Mount St. Helens

Living with the Volcano that Came to Your Backyard

Tephra Explorer

Grade Level: 6-9

Learner Objectives:

Students will:

- Understand distribution patterns of tephra dispersal by wind at Mount St. Helens
- Interpret data from isopach maps
- Recognize that some tephra at Mount St. Helens originated at other Cascade volcanoes

Setting: Classroom

Timeframe: 50 minutes (one class session)

Materials:

- Copies of student pages "Ash Fall Compass" &"Make Your Own Tephra Isopach Map"
- Graphic of "Exploring Tephra Layers at Mount St. Helens"–Tephra Maps 1-5"
- Projection copy or student copies of "Exploring Tephra Layers at Mount St. Helens"
- Map of Cascades Volcanoes

Overview

Students view distribution patterns of tephra layers found around Mount St. Helens and discover their source.

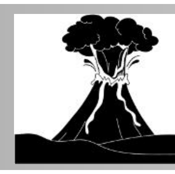
Vocabulary:
Isopach, pumice, scoria, silica, tephra, volcanic ash

Skills:
Prediction, interpretation, map reading

Benchmarks:
This activity aligns with Washington State and nationally approved education standards.

Thanks and Acknowledgements:
This lesson plan is modified and adapted from "Living with a Volcano in Your Backyard" curriculum developed by U.S. Geological Survey scientists at the Cascade Volcano Observatory and National Park Service park educators at Mount Rainier National Park.

Tephra Explorer continued….



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 a s***coria, pumice*** and ***volcanic ash.*** At Mount St. Helens, 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.

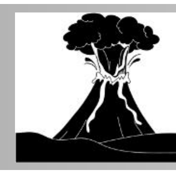
Mount St. Helens, famous for its explosive 1980 eruption has long been the most active volcano in the Pacific Northwest. It has been responsible for over 100 recognizable tephra layers over the past 40,000 years. Most of the tephra strata are classified into ten major groups called sets. Each set includes more than one named layer. Each layer represents a different eruption or group of eruptions. Some of these eruptions produced two to four times more tephra than the May 18, 1980 event!

While its neighbor 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). The eruption of Mount Mazama (Crater Lake), Oregon 7,700 years ago produced layer O that covered broad regions of the Pacific Northwest, including Mount St. Helens and Mount Rainier.

These rogue layers puzzled early researchers who found the ash in unexpected locations and who recognized that their chemical composition differed from rocks at the volcano they were studying. By carefully mapping the thickness of each ash layer, geologists were able to see that the Yn ash layer thickened away from Mount Rainier and thereby were able to trace the ash and pumice to its source—Mount St. Helens. They confirmed their hypothesis, thereby matching the chemical composition of the tephra layers with their volcanic origin.

Far-traveled tephra from Mount 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.

Tephra Explorer continued….



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.***

Side Bar #1 What is an Isopach?

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.

Side Bar #2 How Do Geologists Name Tephra Layers at Mount St. Helens?

At Mount St. Helens, tephra layers are named using letters of the alphabet (Tephra T, Tephra Y, Tephra C, etc.). The letters are not in alphabetical order because when geologists first studied tephra layers at Mount St. Helens, they did not know how many layers they would find. They named the layers after physical characteristics such as color. For example: Tephra B for brown, Tephra W for white, and Tephra Yn for yellow.

Tephra Explorer continued….

Procedure

Exploring Tephra Layers at Mount St. Helens

Determine the origin of tephra layers on the flanks of Mount St. Helens 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 northeast side of Mount St. Helens National Volcanic Monument.

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 copies of the student pages "***Ash Fall Compass"*** and ***"Make Your Own Tephra Isopach Map."***

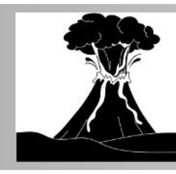
2. ***Begin the activity "Ash Fall Compass".*** Explain that the pie chart graphic reveals the percentage of time that the wind blows in directions over Mount St. Helens. Explain that wind directions are important to geologists because they influence where ash-fall is likely to occur when explosive volcanic eruptions create large ash columns. Have the students use the pie chart graphic to answer the questions on the worksheet.

3. ***Tell students that some tephra layers from Mount St. Helens fell on other volcanoes.*** Explain how a Mount St. Helens tephra layer on Mount Rainer 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 St. Helens. Encourage them to develop hypotheses about how wind direction influences the pattern of tephra fallout.

4. ***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.

5. ***"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 tephra isopach map is a standard tool used by geologists who study volcanic eruptions.

Tephra Explorer continued….



6. ***<u>Use overhead projection to display tephra maps 1 through 6</u>*** 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.

7. ***<u>Promote further discussion</u>*** 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.

8. ***<u>Return to the student page “Make Your Own Tephra Isopach Map.”</u>*** 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 St. Helens 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).

9. ***<u>Invite discussion</u>*** 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.

10. ***<u>Lead a discussion of energy transformation,</u>*** where rising tephra gains potential energy as it rises and loses energy as it falls.

Optional: Provide students with information about some Pacific Northwest tephra layers distributing the information on the teacher pages.

Adaptations

◆ ***<u>Students use protractors with your study of tephra layers.</u>*** 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.

Tephra Explorer continued….

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.

◆ ***Students complete isopach maps from the "Tephra Explorer" activity in "Living with a Volcano in Your Backyard – An Educators Guide to with Emphasis on Mount Rainier.***

1. Students compare and contrast isopach map data from Mount St. Helens and Mount Rainier to determine which volcano poses a greater tephra fall hazard.

2. Students answer the following questions:

a. Which volcano produced the deepest tephra deposits, Mount Rainier or Mount St. Helens?

b. Which volcano's ash fall traveled the furthest, Mount Rainier or Mount St. Helens?

c. Which volcano poses the greatest ash fall hazards to surrounding communities if it were to erupt, Mount Rainier or Mount St. Helens?

◆ ***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."

Tephra Layers

- Cinnamon - .3 cm tephra from volcano far away
- Decorative sprinkles - .4 cm tephra from volcano far away
- Cornmeal - 3 cm tephra from a large eruption
- Flour - 6 cm tephra from a large eruption far away
- Sugar - 15 cm tephra from a large eruption far away

Tephra Explorer continued….

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

Clynne M.A., Calvert A.T., Wolfe EE.W, Evans R.C. Fleck R.J. Lanphere M.A., 2008, The Pleistocene Eruptive History of Mount St. Helens, Washington, from 300,000 to 12,800 Years before Present, U.S. Geological Survey Professional Paper 1750, 611 p.

Sarna-Wojcicki A.M., Shipley S., Waitte Jr. R.B., Dzurisin D., Wood S., 1981 Areal Distribution Thickness, Mass, Volume, and Grain Size of Air-Fall Ash from the Six Major Eruptions of 1980, U.S. Geological Survey Professional Paper 1250, pages 577-588

Mullineaux, D.R., 1996, Pre-1980 Tephra-Fall Deposits Erupted from Mount St. Helens, Washington, U.S. Geological Survey Professional Paper 1563, pages 1-2, 4, 11, 19, 45, 56, 60

Clynne M.A., Ramsey D.W., Wolfe E.W., 2005, Pre-1980 Eruptive History of Mount St. Helens, Washington, U.S. Geological Survey Fact Sheet 2005-3045, 1 p.

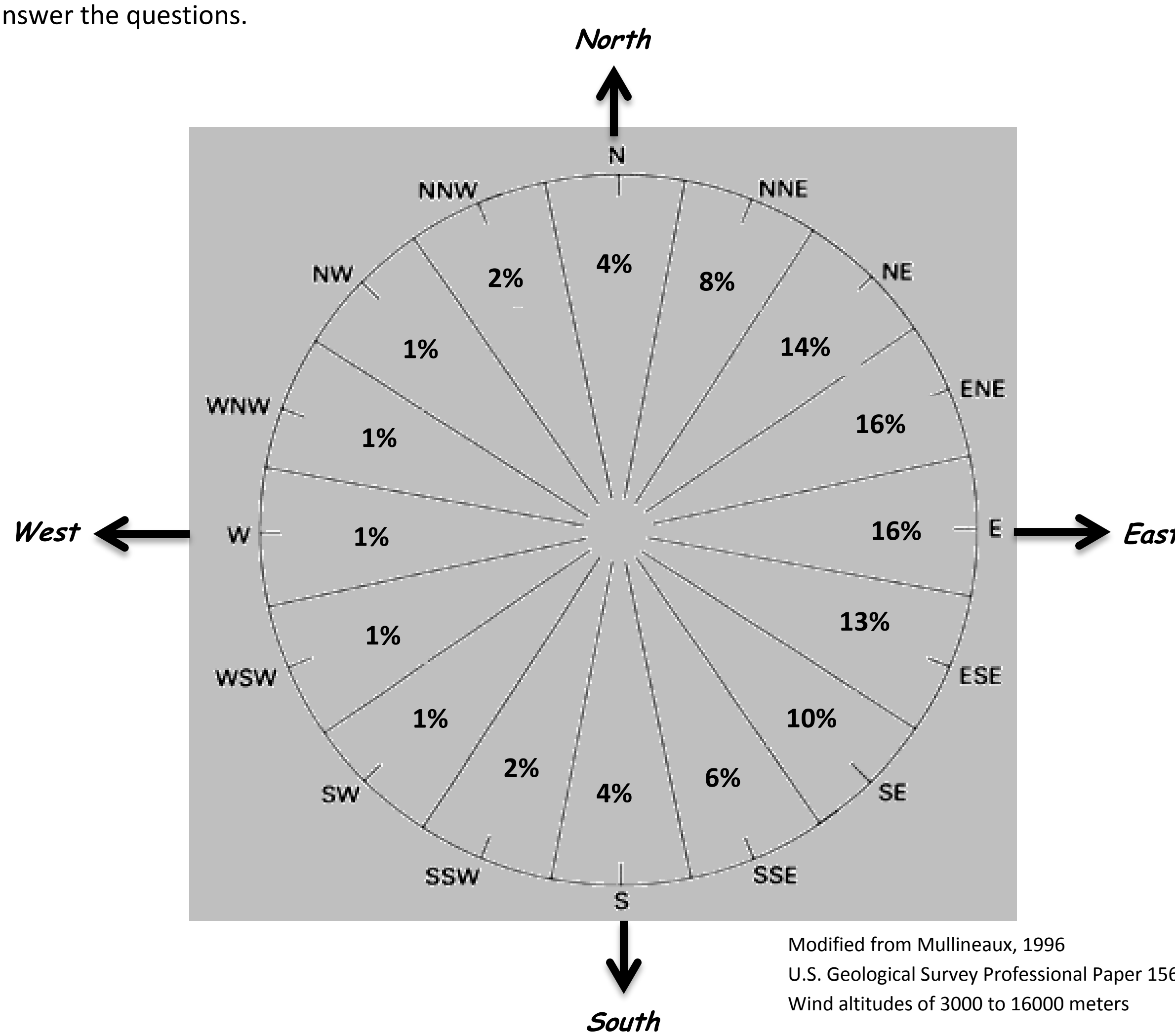
Mullineaux, D.R., 1974, Pumice and other pyroclastics in deposits at Mount Rainier National Park: U.S. Geological Survey Bulletin 1326, 83 p.

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

Student Page

Ash Fall Compass

Directions: Ash Plumes travel the direction the wind blows. The compass below shows the percentage of time the wind blows in specific directions over Mount St. Helens. Use the compass to answer the questions.



Modified from Mullineaux, 1996
U.S. Geological Survey Professional Paper 1563
Wind altitudes of 3000 to 16000 meters

Compare the percentages and list six directions an ash plume is ***<u>most likely</u>*** to travel in the event of an explosive eruption of Mount St. Helens. ____
____

Add the six greatest percentages together. What is the total percentage of time the wind blows in these directions? ____

Where would you expect to find the majority of tephra deposits from Mount St. Helens and why?
____
____

Teacher Page

Ash Fall Compass

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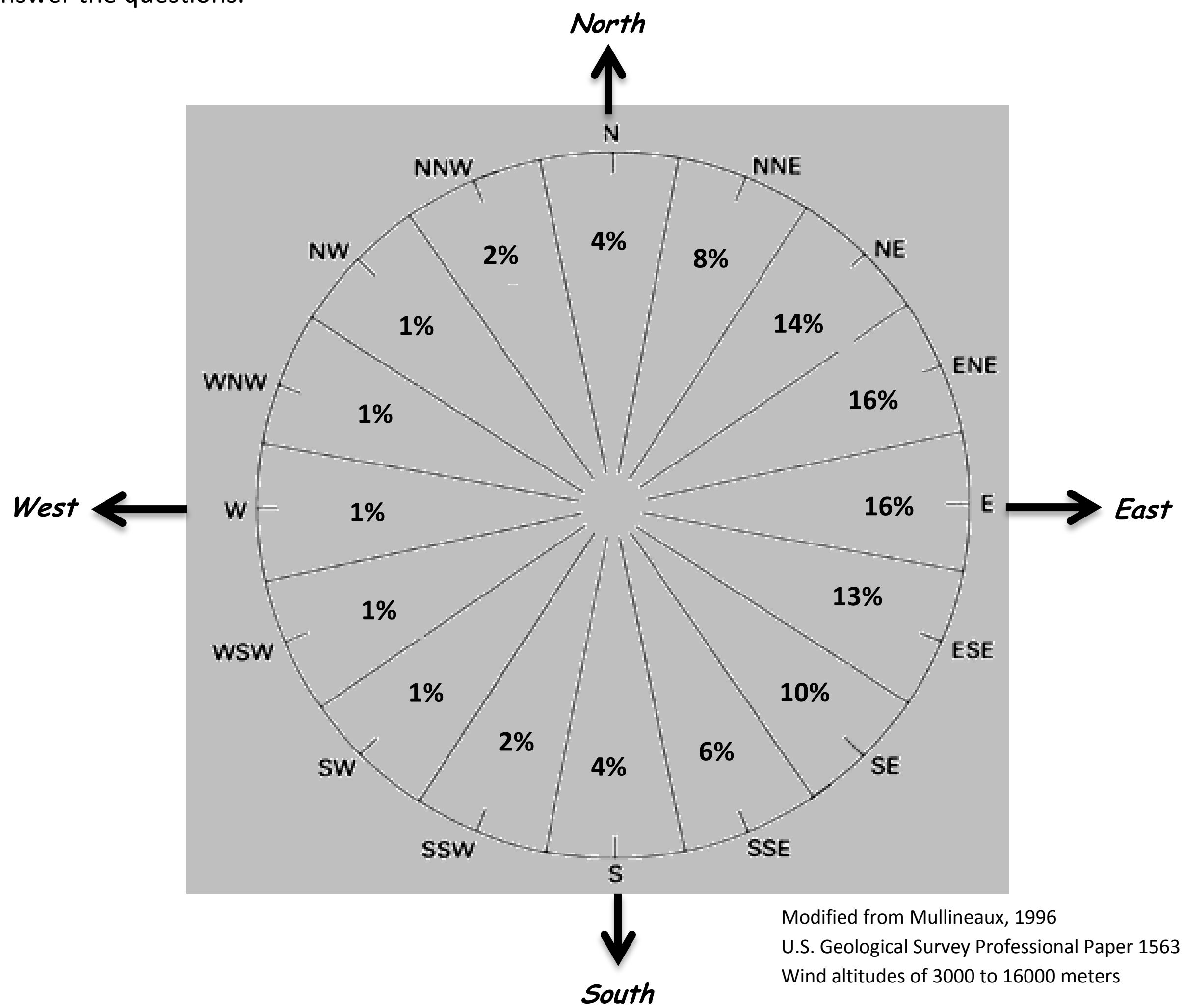


Modified from Mullineaux, 1996
U.S. Geological Survey Professional Paper 1563
Wind altitudes of 3000 to 16000 meters

Compare the percentages and list six directions an ash plume is ***most likely*** to travel in the event of an explosive eruption of Mount St. Helens. ***North-Northeast (8%), northeast (14%), East-Northeast (16%), East (16%), East-Southeast (13%), Southeast (10%).***__________________________________

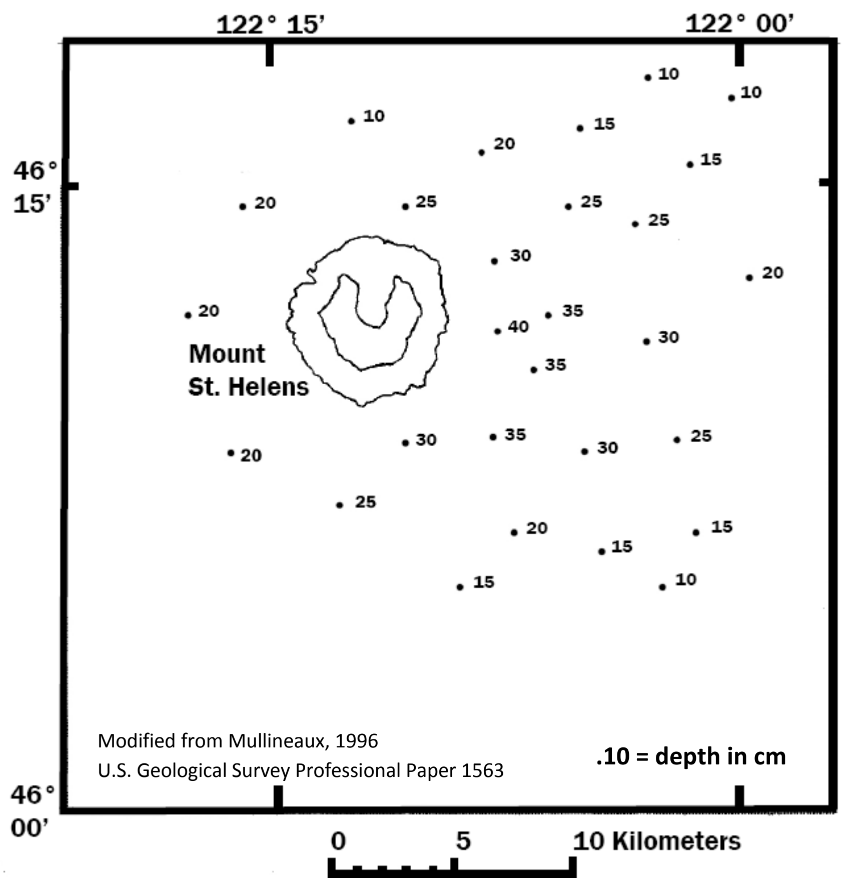
Add the six greatest percentages together. What is the total percentage of time the wind blows in these directions? ***77% of the time the wind blows in these six directions.***____________________

Where would you expect to find the majority of tephra deposits from Mount St. Helens and why? ***Most tephra deposits from Mount St. Helens lie in the 180° sector east of a north-south line through the volcano because of prevailing wind patterns. Wind records indicate 87% of the tephra deposits should be expected to be found in that 180°sector.***

Student Page

Name: ____________________

Make Your Own Tephra Isopach Map

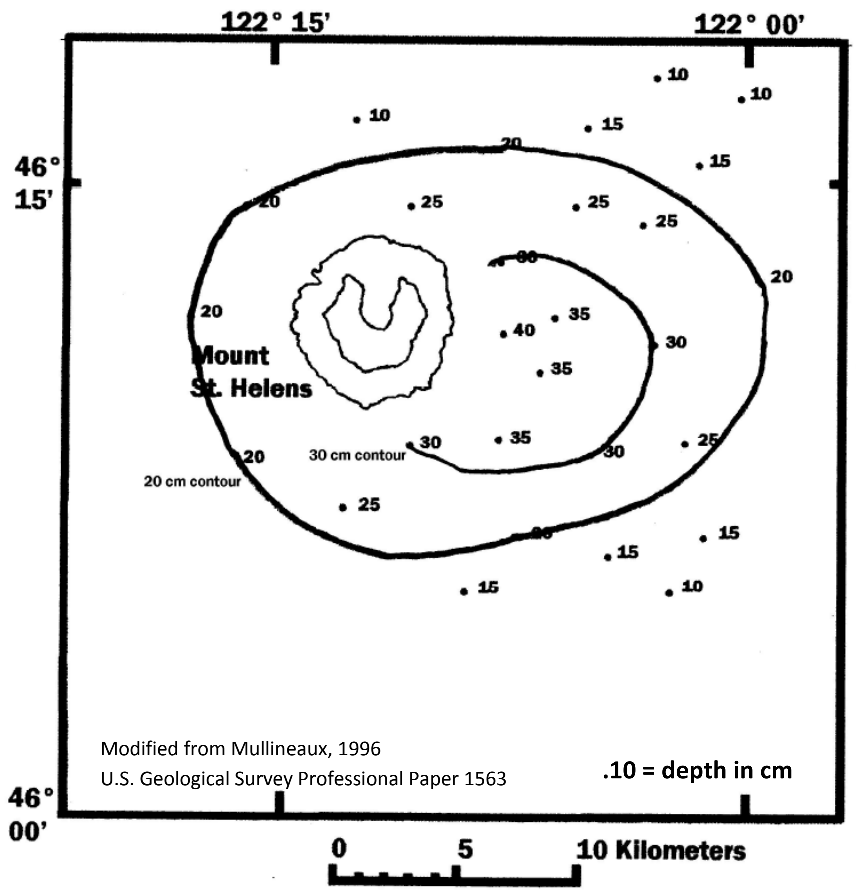


1. Develop a hypothesis that explains how the thickness of tephra fall will vary with increasing distance from the volcano.

2. Draw circles (contours) to separate the 10's from the 15's, the 15's from the 20's, the 20's from the 25's, etc. These contours indicate areas of equal tephra thickness and are known as isopachs.

Teacher Page

Make Your Own Tephra Isopach Map



1. Develop a hypothesis that explains how the thickness of tephra fall will vary with increasing distance from the volcano.
ANSWER: The deposit will be thickest close to the volcano and thinner farther away Topography can also play a role as deposits slough off slopes.

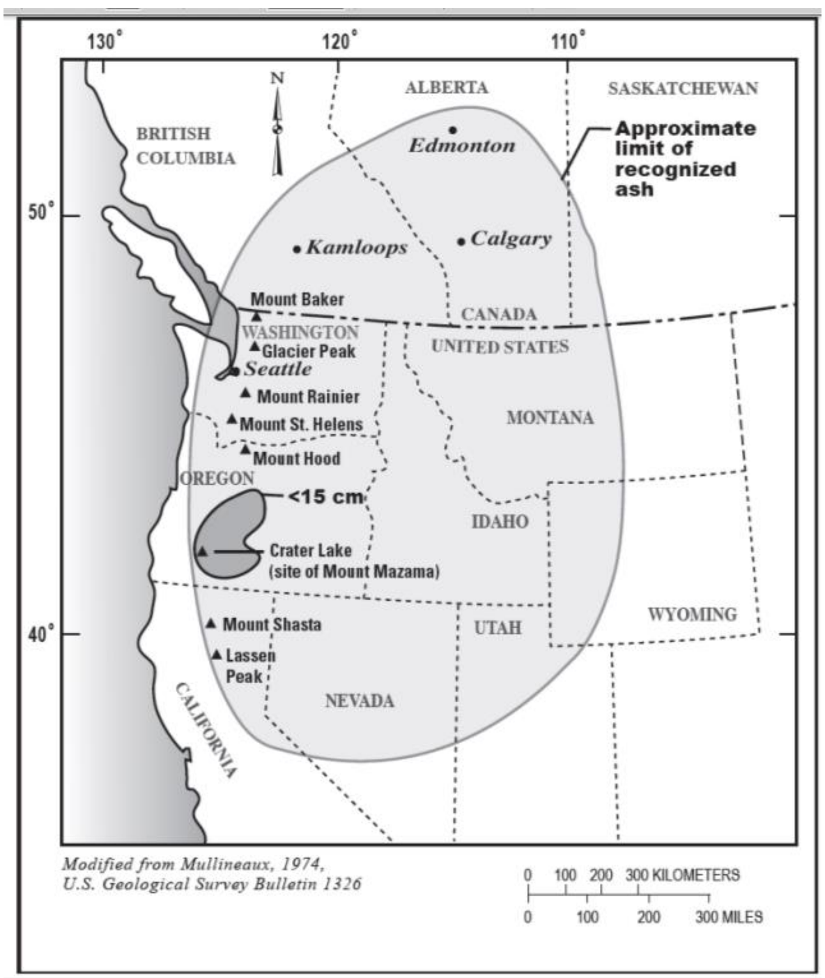
2. Draw circles (contours) to separate the 10's from the 15's, the 15's from the 20's, the 20's from the 25's, etc. These contours indicate areas of equal tephra thickness and are known as isopachs. ***ANSWER: See Map Above***

Student Page

Name: ___________________

Exploring Tephra Layers at Mount St. Helens

Instructions: 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 Here:

Note the oval shape and depth of the fallout. Does this indicate that the prevailing winds were fast and narrowly focused, or slow and dispersed? Explain your answer.

Student Page

Name: ___________________

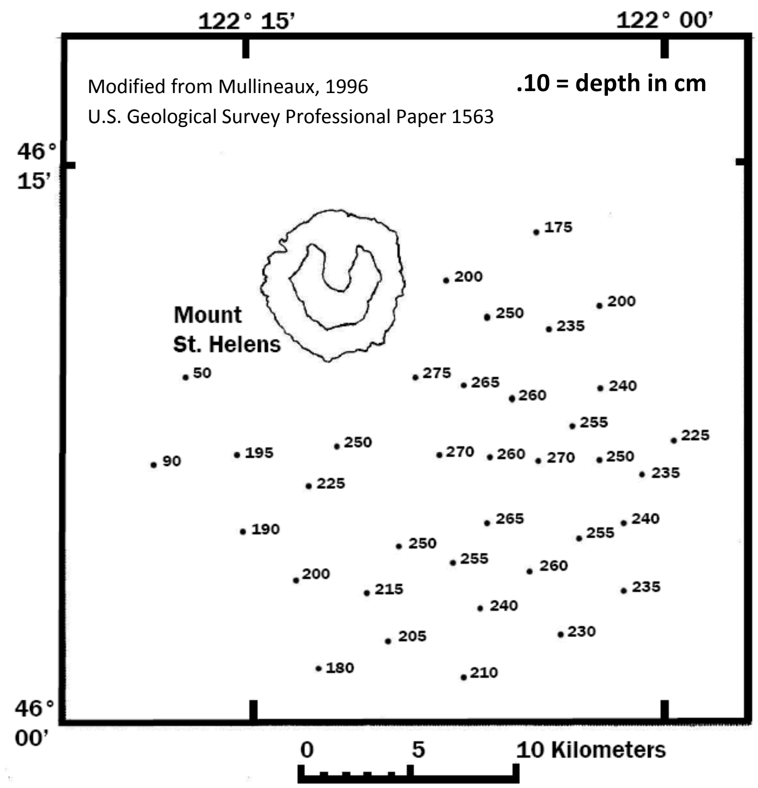
Exploring Tephra Layers at Mount St. Helens

Instructions: Identify the wind direction at the time of the tephra eruption and the probable source volcano.

Tephra Map 2

Wind Direction: ________

Source Volcano: ________



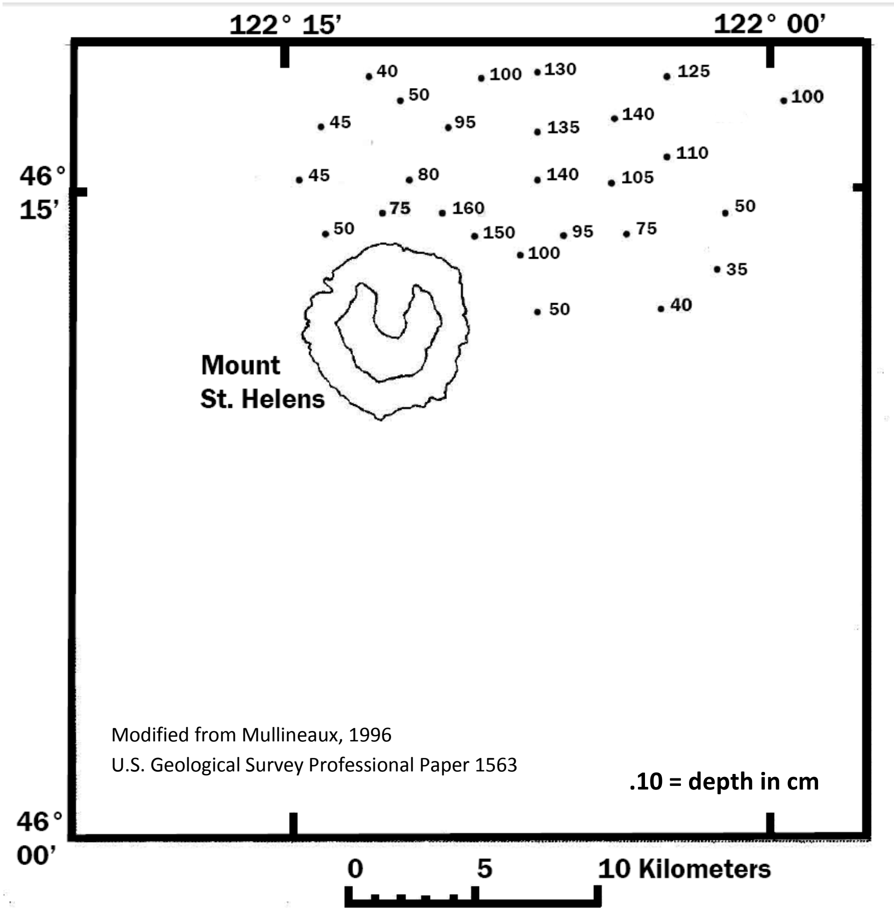
Explain Your Answer Here:

Student Page

Name: ___________________

Exploring Tephra Layers at Mount St. Helens

Instructions: Identify the wind direction at the time of the tephra eruption and the probable source volcano.



Tephra Map 3A

Wind Direction: ________

Source Volcano: ________

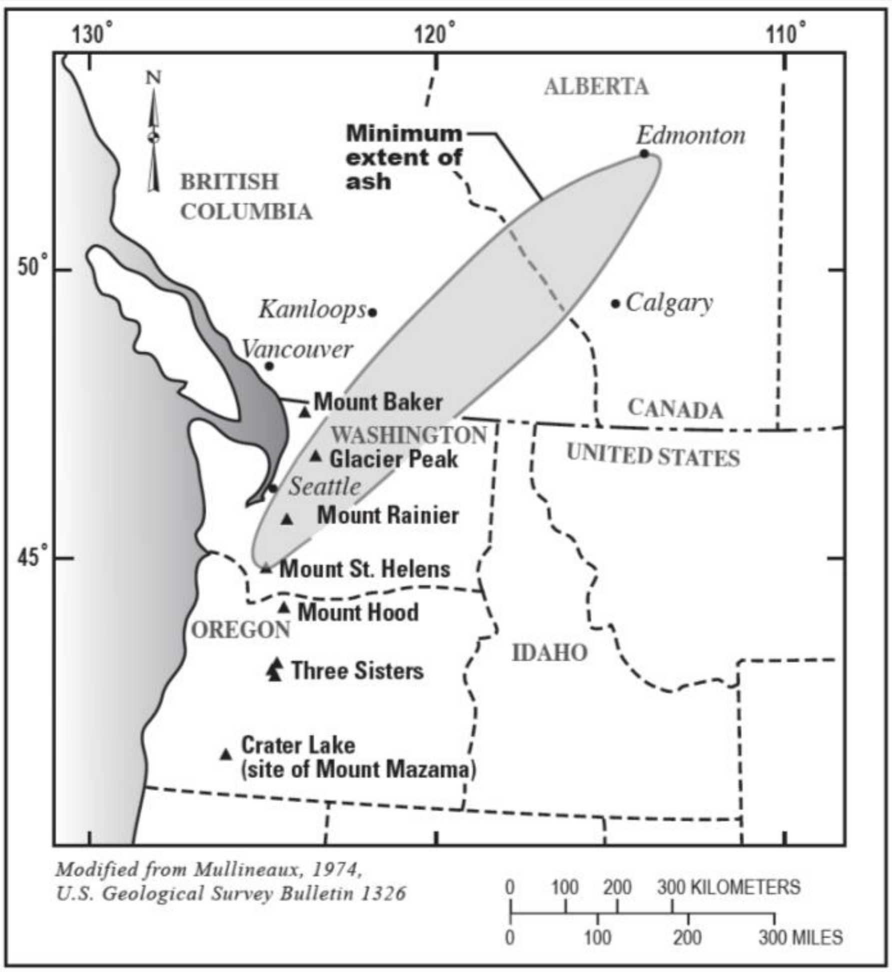
Explain Your Answer Here:

Student Page

Name: ____________________

Exploring Tephra Layers at Mount St. Helens

Instructions: Tephra map 3B reveals the total area impacted by ash fall in map 3A. List the volcano(s) that received tephra deposits from the probable source volcano.



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

Tephra Map 3B

Volcano: ______________

Volcano: ______________

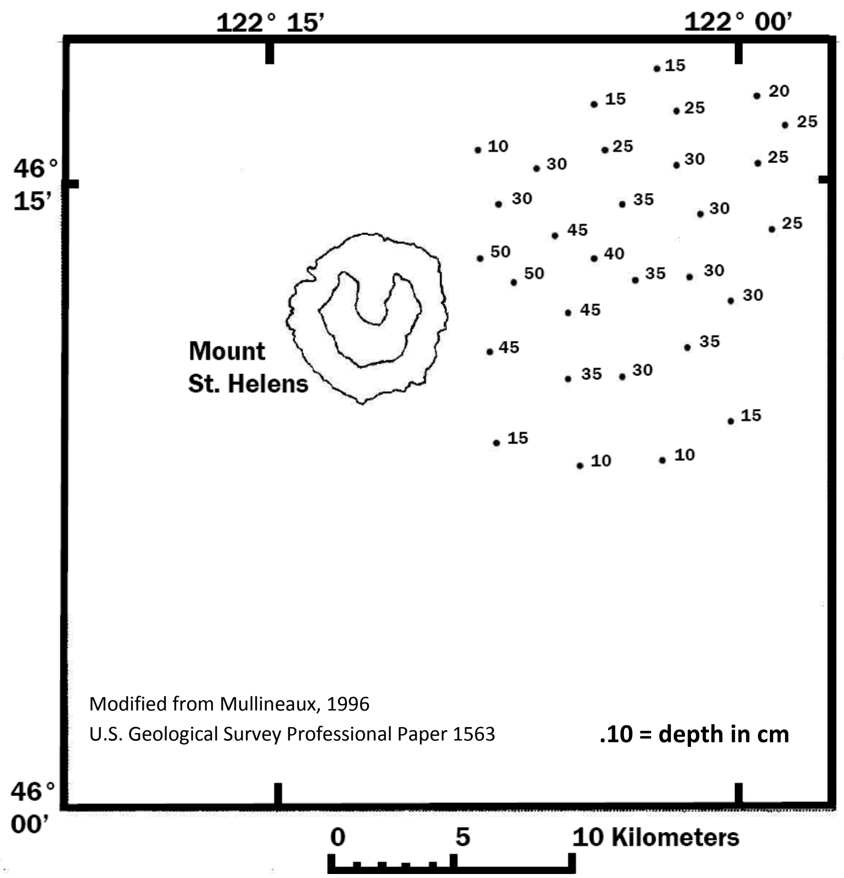
Explain Your Answer Here:

Student Page

Name: ____________________

Exploring Tephra Layers at Mount St. Helens

Instructions: Identify the wind direction at the time of the tephra eruption and the probable source volcano.



Modified from Mullineaux, 1996
U.S. Geological Survey Professional Paper 1563

Tephra Map 4

Wind Direction: ________

Source Volcano: ________

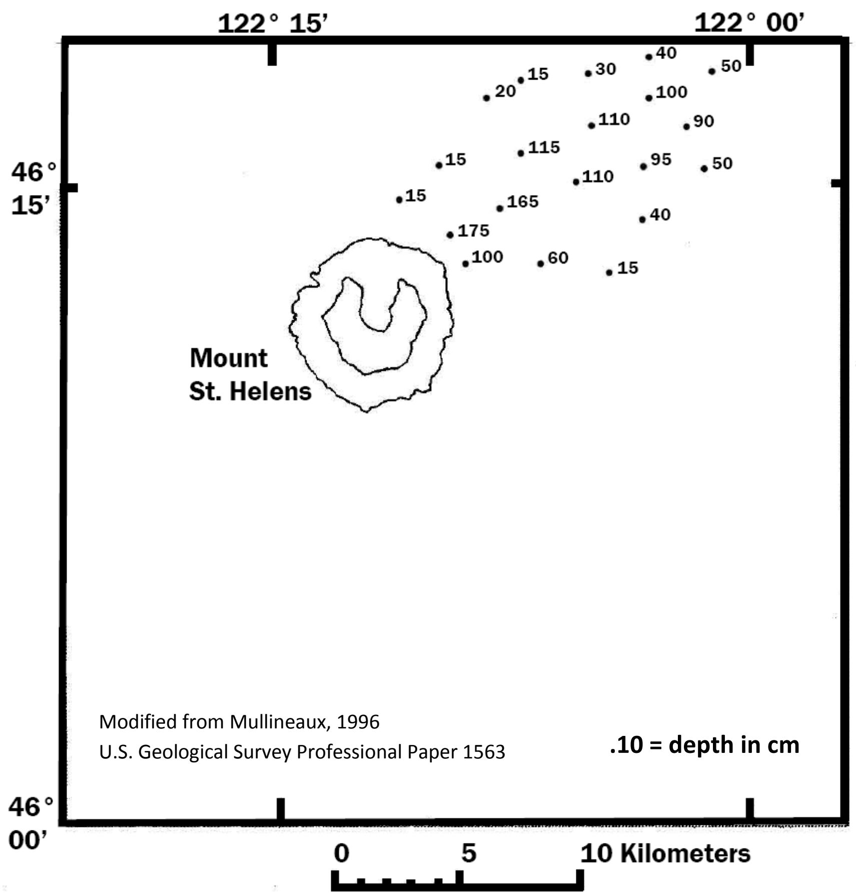
Explain Your Answer Here:

Student Page

Name: ___________________

Exploring Tephra Layers at Mount St. Helens

Instructions: 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 Here:

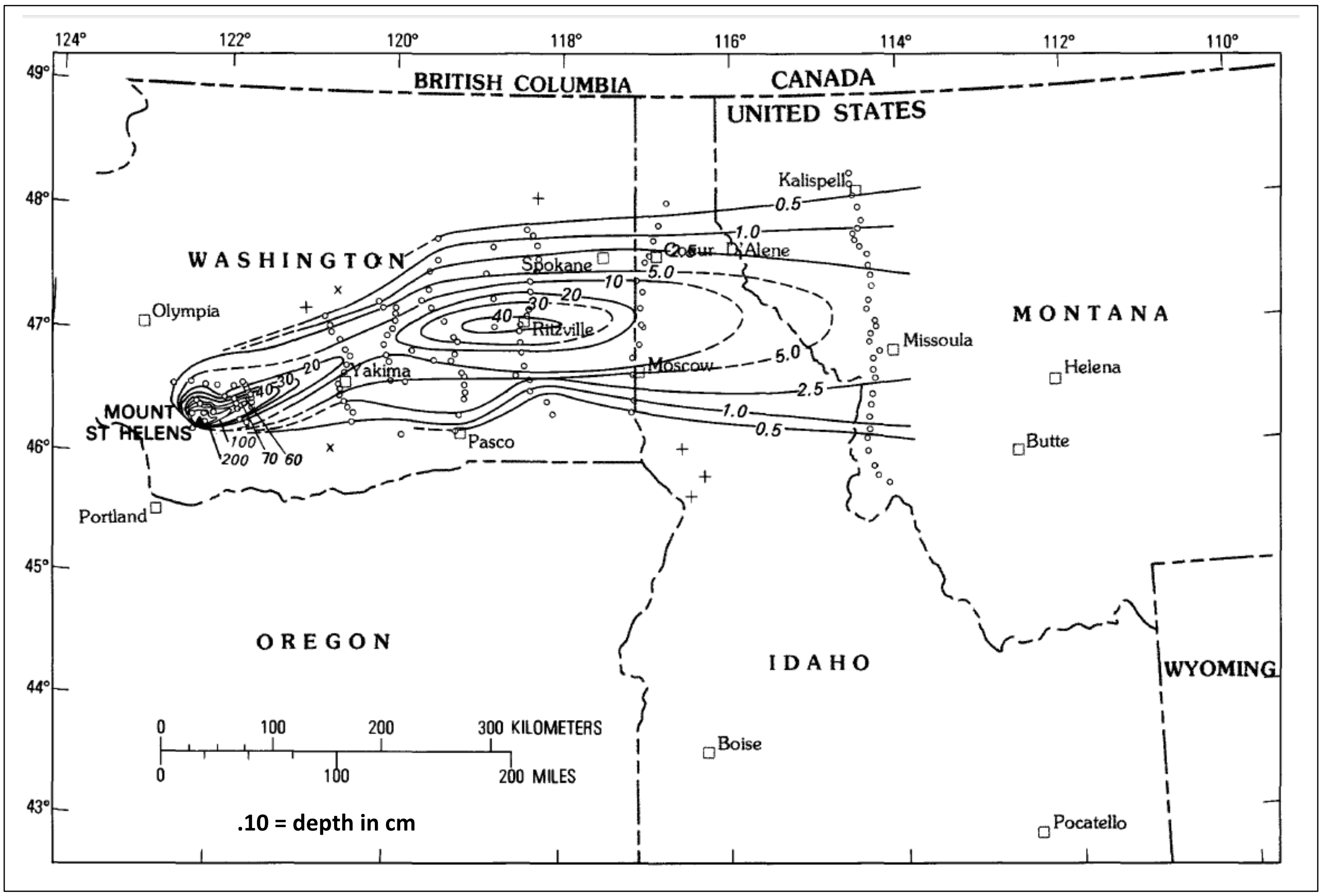
Note the shape and depth of the fallout. Does this indicate that the prevailing winds were fast and narrowly focused, or slow and dispersed? Explain your answer.

Student Page **Name: ________________**

Exploring Tephra Layers at Mount St. Helens

Instructions: Use this isopach map of the May 18, 1980 eruption of Mount St. Helens to determine the thickness of ash deposits in northwest communities.

Tephra Map 6



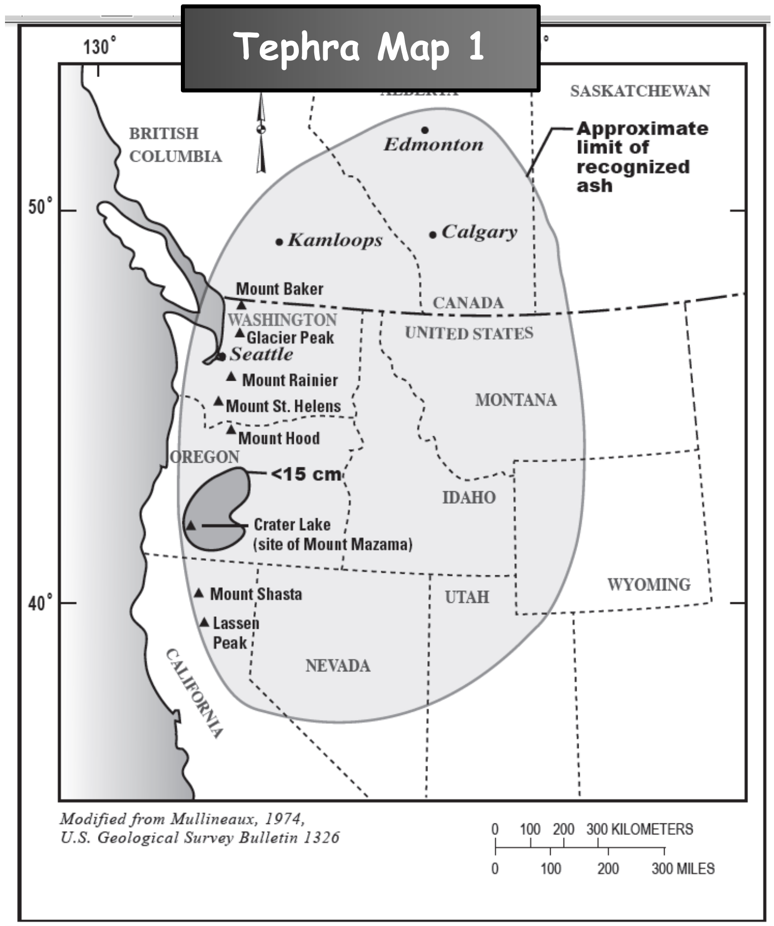
Yakima, Washington _______ **Ritzville, Washington _______** **Portland, Oregon _______**

Pasco, Washington ________ **Moscow, Idaho ________** **Missoula, Montana __________**

Teacher Page

Exploring Tephra Layers at Mount St. Helens

Instructions: Identify the wind direction at the time of the tephra eruption and the probable 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 350 kilometers (200 miles) south of Mount St. Helens, during the largest known eruption in the Cascades in 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 St. Helens, tephra layer O is about five centimeters thick (two inches). The widespread fallout pattern suggests that prevailing wind patterns during this eruption were slow and dispersed.***

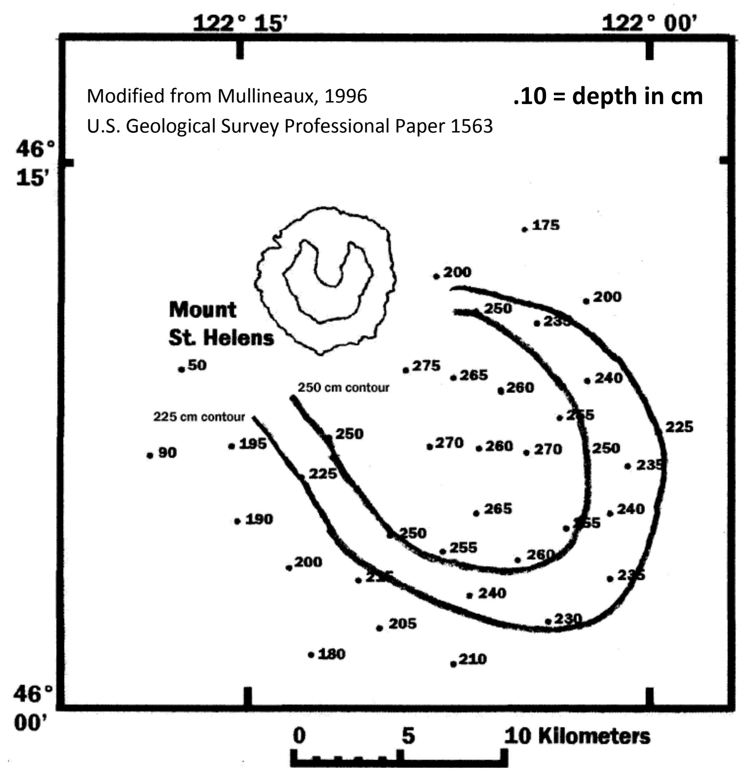
Teacher Page

Exploring Tephra Layers at Mount St. Helens

Instructions: Identify the wind direction at the time of the tephra eruption and the probable source volcano.

Modified from Mullineaux, 1996
U.S. Geological Survey Professional Paper 1563

Tephra Map 2



Tephra C

<u>Wind Direction:</u> From North-Northwest

<u>Source Volcano:</u> Mount St. Helens

<u>Age:</u> 47,400 years ago

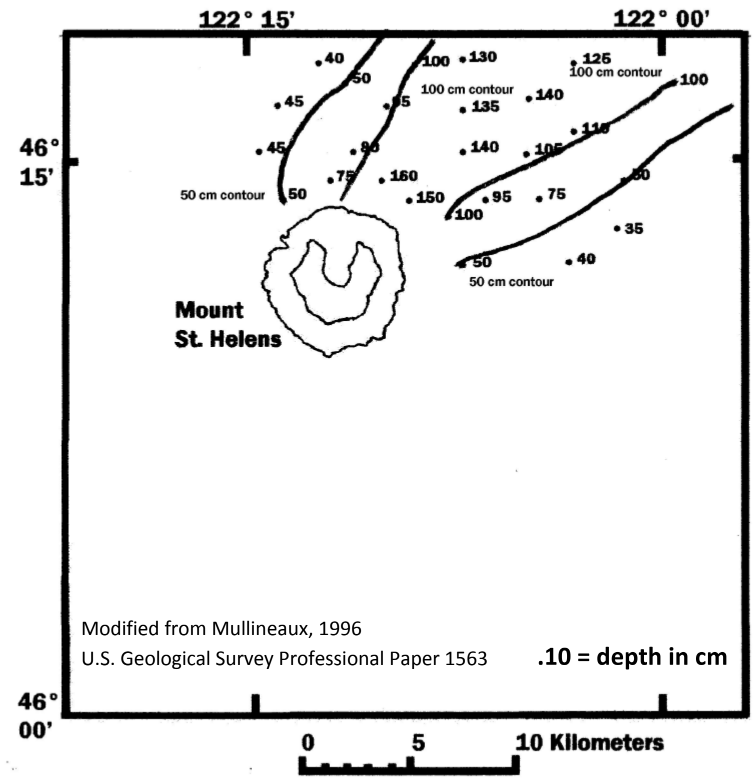
<u>Description:</u> The major pumice layers in tephra set C are clearly records voluminous plinian-type eruptions. Tephra set C was produced during the Ape Canyon stage, which began about 50,000 years ago and continued until about 36,000 years ago. The set contains at least two large-volume dacitic pumice layers and other layers of smaller volume. One contains the largest volume of tephra eruptions known from Mount St. Helens and has been identified in eastern Washington and Nevada as far as 300 and 700 km (185 to 435 miles) from the volcano.

Teacher Page

Exploring Tephra Layers at Mount St. Helens

Instructions: Identify the wind direction at the time of the tephra eruption and the probable source volcano.

Tephra Map 3A



Tephra Yn :

<u>Wind Direction</u>: ***From Southwest***

<u>Source Volcano:</u> ***Mount St. Helens***

<u>Age:</u> ***3,700-3,800 years ago***

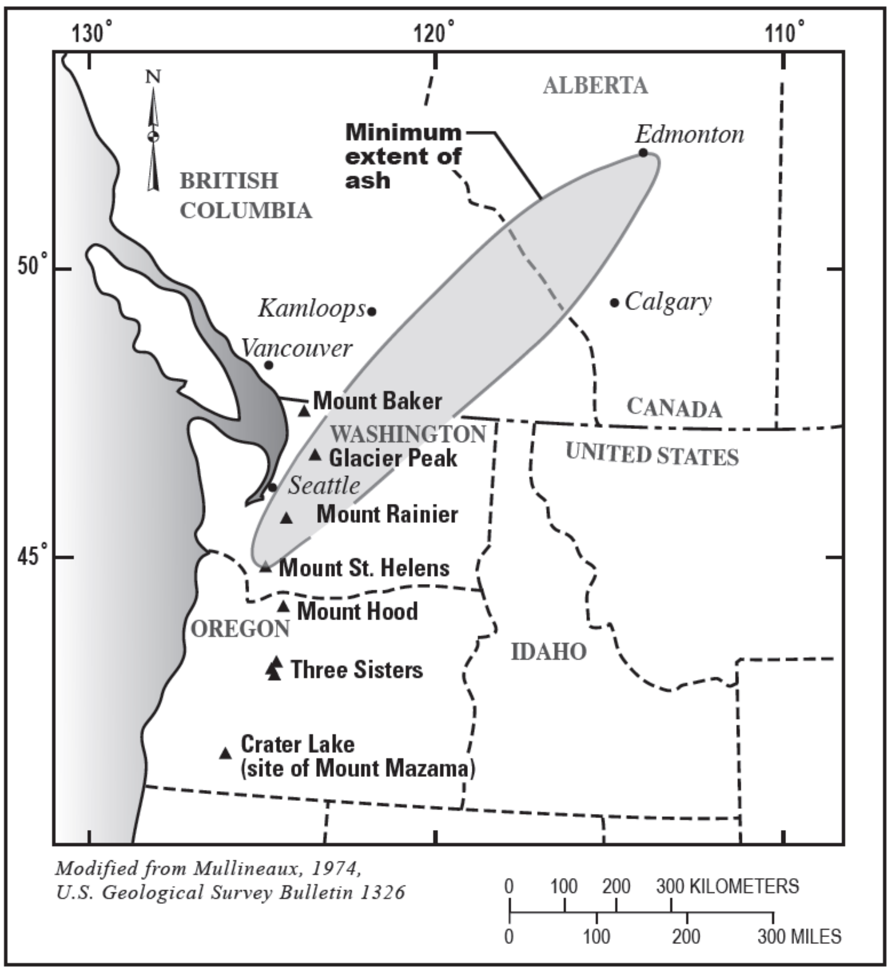
<u>Description:</u> ***Between 3,700 and 3,800 years ago, an enormous eruption at Mount St. Helens formed tephra Yn, a thick layer of pale-brown to yellowish-gray pumice and ash deposits. This eruption was many times larger than the well-known eruption of May 18, 1980. Near the volcano, the Yn layer is 100 to 200 centimeters (39 to 78 inches) thick. It is still up to 46 centimeters (18 inches) thick at Mount Rainier 80 kilometers (50 miles) northeast. Geologists studying at Mount Rainier in the 1970's carefully mapped the thickness of the Yn layer and discovered that it thickened away from Mount Rainier, tracing the ash and pumice to its source—Mount St. Helens.***

Teacher Page

Exploring Tephra Layers at Mount St. Helens

Instructions: Tephra map 3B reveals the total area impacted by ash fall in map 3A. List the volcano(s) that received tephra deposits from the probable source volcano.

Tephra Map 3B



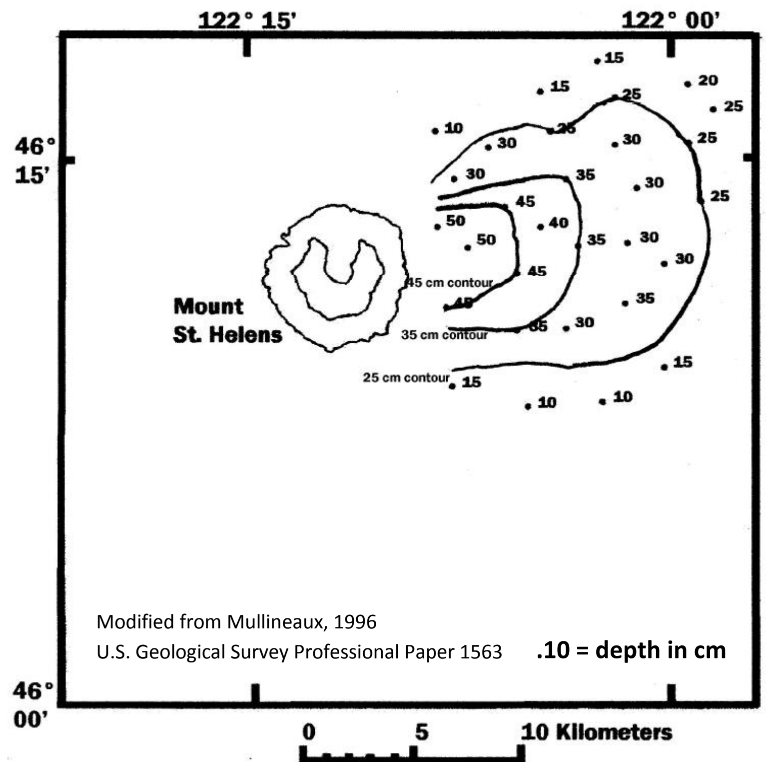
ANSWER: ***Tephra from the Yn eruption of Mount St. Helens was deposited on Mount Rainier and Glacier Peak. This eruption was possibly the most voluminous in Mount St. Helens history. It was about four times larger than the 1980 eruption.***

Teacher Page

Exploring Tephra Layers at Mount St. Helens

Instructions: Identify the wind direction at the time of the tephra eruption and the probable source volcano.

Tephra Map 4



Tephra P:

Wind Direction**:** ***From West-Southwest***

Source Volcano: ***Mount St. Helens***

Age: ***2,900-2,500 years ago***

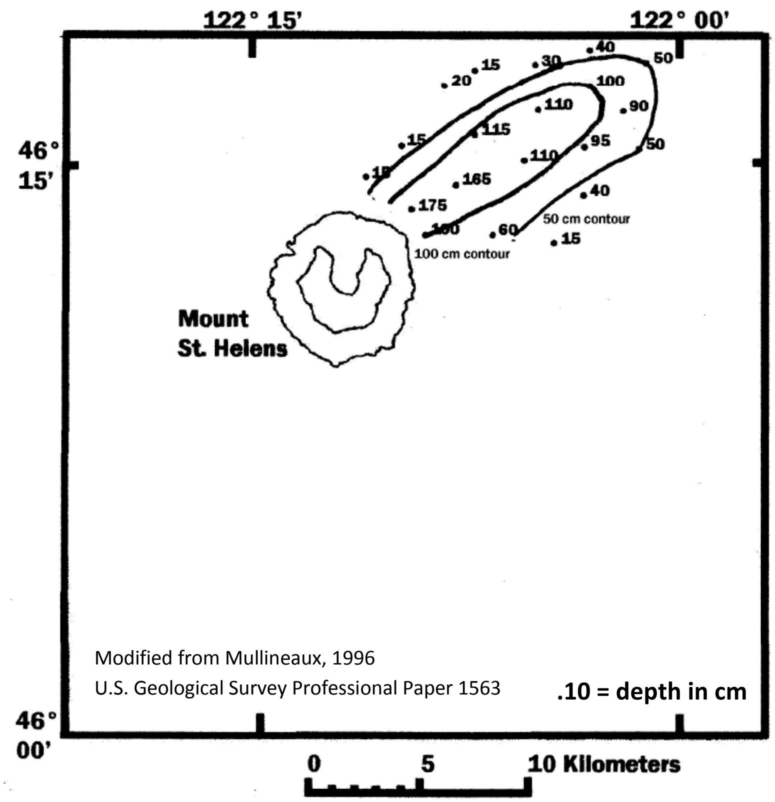
Description: ***The maximum known thickness of layer P tephra is about 50 centimeters (19 inches), at the northeast base of the mountain 5 kilometers (5 miles) from the summit. The actual thickness is probably closer to 100 centimeters (19 inches), but ash-size tephra near the volcano is difficult to distinguish. At 8 kilometers (5 miles) northeast of the volcano set P is as thick as 40 centimeters (16 inches), and at 8 km to the southeast it is as thick as 30 centimeters (12 inches).***

Teacher Page

Exploring Tephra Layers at Mount St. Helens

Instructions: Identify the wind direction at the time of the tephra eruption and the probable source volcano.

Tephra Map 5



Tephra W:

<u>*Wind Direction*</u>: ***From Southwest***

<u>*Source Volcano:*</u> ***Mount St. Helens***

<u>*Age:*</u> **1480 A.D.**

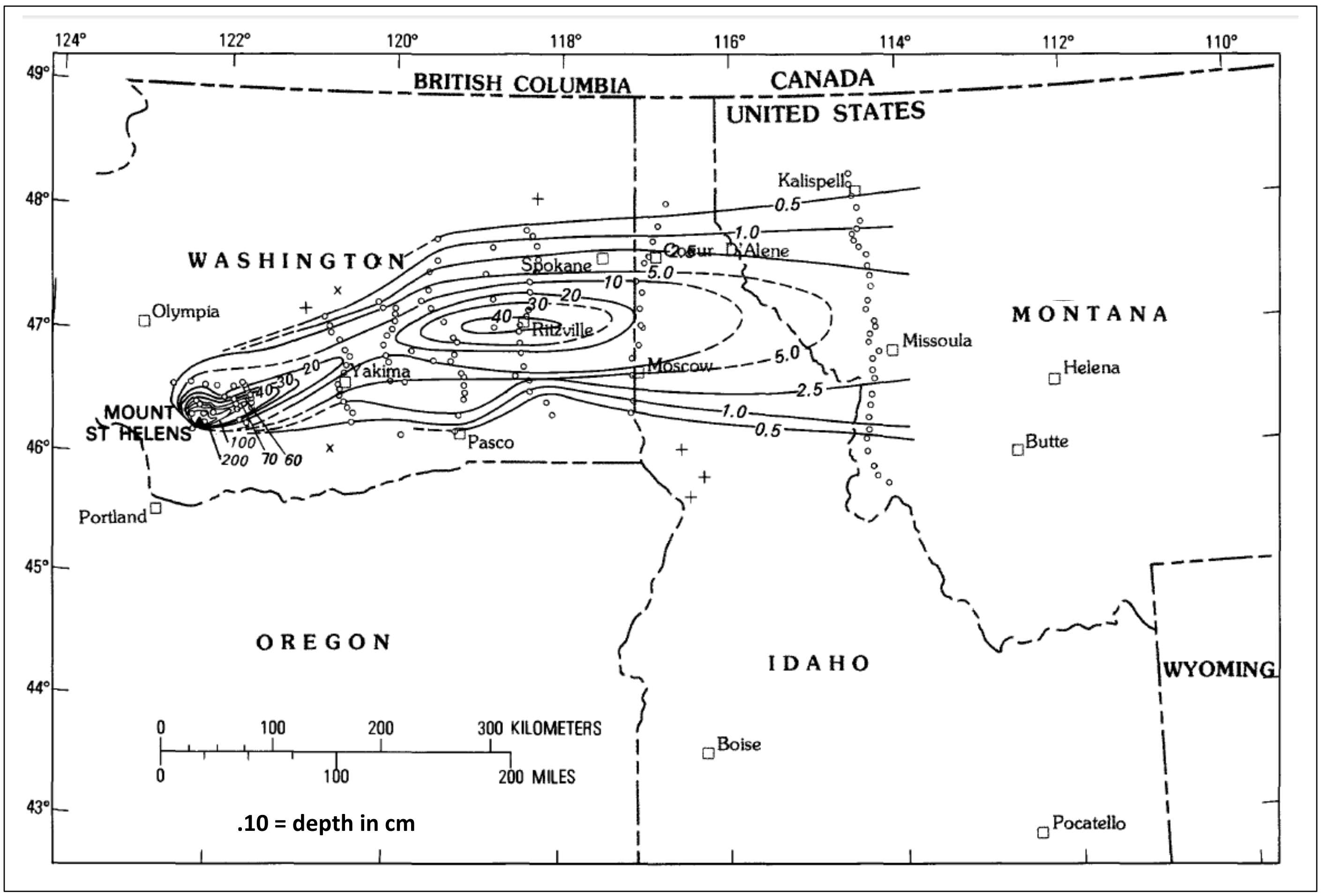
<u>*Description:*</u> ***Tree-ring studies indicate that the eruption that produced tephra layer Wn occurred after the growing season of A.D. 1479 and before the growing season of A.D. 1480 This tephra layer Wn was transported towards the northeast by winds onto the slopes of Mount Rainier 80 kilometers (50 miles) away and coarse gray–white ash deposits can be found 500 kilometers (310 miles) to the north. This eruption also formed small lava flows and pyroclastic flows on the slopes of Mount St. Helens. The fallout pattern and narrow, but deep deposit, suggests that wind patterns were high and focused during this eruption.***

Teacher Page

Exploring Tephra Layers at Mount St. Helens

Instructions: Use this isopach map of the May 18, 1980 eruption of Mount St. Helens to determine the thickness of ash deposits in northwest communities.

Tephra Map 6



Yakima, Washington ***10 mm*** **Ritzville, Washington** ***40 mm*** **Portland, Oregon** ***0 mm***

Pasco, Washington ***0.5 mm*** **Moscow, Idaho** ***5.0 mm*** **Missoula, Montana** ***2.5 mm***

Map of the Cascades

U.S. Geological Survey