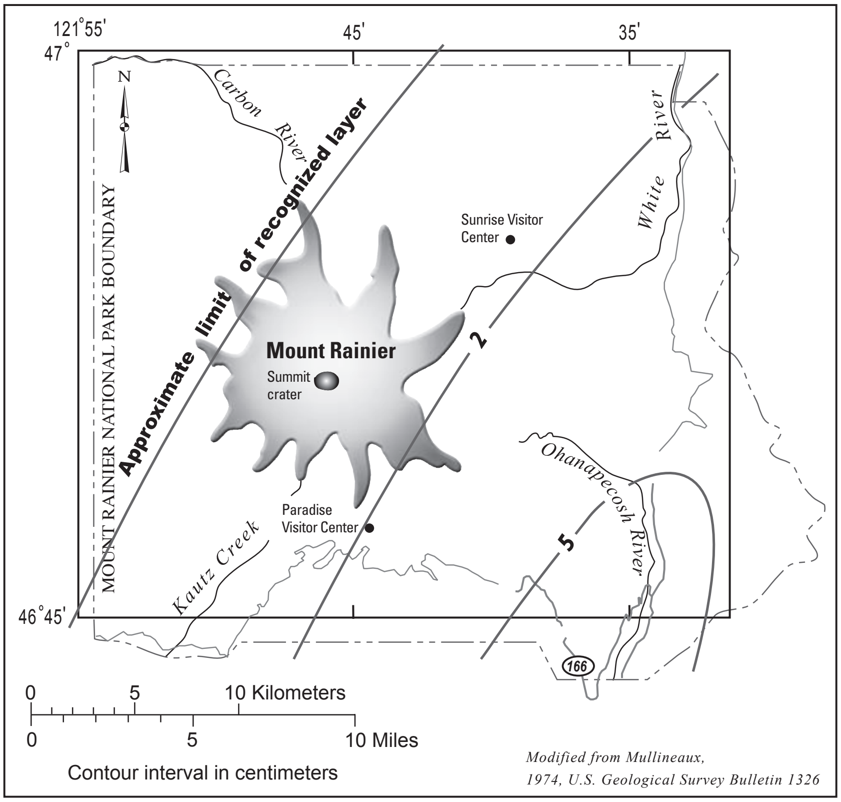
Source Volcano:______________

Tephra L:

Wind Direction: ***From Northwest***
Volcano Erupted From: ***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 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



Tephra Map 6

*Wind Direction:*______________

*Source Volcano:*______________

Tephra W:

Wind Direction: ***From Southwest***
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.

Map of Cascade Volcanoes