

# Oregon 4-H Earth Science Project

Leaders Guide



4-H 340L

Oregon State  
UNIVERSITY

Inside the Lava River Cave Passage. Photo by Dave Bunnell



## Contents

<b>Chapter 1. Oregon’s Geography—The Surface of Things</b>	<b>5</b>
Activity 1A—Mapping Oregon	8
Activity 1B—Weathering Away	14
<b>Chapter 2. The Blue Mountains—Islands and Old Sea Floors</b>	<b>17</b>
Activity 2A—Convection Currents	21
Activity 2B—Floating Densities	26
<b>Chapter 3. The Klamath Mountains</b>	<b>27</b>
Activity 3A—The Rock Cycle	29
Activity 3B—How Do Your Crystals Grow?	32
<b>Chapter 4. Creations of the Cretaceous</b>	<b>41</b>
Activity 4A—Sedimentary Rocks and the Preservation of Fossils	45
Activity 4B—Identifying Rocks and Minerals	47
<b>Chapter 5. The Exciting Eocene</b>	<b>51</b>
Activity 5A—Mountain Building: Folds and Faults	53
Activity 5B—Earthquakes!	59
<b>Chapter 6. Where Have all the Oreodonts Gone?</b>	<b>63</b>
Activity 6A—John Day Basin Timeline	69
Activity 6B—Be a Fossil Detective	73
<b>Chapter 7. Growing Mountains and Pouring Lava</b>	<b>75</b>
Activity 7A—Volcano Anatomy	78
Activity 7B—Formation of Igneous Rocks	80
<b>Chapter 8. Glacial Ice and Giant Floods</b>	<b>87</b>
Activity 8A—Oregon’s First People: Climate and Stone Tools	89
Activity 8B—Soil: A Stop Along the Rock Cycle	95
<b>Chapter 9. People on the Landscape</b>	<b>99</b>
Activity 9A—The Bridge of the Gods: Landslides and People	102
Activity 9B—Gold Mining in Oregon	107
<b>Appendix—Resources</b>	<b>114</b>

Revised April 2017 by Virginia (Thompson) Bourdeau. Original text by Virginia Thompson, Extension 4-H specialist, Oregon State University. Chapter 9 co-author Alex Bourdeau, U.S. Fish and Wildlife Service. The author wishes to thank the review team for its contributions: Dr. George W. Moore, OSU Department of Geosciences; Dr. J. Herbert Huddleston, OSU Extension soil science specialist; Ken Emo and Marilyn Moore, Extension 4-H agents; Fay and Sherm Sallee, Tom Thompson, Ryan Collay, Patti Ball, and Alex Bourdeau, 4-H volunteers.

Cover photo of the Lava River Cave Passage By Dave Bunnell (Own work) [CC BY-SA 4.0 (<http://creativecommons.org/licenses/by-sa/4.0/>)], via Wikimedia Commons

Illustrations by Erik Simmons, © Oregon State University. Photos by Virginia Bourdeau, © Oregon State University



## Introduction

Welcome to the Oregon 4-H Earth Science project. This leader guide is designed for use in traditional 4-H clubs and camps and also for school enrichment and after-school delivery. Please be sure to go to the Oregon 4-H Geology web page for additional interactive tutorials, videos, and other resources to use with the activities in this guide: <http://oregon.4h.oregonstate.edu/projects/natural-science/geology>

For ease of reading, the word “leader” has been used throughout the text to represent leaders, counselors, teachers, program assistants, and others who can lead these activities with youth. Leaders will find many opportunities to integrate each chapter’s activities with the *4-H Geology Member Guide (4-H 340)*, which focuses on creating a rock and mineral collection. The 4-H Geology Advancement Program in the *4-H Geology Member Guide* provides a series of additional learning experiences. Advancement programs are designed for learners to establish their own speed of learning and to select skills and personal development options as they go through the 4-H experience. Leaders also need to obtain a copy of *A Description of Some Oregon Rocks and Minerals (4-H 3401L)*.

The activities in this leader guide provide a basis for youth to design original research and develop educational displays or presentations. In addition to displaying rock collections at county and state fairs, youth may display a Science Inquiry Investigation poster. See more information on this at the Oregon 4-H Science and Technology page under Science Inquiry Training at <http://oregon.4h.oregonstate.edu/projects/sci-tech-eng>.

Each chapter in this leader guide contains a Background section followed by two activities. Leaders should select or adjust the activities to meet their learners’ ages and abilities by reviewing the Background material prior to each session.

Most of the materials needed for the activities are easy to obtain. The mineral test kits needed in Activity 4B, the rock and mineral samples needed in Activities 4B and 7B, and the salol crystals needed in Activity 7B are notable exceptions. Order these items in advance from a science supply company. Additional information on suppliers appears in the Appendix.

Many chapters list field trip locations that support learners’ understanding of the Oregon-specific information in the Background. The Oregon 4-H Junior Master Naturalist web page (<http://oregon.4h.oregonstate.edu/projects/nat-sci/junior-master-naturalist>) has six units covering Oregon watersheds, forests, animals, and marine habitats, including field trip information, which can be used to enrich a geology field experience. In addition, links are provided to information on eight Oregon ecoregions.

Please use the resources on the Oregon 4-H Challenge and Adventure web page (<http://oregon.wh.oregonstate.edu/programs/outdoor>), under the headings Forms and Challenge and Adventure Activities, for resources and 4-H program requirements for planning a day hike, camping, backpacking, or other outdoor activities.

When providing leadership for a group in the outdoors, safety is the primary concern. Leaders should keep informed of current road and trail conditions and watch for extreme weather events. Staff with the state parks, U.S. Forest Service (USFS), Bureau of Land Management (BLM), and National Parks and Monuments are happy to assist with planning



trips. Information on contacting land-management agencies for locations of field trips suggested in the text is in the Appendix.

The period of time and the complexity of Oregon's geologic history are impossible to completely capture in one curriculum. Leaders may wish to purchase one or more key resources for going beyond the lessons. Some of these will also assist in planning field trips.

*Geology of Oregon* (Sixth Edition), Elizabeth Orr, William Orr, and Ewart M. Baldwin, Oregon State University Press, 2012.

*Hiking Oregon's Geology* (Second Edition), Ellen Morris Bishop and John Eliot Allen, The Mountaineers, 2004.

*In Search of Ancient Oregon, a Geological and Natural History*, Ellen Morris Bishop

*Oregon Fossils*, (Second Edition), Elizabeth Orr, William Orr. Oregon State University Press, 2009

Oregon Department of Geology and Mineral Industries, Portland, OR <http://www.oregongeology.org/sub/default.htm>

- Interactive Geologic Map <http://www.oregongeology.org/geologicmap/>
- Oregon a Geologic History, <http://www.oregongeology.org/sub/publications/IMS/ims-028/index.htm>

*Roadside Geology of Oregon*, David D. Alt and Donald W. Hyndman, Mountain Press, 1998.

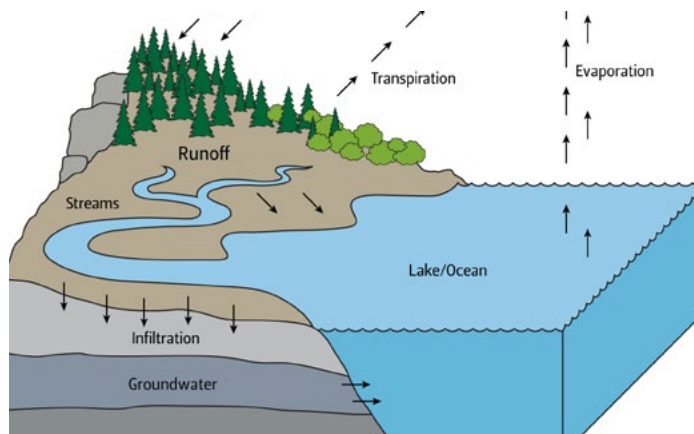


# 1. Oregon's Geography—The Surface of Things

## Objectives

### LEARNERS WILL BE ABLE TO:

- Locate and name some of Oregon's major geologic provinces
- Locate and name some of Oregon's major rivers
- Define the word "watershed"
- Name one or more physical and chemical weathering properties



### NEXT GENERATION SCIENCE STANDARDS (NGSS) PRACTICES:

1. Asking questions
2. Developing and using models
4. Analyzing and interpreting data
6. Constructing explanations
8. Obtaining, evaluating, and communicating information

## Background

Oregon's geography and topography today are the results of more than 360 million years of geological and meteorological forces. Volcanoes, plate tectonics, folding, faulting, sediment deposition, weathering, and erosion have built up and then worn down the land. The Rock Cycle (Activity 3A) is a model of the geologic processes that continually change the Earth. These continual changes take place not only on the surface (crust) where people can observe them but also deep inside the Earth. Crustal rock recycles into subduction zones to be remelted and recreated as new crustal material.

The Water Cycle (Figure 1, page 6) is a diagram of the processes that move water on Earth. It is driven by solar energy and gravity. Evaporation and transpiration draw water droplets into the atmosphere, eventually forming clouds. The clouds release their water back to the Earth as precipitation. The water finds its way downhill in watersheds to return to the ocean. The Rock Cycle and the Water Cycle together continue to change Oregon's topography.

**Physical weathering** processes are driven by the movement of wind and water. Blowing wind and moving water erode rocks and break large rocks into smaller rocks. Water seeps into cracks and pockets in rocks. If the water freezes, its volume expands by 9 percent. This can break off pieces of rock. Small rocks and their mineral components may be moved across the land surface by water, ice, and wind, in turn wearing down the rocks they contact. In western Oregon, rain is an abundant source of landform weathering. Watersheds carry the water off the land and back to the sea.

**Chemical weathering** takes place when a rock's mineral components are dissolved by water or when they are oxidized. Rusting is caused by oxidation of iron. The third type of chemical weathering is hydrolyzation. Hydrolyzation occurs when the rock's original mineral components unite with water, forming different minerals.

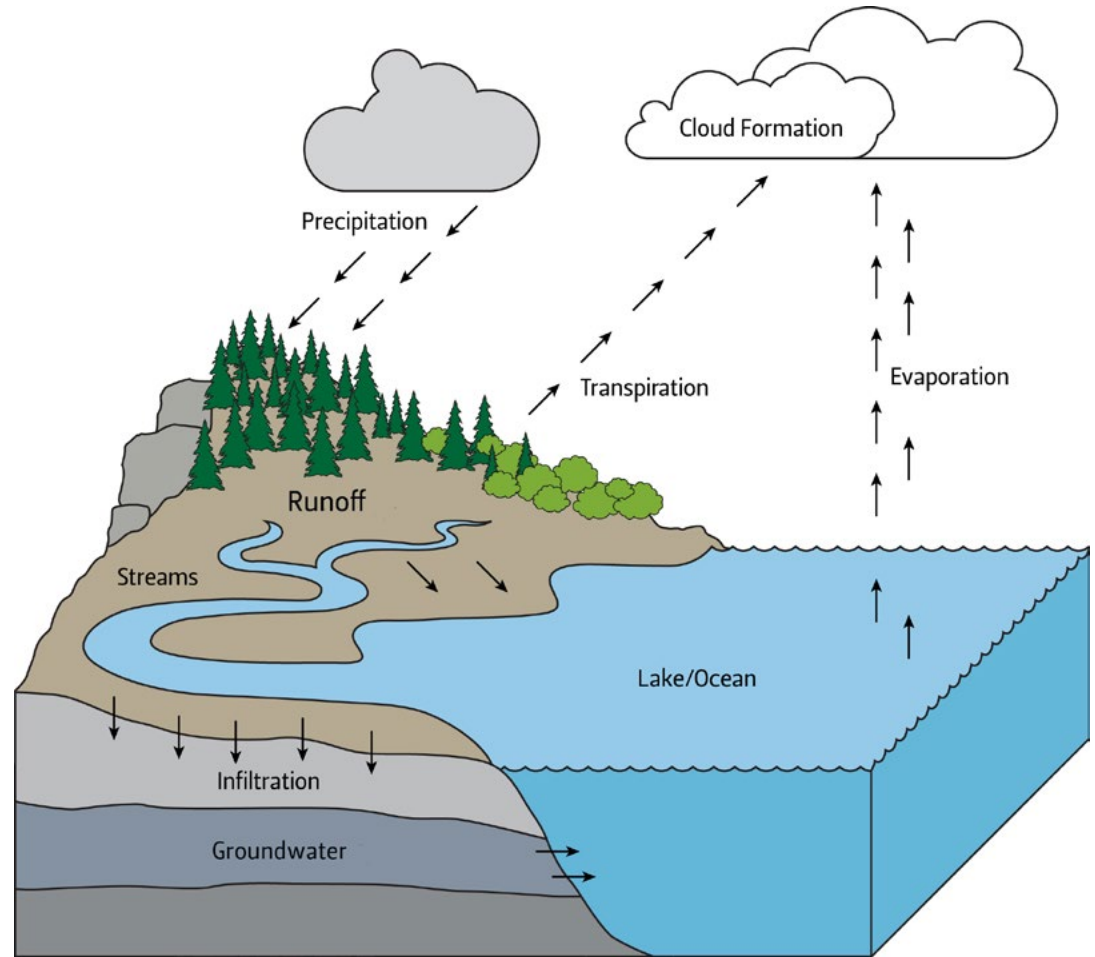


Figure 1. The Water Cycle

Acid rain increases the speed of erosion on limestone and marble materials used by humans. In Activity 1B, learners will see that vinegar, an acid, causes the carbonate in limestone to fizz. Oregon is at the mercy of these large and small geological and meteorological forces today—they are still at work.

Scientists date the Earth at around 4.5 billion years old (Figure 2, page 7). The extent of the geologic time scale may seem very remote to young learners. In the Holocene, the most recent epoch, the geologic activity can be matched to human history that is recognizable. For instance:

- The last eruption period on Mount Hood began around 10 to 15 years after the signing of the United States Declaration of Independence; and
- William Shakespeare was writing plays in Britain at the time Native American oral history tells us of a large landslide filling the Columbia River, providing a land bridge known as The Bridge of the Gods (Activity 9A).

Even these “recent” events may seem ancient, and yet they are at the very end of a story that began many billions of years ago. Devonian corals in limestone outcrops in what is now Central Oregon were deposited around 365 million years ago. Another way to think of Oregon’s geologic time scale is to condense it into a single “geologic year” of 365 days. The entire Holocene Epoch (0.01 million years) represents the last 272 hours of the geologic year. The last 500 years of human history on Earth would have taken place in the last 14 seconds of a geologic year viewed on this scale (Figure 3, page 8).

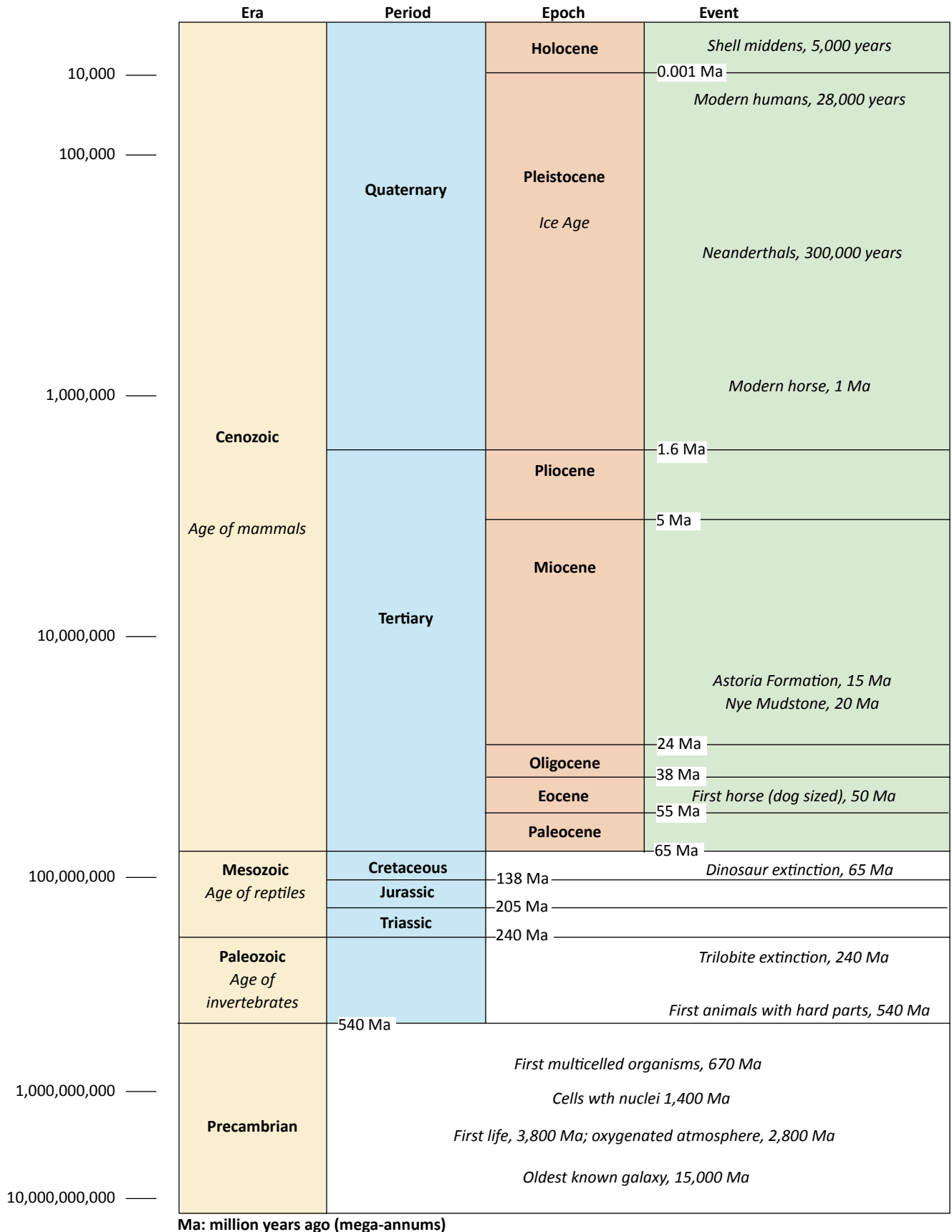


Figure 2. Geologic time scale. (©George W. Moore. Used by permission)



ERA	PERIOD	EPOCH	AGE	365-DAY MODEL
Cenozoic	Quaternary	Holocene		December 31 midnight 1 hour + 27 minutes
		Pleistocene	0.001	December 31 22 hours + 33 minutes
		Pliocene	1.6	December 30 10 a.m. 3.4 days
	Tertiary	Miocene	5	December 26 19 days
		Oligocene	24	December 7 14 days
		Eocene	38	November 23 17 days
		Paleocene	55	November 6 10 days
Mesozoic	Cretaceous		65	October 27 73 days
	Jurassic		138	August 15 67 days
	Triassic		205	June 9 35 days
Paleozoic	Permian		240	May 5 40 days
	Carboniferous		280	March 26 65 days
	Devonian		345	January 20 20 days
			365	New Years Day

Figure 3. A geologic year

## Activity 1A— Mapping Oregon

### Part 1: Discovering Oregon

#### MATERIALS

- One copy per learner of the Oregon outline map worksheet (page 11)
- One copy per team of the Oregon geologic provinces map (Figure 4, page 12)
- One copy per team of the individual maps specified below
  - 1) From the online resources at Portland State University's (PSU) Center for Geographic Information, purchase copies of the Student Atlas of Oregon (available in English and Spanish) from <https://www.pdx.edu/geography-education/instructional-materials-0>  
OR
  - 2) download and print maps from <https://www.pdx.edu/geography-education/student-atlas-of-oregon> (click on the Table of Contents link for a directory of maps).  
OR
  - 3) PowerPoint slides can also be created from the maps to project as needed through the activity. Take a screen print of your computer screen, paste it onto a PowerPoint slide





and crop out any unwanted areas. It is suggested that you make PowerPoint slides of the General Reference map and the Ecoregions map at a minimum, as they are used throughout the activities in this book.

- [General reference map](#)
- [Ecoregions map](#)
- [Topographic map](#)
- [Elevation cross-section map](#)
- [Average Annual Precipitation](#)
- [Climographs](#)
- [Vegetation Zones](#)
- [Rivers and lakes](#)
- [Pacific Northwest Watersheds](#)

- Crayons or colored pencils

## FYI

All water moves on and in the Earth through the water cycle (Figure 1, page 6). The salt water of the oceans makes up 97.2069 percent of the Earth's water. The amounts of fresh water are much smaller: ice caps/glaciers = 2.15 percent; groundwater = 0.62 percent; lakes = 0.017 percent; soil moisture = 0.005 percent; rivers/streams = 0.0001 percent; atmospheric water = 0.001 percent. In Oregon, the depth of the snowpack that builds up each winter is important to provide fresh meltwater in spring and summer for recreation and irrigation. Water moves off the land and back to the ocean in watersheds.

Be sure learners understand the definition of a watershed. This is the land area that channels water into streams and rivers. Water flows downhill in response to gravity. Watersheds are divided by the ridges and mountains that make up Oregon's topography. Refer to the [Student Atlas of Oregon Pacific Northwest Watersheds](#) map. The Columbia River is the largest watershed on this map. It is fed by smaller watersheds, such as the Snake, John Day, Deschutes, and Willamette rivers. On this map, you will see the Willamette is fed by the North Santiam and South Santiam. However, there are actually many rivers not shown that feed into the Willamette. Each stream and major river has a watershed.

## PROCEDURES

To comprehend the geologic history of Oregon, learners first must become familiar with the forces that shaped the landforms we see today. Using the *Student Atlas of Oregon* reference maps, assist learners to locate the Coast and Cascade Mountain ranges, and the Klamath, Blue, and Wallowa mountains.

Ask learners to label the rivers on their Oregon outline map worksheet. Using the Pacific Northwest Watersheds map, discuss the role of watersheds in channeling and moving water off the landscape and back to the ocean.

After the mountain ranges and rivers are labeled, ask learners to trace the geologic provinces on to their outline map. Using the Ecoregions, Precipitation, and Elevation cross-sections maps, discuss the characteristics of the ecoregions.



Ask learners to locate where they live, where other family members live (if in Oregon), and where they have been to visit on a vacation or to camp.

## Part 2: Mapping Closer to Home

### MATERIALS

- Several copies of the geological series quadrangle (“quad”) map for your local area. It can be downloaded [here](#).
- Modeling/play/craft clay
- Thin wire, 7- to -8-inch length
- White paper
- One copy of the Hills and Valleys worksheet for each learner (Page 13)



Photo 1. Use the wire to slice up your model mountain and trace each section’s outline to demonstrate how topographic maps work.

### PROCEDURES

Before looking at the topographic quad maps in detail, present a demonstration of how topographic lines show altitude. Using modeling clay, make a three-dimensional model of one of the hills on your local topographic map or from the Hills and Valleys worksheet. Grasp the thin wire tightly with one end in each hand, and draw it through the model hill about a third of the distance from the working surface. Repeat this procedure about a third of the way down from the top of the model hill. You

should now have three hill slices that can be separated from each other.

Place the bottom hill slice on a blank piece of white paper and draw the outline of this slice at its widest point. Remove the bottom slice from the paper. Place the second slice on the paper inside the outline of the bottom slice. Draw the outline of the second slice. Repeat this process with the top slice of the hill. Remove all the slices from the paper. Discuss with learners how the topographic lines on the paper represent the model hill. If time and the materials budget allow, have teams of learners repeat the demonstration (see Photo 1).

Using the quad maps, ask learners to locate their homes, schools, and other points of interest to them on the maps. The map will be color coded for “Surficial Geological Units” and “Bedrock Geological Units.” Hills, valleys, and other surface features will be indicated by topographic relief lines similar to those created in the clay demonstration.

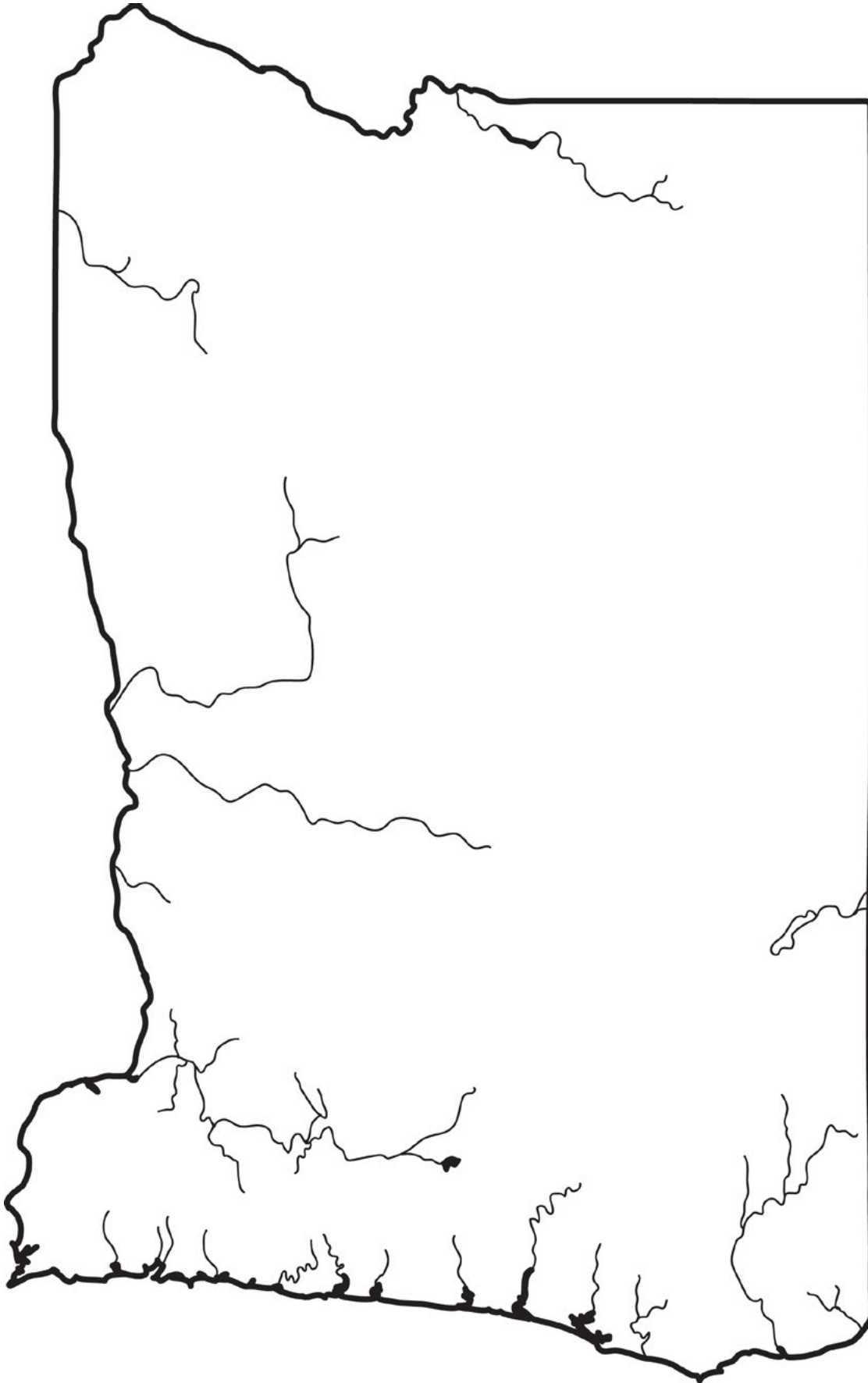
To allow learners to demonstrate an understanding of visualizing topographic features, pass out a copy of the Hills and Valleys worksheet to each learner and ask them to complete it. This activity may be done in pairs or as a full group. Ask learners whether they understand that the closer the topographic lines are together, the steeper the slope of the landform. Note that the bold topographic lines on the quad map are labeled with the elevation.

### ANSWERS TO THE HILLS AND VALLEYS WORKSHEET

From the top line to the bottom line the answers are, in order: B, E, D, C, F, A.



## Oregon map worksheet



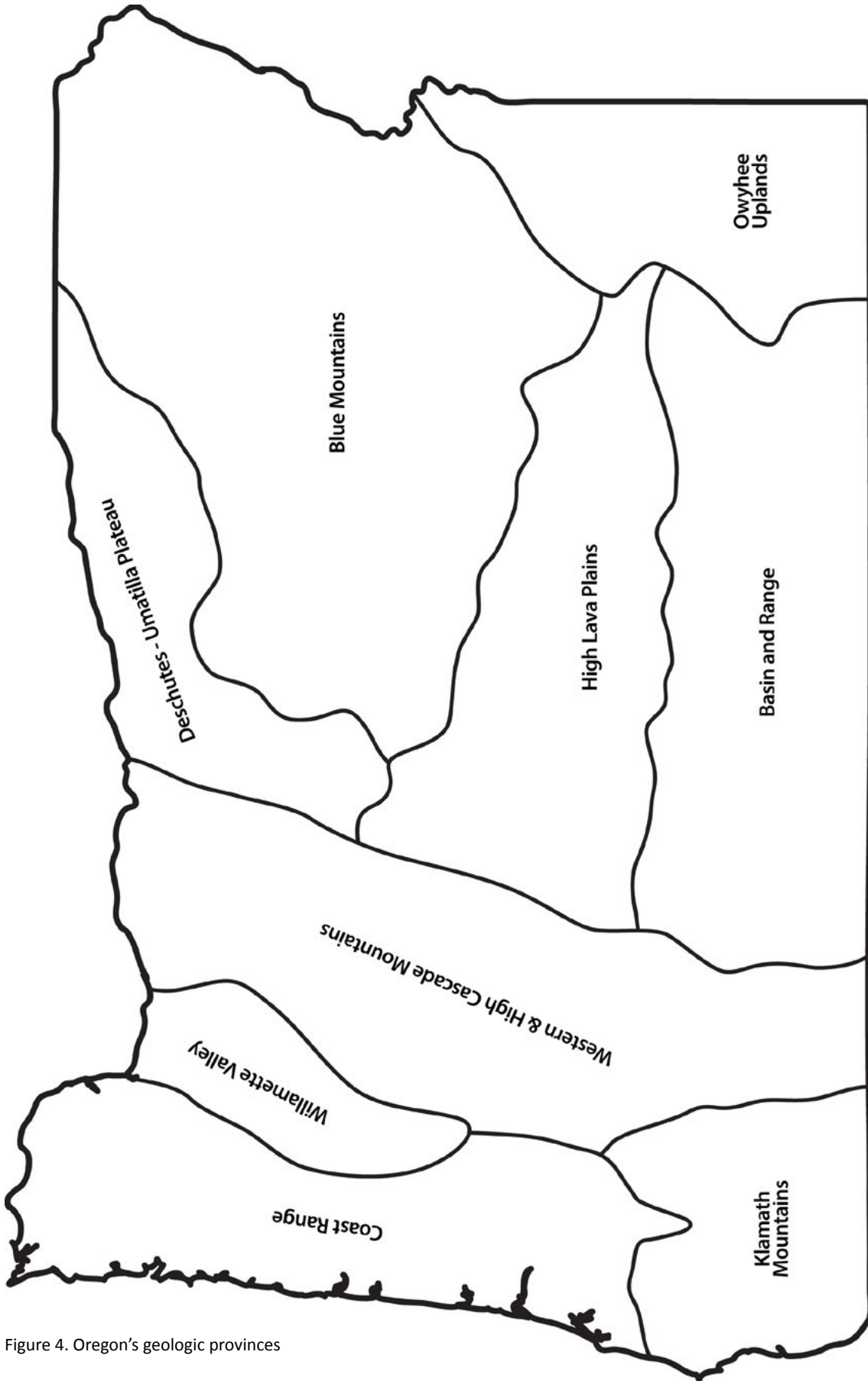


Figure 4. Oregon's geologic provinces



### Hills and valleys worksheet

Match the following:

_____		A	
_____		B	
_____		C	
_____		D	
_____		E	
_____		F	



## Activity 1B—Weathering Away

### MATERIALS

Provide a set for each team:

- One copy of the Weathering Away Experiments worksheet
- 2 tablespoons vinegar in a small paper cup
- Eyedropper
- Heavy-duty paper plate
- Rock samples of limestone and basalt
- Water and water spray bottle
- Pottery clay
- Clear plastic wrap
- Sample of soil
- Access to a freezer if using the Mighty Ice activity

### FYI

Rainwater is naturally slightly acid, with a pH of around 5.6. Acid rain—rain with a pH below 5.5—can be a result of air pollution or volcanic activity. This is a greater problem in large urban areas, especially on the East Coast, than in Oregon. Gasses produced by burning fossil fuels are a major cause of air pollution. When burned, fossil fuels such as heating oil, coal, and the gasoline used in our motor vehicles release invisible gasses (sulfur dioxide and nitrogen oxide). These gasses combine with water vapor in clouds to form acids. The acids (sulfuric and nitric) then fall to the Earth as rain, hail, and snow. In this experiment, learners will put vinegar (pH about 2.0) on basalt and limestone rocks and observe the reaction.

### PROCEDURES

Before beginning the Weathering Away Experiments, use the information in the Background to discuss with learners the nature of **physical weathering** and **chemical weathering** processes.

Physical weathering is demonstrated in the “Here’s the Rub” and “Mighty Ice” activities. Read through the “Here’s the Rub” and “Mighty Ice” experiments with learners, then ask them to complete the tasks listed.

Before allowing learners to begin “The Acid Test” section of the Weathering Away Experiment, discuss acid rain. Acid rain is an example of chemical weathering. Rainwater is naturally mildly acidic, with a pH of around 5.6. A pH of 7.0 is considered neutral. The pH of acid rain may be as low as 2.0, equal to the pH of vinegar. In the event that learners do not get a rapid reaction from the vinegar on the limestone, try placing a piece of limestone and basalt each in a cup and leaving them for a period of time, checking at regular intervals for signs of change. Additionally, try scraping any patina off the limestone or warming the vinegar. The limestone should have a visible reaction to the vinegar; the basalt should not.

### EXTENSION

Visit a local graveyard where tombstones and monuments have been made from granite, marble, limestone, and slate. These dated rock samples are ideal for studying weathering of rock over time. Look for lichen growths on the rocks. Lichens hold moisture against the stone and the plants are also mildly acidic. Look for roughened, grooved, or pitted surfaces. Look for evidence of cracking and flaking. Which type of stone shows the greatest resistance to weathering? What type of weathering is taking place? (Chemical.)



## Weathering Away Experiments worksheet

Use a sheet of notebook paper to write out the answers to the questions and record observations from the experiments.

### HERE'S THE RUB PHYSICAL WEATHERING

- Rub two pieces of basalt rocks together over a piece of white paper. What happens?
  - Next, rub two pieces of limestone together over the paper.
  - Predict what will happen. Try it and record your observations.
  - Predict what will happen if you rub basalt and limestone rocks together over the paper. Try it and record your observations.
  - What is on the paper as a result of rubbing the rocks together? Describe the material created. Where might you find rocks being rubbed together in the natural world?
- Examine the sample of soil provided by your leader. Is the soil similar to the material on the paper? Explain how it is similar and different.
  - Without blowing the sand onto his or her teammates or off the paper, one member of the team will now blow gently on the sand. What happens? Record your observations.
  - Predict what will happen if the water spray bottle is used to lightly spray the sand, then someone blows on the sand again. Try it.
  - Where would you expect to find wind moving sand in the natural world?
  - In this experiment, are rocks being weathered by physical or chemical processes?

### MIGHTY ICE PHYSICAL WEATHERING

For this experiment, you will need access to a freezer.

Make three round balls of pottery clay, each approximately 3 inches across. Using a pencil with a sharp point, label the balls A, B, and C.

**Ball A**—Using the eraser end of the pencil, make a hole in the top of the ball. Wrap in plastic wrap. This is your “control.”

**Ball B**—Using the eraser end of the pencil, make a hole in the top of the ball. Fill the hole with water. Wrap in plastic wrap.

**Ball C**—Using the eraser end of the pencil, make 3 to 6 holes in the ball. All these holes should be positioned so that they can hold water. Fill all the holes with water. Wrap the ball in plastic wrap. Put all the clay balls in the freezer. Be careful not to let any of the water spill out of the holes. What do you expect to happen to the clay and the water?

After a minimum of 24 hours, take the balls out of the freezer and compare them. What has happened to the clay and the water? Why has this happened?

If the clay were a solid rock, how would the water act differently?



Thaw the clay balls, and then freeze them again. Repeat this several times. What do you observe? Where might you expect to find rocks being frozen naturally on Earth? In this experiment, are rocks being weathered by physical or chemical processes?

---

### **THE ACID TEST CHEMICAL WEATHERING**

In this experiment, you will be testing the effect of an acid—vinegar—on basalt and limestone. Place the basalt and limestone samples on a heavy-duty paper plate. What do you expect will happen if you put several drops of vinegar on the basalt? Try it. Wait and watch a few minutes. Record your observations.

How do you expect the limestone to react to the vinegar? Try it. Watch both rocks and record your observations. In this experiment, are the rocks being weathered by physical or chemical processes?





## 2. The Blue Mountains—Islands and Old Sea Floors

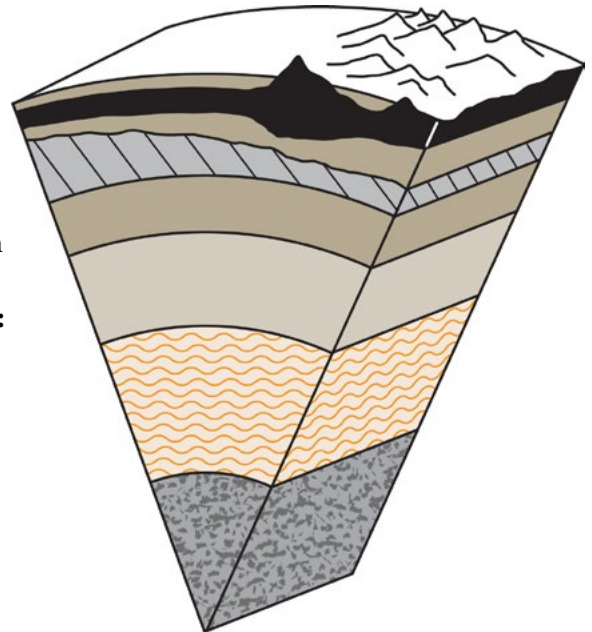
### Objectives

#### LEARNERS WILL BE ABLE TO:

- Explain the role of density in convection currents
- Explain how convection currents move tectonic plates
- Understand how the plate tectonic theory helps to explain the origin of the early Blue Mountains

#### NEXT GENERATION SCIENCE STANDARDS (NGSS) PRACTICES:

1. Asking questions
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
8. Obtaining, evaluating, and communicating information



### Field Trips

1. Wallowa Mountains, Eagle Cap—coral reefs, sea floors, and glaciers. Information from Eagle Cap Ranger District (USFS)
2. Hells Canyon—layers through geologic time. Information from Hells Canyon National Recreation Area
3. Elkhorn Mountains—gold prospecting. Information from Wallowa-Whitman National Forest or Bureau of Land Management, Baker City

### Background

The Earth's interior is made up of three main layers. These are the crust, the mantle, and the core (Figure 5, page 18). Each of these layers may be divided into smaller layers by their specific properties.

The crust is the outer layer, similar to the shell of a boiled egg. Like an eggshell, the crust is thin compared to the thickness of the mantle and core. The crust ranges in thickness from as little as 4 miles (6 kilometers) thick beneath the oceans to more than 50 miles (80 km) thick under continental mountains.

The mantle is directly beneath the crust, similar to the white of a boiled egg. It is a hot layer of semi-solid rock that contains more iron, calcium, and magnesium than the crust. It is hotter and denser than the crust because temperature and pressure inside the Earth increase with depth.

The core of the Earth is similar to the yolk of an egg. It is composed of a metallic iron-nickel alloy and is nearly twice as dense as the mantle. The core is differentiated into two zones, the outer core and the inner core. The outer core is a thick liquid, approximately 1,800 miles deep. The inner core is solid, due to the intense pressure at this depth. As the Earth rotates, the liquid outer core slowly flows, creating the Earth's magnetic field.

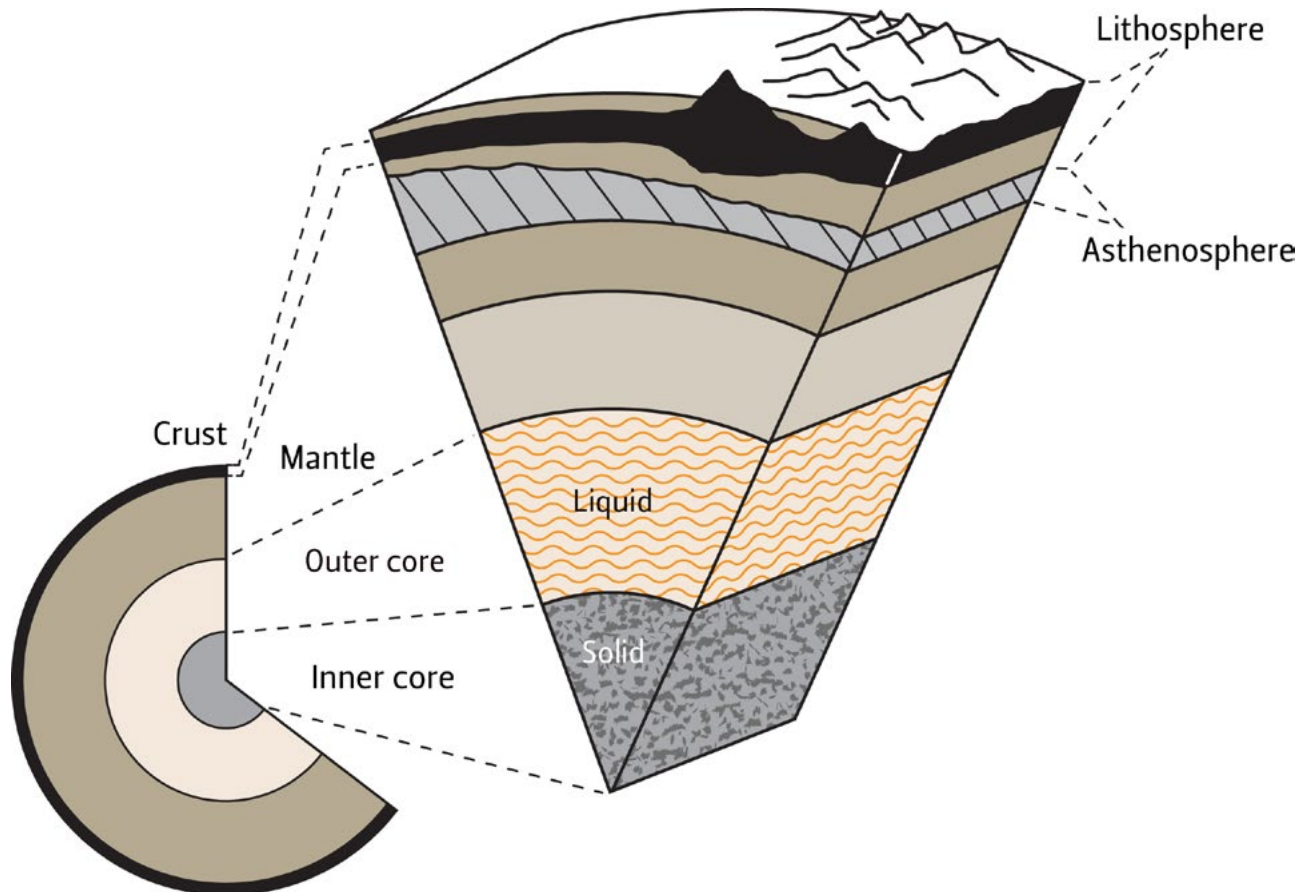


Figure 5. The Earth's interior

The lithosphere is the name given to the combined layers of crust and a cool outermost shell of the mantle. The theory of plate tectonics states that the lithosphere is composed of a dozen (or more) plates that move relative to one another as they ride atop a hotter, more mobile zone called the asthenosphere. The plates move at average speeds of a few inches per year, about as fast as a human fingernail grows.

Temperature differences at different depths in the mantle cause the asthenosphere to move by convection currents. The asthenosphere is composed of hot, semisolid material which can soften and flow after being subjected to high temperature and pressure over geologic time. In Activity 2A, learners will explore convection currents.

A tectonic (or lithospheric) plate is a massive, irregular slab of solid rock. Plates are divided into two types, oceanic and continental plates, based on their physical properties. The difference in density of the oceanic and continental plates is important in understanding how the plates behave when they come into contact with each other. Learners will explore Floating Densities in Activity 2B.

Continental plates have a thick crust composed of granitic rocks, which are made up of relatively lightweight minerals such as quartz and feldspar. By contrast, oceanic plates are denser and heavier and have a crust composed of iron-rich basaltic rocks. The crust under continents is on average around 20 miles thick. The crust under the oceans generally is only about 3 miles thick. Oceanic plates are created along oceanic ridges where mantle material rises toward the thin oceanic crust (Figure 6, #1, page 19). When the two types of plates meet, the oceanic plate, with its greater density, descends below the continental plate.



## Tectonic plates

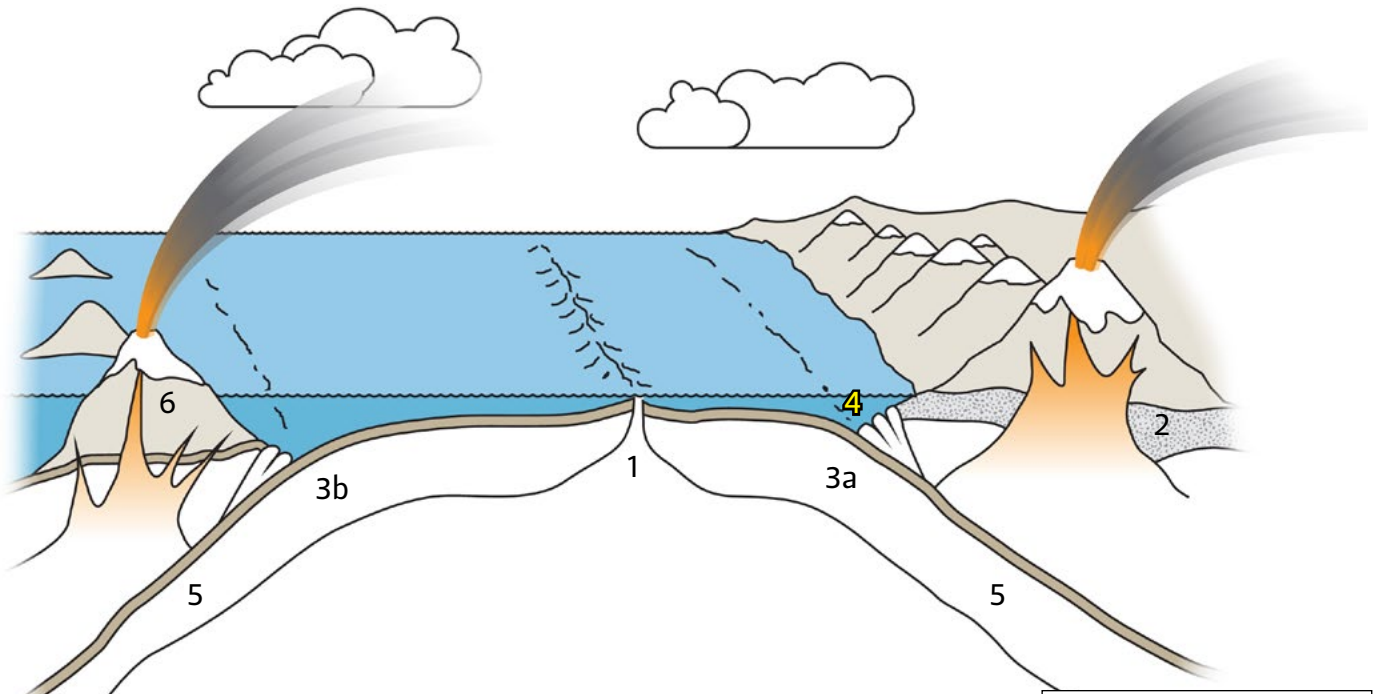


Figure 6

1. Oceanic plates are created along oceanic ridges where hot lower mantle material rises through the cold lithosphere.
2. Continental plate
3. Convergent plate boundary, where crust is destroyed as one plate dives under another
- 3a. Oceanic-continental plate converging
- 3b. Two oceanic plates converging
4. A trench is created by subduction of a plate. Trenches are the deepest parts of the ocean floor.
5. Subducting plate
6. Island arc volcanoes

Where a continental plate moves over an oceanic plate, the oceanic plate descends into the mantle in a subduction zone (Figure 6, #5).

The creation and destruction of lithospheric plates happen very slowly. The interaction of crust and mantle in creating, destroying, and changing rocks is described by the Rock Cycle (Activity 3A). About 200 million years ago, the western edge of the North American continent ended approximately at the current location of the western edge of the state of Idaho. The continent has been moving westward for at least 200 million years and is still on the move today. As the edge of the North American continental plate has moved west, it has ridden over the heavier Pacific oceanic plate (Figure 6, #3a). The oceanic plate is moving downward into the mantle in an offshore subduction zone. This is a convergent plate boundary, one of three types of tectonic plate boundaries.

The other two types of plate boundaries are divergent boundaries, where new crust is generated as plates pull away from each other; and transform boundaries, where the crust is neither produced nor destroyed as plates slide horizontally past each other. The *Student Atlas of Oregon* Pacific Northwest Plate Tectonics map shows the location of all three types of plate boundaries off the coast of Oregon.

Convergent plate boundaries can occur in one of three ways:

- (1) Between an oceanic and continental plate (Figure 6, #3a)
- (2) Between two oceanic plates (Figure 6, #3b)
- (3) Between two continental plates

Convergent plate boundaries are associated with subduction zones, where crust on one



side is being destroyed. They also are associated with large-scale volcanic and seismic (earthquake) activity. The crust and lithosphere material melt under great pressure as it enters the asthenosphere. Some of this melted material rises to feed the magma chambers of volcanoes (Figure 6, #5).

Where continental crust rides over oceanic crust, as on the western coast of the North American continent, volcanic mountains such as the Cascade Range may be uplifted. Where two oceanic plates converge, the subduction process results in the formation of a chain of “island arc volcanoes” (Figure 6, #6). The chain of volcanoes closely parallels the subduction trenches that give rise to them, and generally forms islands oriented in a curved pattern. An example of island arc volcanoes associated with modern earthquake and volcanic activity is Alaska’s Aleutian Islands, where 40 volcanoes are considered active.

The area identified as the Blue Mountains (Figure 4, page 12) in northeast Oregon began as island arc volcanoes in the warm seas off the western edge of North America. They were created in response to a subduction zone within the Pacific Basin. These island archipelagos were carried east on the oceanic plate until it collided with the west coast of North America as it moved westward. The collision that incorporated the islands into the continent caused enough heat and pressure to change some of the igneous and sedimentary rocks involved into metamorphic rocks.

The collision and subduction of plates cause changes in the landforms of both the oceanic and continental types of crust. Sediments on the ocean floor may be scraped off the subducting slab and added to the continental edge, creating coastal mountain ranges. In addition, the massive plates can build up tremendous pressure as they move past each other. Sometimes the pressure built up over time is released suddenly, causing an earthquake. Both volcanic and earthquake activity are common along the plate boundary marking the rim of the Pacific Ocean. This line where the Pacific Plate meets its many surrounding plates is called the Ring of Fire. In the Pacific Northwest, the North American plate is moving west off the coast and meeting the Pacific Plate and the Juan de Fuca plate. Volcanoes from Mount Baker to the former Mount Mazama, which created Crater Lake, are the result.

See also Oregon: A Geologic History, Batholiths and Plutons <http://www.oregongeology.org/sub/publications/IMS/ims-028/unit02.htm>; Oregon’s First Coast at <http://www.oregongeology.org/sub/publications/IMS/ims-028/unit03.htm>

## Reference

- Alaska Volcano Observatory: [www.avo.alaska.edu/](http://www.avo.alaska.edu/)
- Inside the Earth, United States Geological Survey, 1999, retrieved at <https://pubs.usgs.gov/publications/text/inside.html>
- Oregon: A Geologic History, Oregon Department of Geology and Mineral Industries, <http://www.oregongeology.org/sub/publications/IMS/ims-028/timeline.htm>



## Activity 2A—Convection Currents

### MATERIALS

- A Mercator projection map of the Earth
- One copy per team of the individual maps specified below
  - From the online resources at Portland State University's (PSU) Center for Geographic Information, purchase copies of the *Student Atlas of Oregon* (available in English and Spanish) from <https://www.pdx.edu/geography-education/instructional-materials-0> or
  - download and print maps from <https://www.pdx.edu/geography-education/student-atlas-of-oregon>, click on the Table of Contents link. or
  - PowerPoint slides can also be created of the map to project as needed throughout the activity. Take a screen print of your computer screen, paste it onto a PowerPoint slide and crop out any unwanted areas.
  - [Pacific Northwest Plate Tectonics](#)

### FOR DEMONSTRATION

- Clear glass Pyrex 2-cup measuring cup, or large beaker
- 1 sheet of white paper
- Fondue pot stand or beaker stand (If the stand will not hold the cup or beaker safely, place a square of hardware cloth on top of the stand under the cup or beaker.)
- Food-warming candle or solid alcohol fuel
- Blue food coloring
- Cooking oil
- Small empty bottle for mixed food color and oil
- Eyedropper
- Access to a refrigerator
- Hot pads

### FOR LEARNER INVESTIGATION—1 SET PER TEAM

- Clear/opaque plastic box (shoe box size)
- Room temperature water supply—store in gallon jugs with caps
- Ziploc® sandwich bag
- 2 clothespins
- Plastic bottles with lids—1 cup or less capacity. Nalgene® bottles work well.
- 1 cup hot water
- 1 cup ice
- Liquid food coloring—red and blue
- Colored pencils or pens—1 each, red and blue

**FYI**

Convection currents are caused by differences in temperature. These currents cause a circular motion, moving material away from a heat source as the material warms and expands. When cooling occurs away from the heat source, the material contracts. In the demonstration, the water will be warmed over the candle, rise to the surface, move to the outside edge of the container, and then sink toward the bottom, creating a circular current.

Convection currents are found not only in the Earth's mantle; they're also found in the atmosphere, as seen when large thunderhead clouds form, and in large bodies of water such as lakes and the ocean. They are responsible for the motion of oceans and lakes that redistributes nutrients through aquatic systems.

Scientists believe that a huge land mass called Pangaea, comprising all the existing continents, began to break up about 200 million years ago. The smaller pieces of Pangaea have been drifting apart or bumping together again ever since. Something as big as a continent does not move very rapidly. The continents that we see today are riding on plates that in turn ride on hot mantle material (Figure 5, page 18) that is moved by convection currents. Look at a Mercator projection map of the Earth; note how many continents could be fit together like a jigsaw puzzle to form one continent.

**PREPARATIONS**

Gather all the materials to be used in the activity. Mix  $\frac{1}{8}$  cup of cooking oil with a few drops of blue food coloring in the small bottle. Put the mixture in a refrigerator at least 24 hours prior to this demonstration.

**PROCEDURE—DEMONSTRATION**

Provide one copy of the Pacific Northwest Plate Tectonics map per team or create a PowerPoint slide to project for the discussion. Have the learners notice how many plates are under the Pacific Northwest and where the plate boundaries are. What plate do the learners live on?

Place  $1\frac{3}{4}$  cups of water in the glass measuring cup and warm it in a microwave. When the water is evenly warm, place the glass measuring cup on the stand over the lighted candle. Use extreme care in removing the cup from the microwave and transporting it to the stand.



When the cup of water is placed on the stand over the candle, the water in the center will continue to warm. Noticeable bubbles will begin to form and rise toward the surface. The cooler water on the edges of the cup is denser and will begin to sink toward the bottom of the cup.

Tell the learners that you are going to put a few drops of the refrigerated blue oil into the water near the edge of the cup. Ask what they think will happen. Will it stay in one place? Be dissolved into the water? Or move in a particular direction? After the learners have made some suggestions, drop in some blue oil and observe what happens. Repeat this experiment by putting blue oil in the center of the cup.

### **PROCEDURE—LEARNER INVESTIGATION**

Now learners will do an investigation of temperature and density themselves. Read over the procedures on the Currents and Density worksheet with learners before they start. Distribute the materials to each team. Learners should use caution when handling the bottle full of hot water. Be sure learners follow the instruction to fasten the bag of ice to the box with clothespins. The bag should be secured against the wall of the box, NOT slumped on the bottom. Ask learners to complete the investigation and fill in their worksheets, and then lead a discussion of their observations for each of the three observation times. What is driving the currents in the box? How is this similar to the temperature differences in the mantle that cause the asthenosphere to move by convection currents? (Figure 6, page 19)

### **DISCUSSION**

Introduce learners to the idea that the Earth's tectonic plates at the Earth's surface are moved on the fluid asthenosphere by convection currents in the mantle. Use the information provided in the Background section to discuss how the Blue Mountains (Figure 4, page 12) resulted from the collision of North America with island arc volcanoes. Use the Mercator projection map of the Earth to lead a discussion on the break-up of Pangaea into the current continents.

Note: If possible, complete Activity 2B, "Floating Densities" soon after Activity 2A to assist learners in understanding these complex processes.

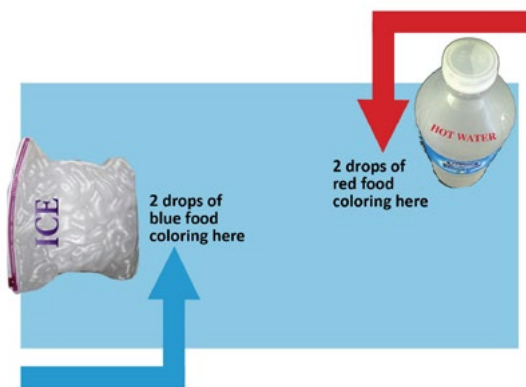


## Currents and Density worksheet

- Place the plastic box on the sheet of white paper. Fill it about  $\frac{3}{4}$  full with room temperature water.

The next steps should be done as quickly as possible.

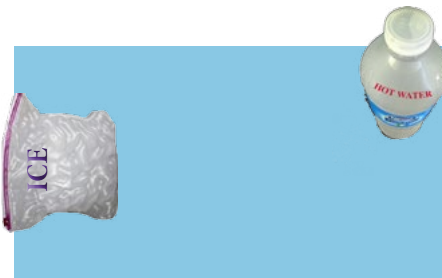
- Have two team members ready to add the red and blue food color as soon as the investigation is set up. See the illustration.
- Have one team member ready to time the investigation as soon as the food color enters the water.
- Place ice cubes in the Ziploc® sandwich bag and secure it to one end of the box with the clothes pins. The ice should be on the side of the box, not slumped on the bottom.
- Fill the plastic bottle with hot water. Use caution! Place the plastic bottle at the end of the box opposite the ice.
- Immediately after the hot water and ice are in place, the food color should be added. The red goes in front of the hot water. The blue goes in front of the ice.



## Observations

Immediately draw what is happening to the red and blue food color. Be sure to observe from the side as well as from the top.

**From the top:**

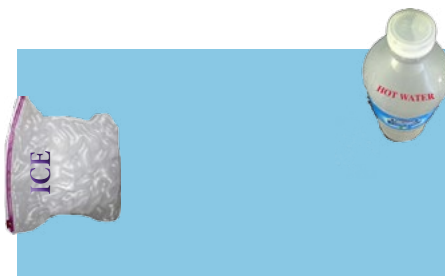


**From the side:**



At 2 minutes, draw what is happening to the red and blue food color. Be sure to observe from the side as well as from the top.

**From the top:**



**From the side:**



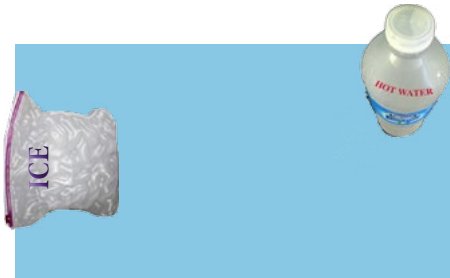




### Currents and Density worksheet

At 5 minutes, draw what is happening to the red and blue food color. Be sure to observe from the side as well as from the top.

From the top:



From the side:



### QUESTIONS

A) Which color was in the water with the greatest density? How do you know?

---

---

B) Is the model similar to the movement of convection currents in response to temperature differences in the mantle that cause the asthenosphere to move by convection currents? Why or why not?

---

---

---



## Activity 2B—Floating Densities

### MATERIALS

- An aquarium or large glass bowl
- Two thick-skinned oranges (if thick-skinned oranges are not available, try comparing cans of diet and regular soda of the same brand)
- A raw egg (in the shell)
- Salt
- Spoon
- A glass or beaker of water
- Knife (to peel the orange)

### FYI

The mathematical formula for density is  $\text{Density} = \text{Mass}/\text{Volume}$ . The density of an item—gas, solid, or liquid—is not related to its size or shape. In the experiment, learners will use water to compare the density of an orange with and without its skin. The orange with its skin is like the continental plate—it will float. Even though the orange with its skin on is larger, the thick, low-density skin acts like a life jacket, keeping the orange afloat. The peeled orange will sink because the high-density pulp is denser than the water.

### Procedure

#### PART 1: ORANGE DENSITY

Ask learners what density is. Write suggested definitions on a board where all can see them. Fill the container with water. Hold the two oranges where learners can see them, then peel one of the oranges. Ask learners what is the same and what is different about these two oranges. Explain to learners that you will be placing both the oranges into the water. Ask learners what they predict each of the two oranges will do.

Place the oranges in the water and discuss the results. (The orange without a peel will sink. If a thick-skinned orange has been used, the orange with skin should float higher in the water than the peeled orange. Thin-skinned oranges will not float.) Explain the relationship of the different densities of continental and oceanic plates and how this is similar to the oranges. Refer to the Background section for information to assist the discussion.

#### PART 2: THE DENSITY OF WATER

The density of pure water is always the same at a given temperature.

However, the density of water can be changed by adding things to it so it is no longer pure water.

Place a fresh, raw egg (in the shell) in a glass of water. Ask learners why the egg sinks. (A raw egg is denser than water.) Ask learners what they might do to change the density of the egg or the water to make the egg float. (Photo 2)

After the learners have provided ideas on changing densities, begin stirring salt into the water, 1 tablespoon at a time. Have a learner record the amount of salt being added. The egg will rise to the top when the salt water becomes denser than the egg. Discuss what the learners believe to be happening. (Photo 3)

Ask the learners for ideas on other ways density may be changed. Try as many of the learners' ideas as possible.



Photo 2



Photo 3



## 3. The Klamath Mountains

### Objectives

#### LEARNERS WILL BE ABLE TO:

- Explain the origins of metamorphic, igneous, and sedimentary rocks and where they are found in the Rock Cycle
- Describe some geometric shapes of crystals

#### NEXT GENERATION SCIENCE STANDARDS (NGSS)

##### PRACTICES:

2. Developing and using models
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information



### Field Trips

1. Upper Table Rock—remnants of Miocene Cascade basalt flows. Information from Medford Bureau of Land Management office.
2. Humbug Mountain State Park—Cretaceous, pebbly beach. Information from Oregon State Parks and Recreation Department.
3. Mount Ashland—Jurassic granitic pluton. Information from Ashland Ranger District (USFS).
4. Oregon Caves National Monument—Triassic limestone. Information from Oregon Caves National Monument.

### Background

The area identified geologically as the Klamath Mountains in southwest Oregon contains pieces of the oldest and most diverse rocks and landscapes in the state (Figure 4, page 12). Only about a quarter of the Klamath Mountains are in Oregon. The majority of the range is in northern California. The oldest part of these mountains was born as island arc volcanoes (Chapter 2, Background) in the warm ocean off the Oregon and California coast of the Paleozoic Era.

The Klamath Mountains were created by wave after wave of separately generated island arcs. The lithospheric oceanic plate on which these islands rode moved north and east from their point of origin. A new series of volcanic islands was formed as the plate moved the previously created island arc away from a zone of sea floor spreading (Figure 6, #6, page 19).

At the same time the Klamath island arcs were moving east, the western coast of North America was continuing to move west. When the oceanic and continental plates collided, the islands were scraped off the oceanic plate and added to the continent in a violent process that resulted in massive earthquakes and additional volcanic activity. The lines of island arcs may have been pushed into a single island by the time their oceanic plate collided with the North America continental plate. The island arcs are welded together by magma that intruded into the previously formed volcanic islands (Figure 4, page 12, and Figure 7, page 28).

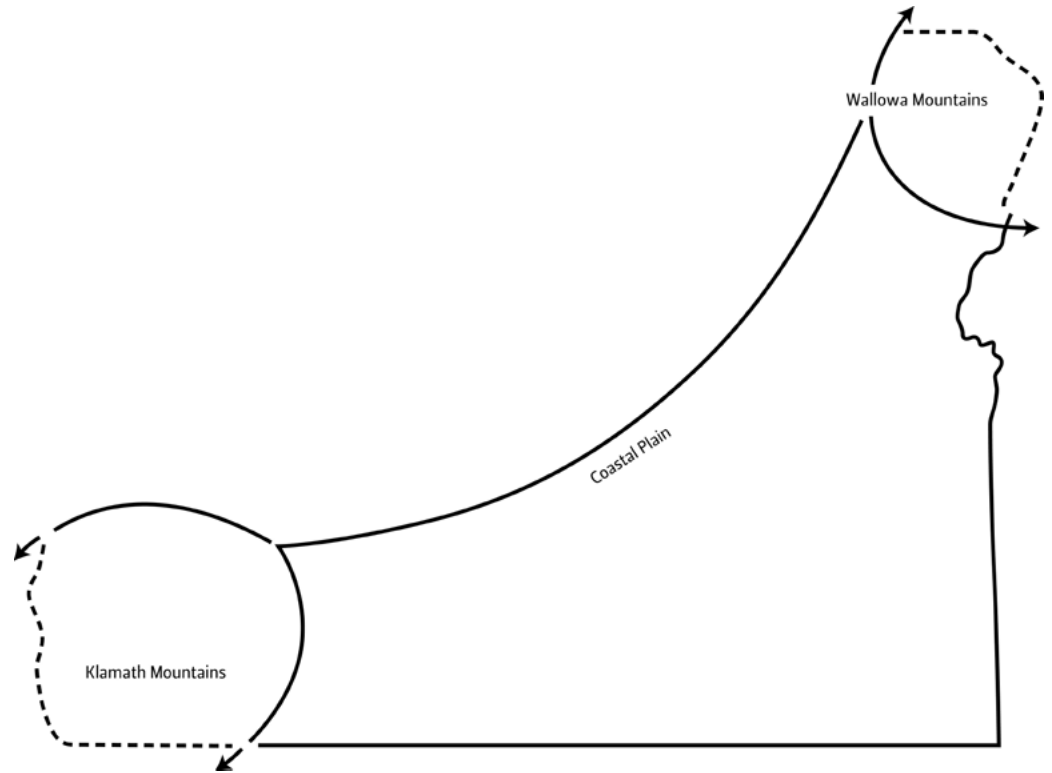


Figure 7: Jurassic Oregon map

Igneous rocks are formed when magma cools. When the magma cools underground, the rocks formed are called plutonic rocks. When the magma reaches the surface, it is called lava when it is still hot and fluid. The rocks formed when lava cools are called volcanic (or extrusive) rocks. The magma that intruded into the Klamath island arc volcanoes contained a high level of quartz, potassium-rich feldspar, and biotite, which cooled and solidified underground, creating intrusions and plutons made of the igneous rock granite.

Mount Ashland is a pluton, a dome-shaped mass of igneous rock 7,523 feet in elevation, which intruded into older, softer shale material. The granite that makes up Mount Ashland rose from deep inside the Earth as magma. The magma formed a dome that cooled without reaching the surface. Over time, the softer shale material covering the granite intrusion has weathered away, leaving the dome-shaped pluton of Mount Ashland. (Activity 1B).

Due to weathering over millions of years, much of the material that once covered the pluton is on its way to the ocean, perhaps as waterborne sediment of the Rogue River. When it reaches the ocean, the sediment may be carried into the trench created where the oceanic plate enters the subduction zone and is moved under the continental plate. The Rock Cycle describes the geologic processes that are slowly at work, continuously changing the Earth. Learners will use a diagram in Activity 3A to assist in understanding the many processes at work in the Rock Cycle.

The marble of the Oregon Caves, a part of the Klamath Mountains province, is metamorphic rock that was once a limestone coral reef, rich in calcite that formed at the base of the island arc volcanoes in the ancient tropical ocean (Figure 4, page 12). Metamorphic rocks are created when igneous or sedimentary rocks are exposed to great heat and pressure. Over time, the limestone, a sedimentary rock, was folded, fractured, and exposed to heat and pressure from the collisions of the island arcs and the North



American continent. This geologic activity created a low-grade marble full of cracks and faults. Limestone and marble are made of calcite, which dissolves in water. Water flowing underground through the cracks dissolved and eroded the marble, creating the Oregon Caves. The dripstone formations are created when the dissolved calcite is redeposited. The icicle-like formations that grow down from the cave ceiling are called stalactites. Stalagmites are the formations that point up from the cave floor.

Calcite is found in the Oregon Caves both as a solid part of the dripstone formation and also dissolved in water. As the calcite is deposited in successive layers, it appears that the dripstone is growing, although it is not a living thing. All solid minerals “grow” or crystallize from vapor, magma, or a liquid solution. Matter comes in three forms— solid, liquid, and gas. When matter changes from one form to another (e.g., from liquid water to solid ice), it’s called a change of state. Some crystals such as salt, sugar, and quartz are solid at room temperature. Others, such as ice, must be frozen to be solid. The shape of each solid mineral, its crystallization pattern, is always the same. Crystal shape is one characteristic used to identify minerals. In Activity 3B, learners will explore ways crystals are created.

See also Oregon: A Geologic History, Oregon’s First Coast at <http://www.oregongeology.org/sub/publications/IMS/ims-028/unit03.htm>

## Activity 3A— The Rock Cycle

### MATERIALS

- One copy of the Rock Cycle worksheet (page 31) for each learner

### PROCEDURE

Work with the learners to label the Rock Cycle worksheet. The Rock Cycle worksheet is a diagram of the geologic processes that continually change the Earth. Discuss the events that shaped the Blue Mountains (Chapter 2) and the Klamath Mountains and where these are represented on the Rock Cycle diagram. Discuss how a coral reef is converted into the metamorphic rock marble. What geologic processes are at work turning coral to marble (Rock Cycle diagram, #4) and marble to dripstone formations (Rock Cycle diagram, #1 and #2)? Where are these processes represented in the Rock Cycle? Where do learners see the processes illustrated in the Rock Cycle diagram taking place today?

Answers to the Rock Cycle worksheet

1. Weathering (Chapters 1 and 3, Background)
2. Sediment deposited by water. (More in Chapter 4, Background and Activity 4A)
3. Sediments are compacted over time to form sedimentary rocks.
4. When sedimentary or igneous rocks are subjected to great heat and pressure, metamorphic rocks are created. (Chapter 3, Background)
5. Metamorphic rocks can melt inside the Earth to become molten magma. (Chapters 2 and 3, Background)
6. Magma rises to the Earth’s surface in areas of volcanic activity.
7. Igneous rocks are formed from magma. When magma cools underground, the rocks formed are called plutonic igneous rocks.
8. When magma reaches the surface, it’s called lava. When the lava cools, the rocks formed are called extrusive igneous rocks. (Chapter 7, Background and Activity 7B)



## EXTENSION

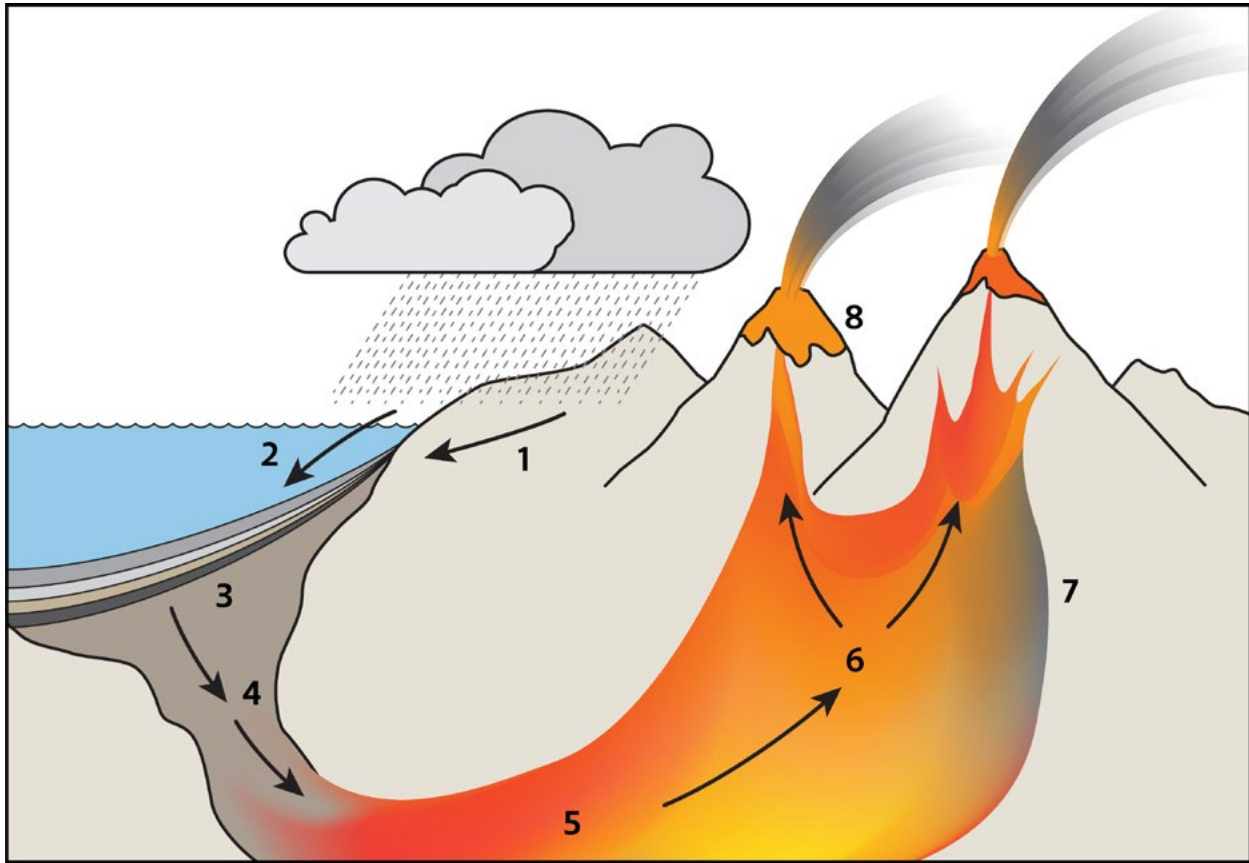
### *Research Activity*

Coral reefs have had a huge impact on the geologic history of Earth. Thick limestone layers—once reefs—underlie North America from Idaho to the Dakotas. Today on Earth, tropical coral reefs are found where the water surface temperature averages 68 degrees. Coral colonies grow slowly. In ideal conditions they grow at about a half inch per year. Some currently living atolls that are around a mile thick have been growing for 50 million years!

Develop some questions and research coral reefs. What does the coral-creating animal look like? Where are they found on Earth today? What is an atoll? What plants and animals live in coral habitat? How are coral reefs important to the local people and economy? Use the National Oceanic and Atmospheric Administration (NOAA) coral reef education site for answers: <http://coralreef.noaa.gov/education/coralfacts.html>



## Rock Cycle worksheet



1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_
4. \_\_\_\_\_
5. \_\_\_\_\_
6. \_\_\_\_\_
7. \_\_\_\_\_
8. \_\_\_\_\_



## Activity 3B—How Do Your Crystals Grow?

### Part 1: Quick Crystals

#### MATERIALS

- Box of rock salt
- Bag of “cocktail” ice, one for each 10 learners
- Measuring spoons

For each pair of learners:

- A pair of mittens or gloves (Ask learners to bring these from home.)
- 1-gallon Ziploc® freezer bag
- 1-quart Ziploc® freezer bag
- 1½ cups of whole milk—plain, chocolate, or egg nog
- 2 tablespoons sugar
- 1 teaspoon vanilla
- Two spoons
- Two paper cups



Photo 4

#### PROCEDURE

Ask learners what the term “change of state” means. Use one of the ice cubes to illustrate the solid, crystalline form of water. What happens to milk when it’s frozen? What is a popular form of frozen milk? (Ice cream.) Does frozen milk contain crystals? (Yes.)

Explain to learners that they are going to put milk, and some other ingredients, in a bag, place this bag into a larger bag, add ice and salt to the larger bag, and SHAKE. What do learners predict will happen?

Have each pair of learners measure the milk, sugar, and vanilla into a quart-size bag and mix gently. Ask learners to note that the material in the bag is a liquid. Now be sure that all the quart bags are securely sealed. Learners will place the quart bag into a gallon bag. Layer ice and salt into the gallon bag. Start with a one-to-one, salt-to-ice ratio. Leave room in the gallon bag for it to be sealed. You might want to experiment with different ratios of salt to ice, and time needed to get results.

The learners should now put on their gloves. Ask each pair of learners to take one end of the gallon bag and shake it together for approximately 15 minutes. Ask learners to observe what is happening in both the bags. Add more salt and ice as needed. Remind learners that often in science it is not a good idea to taste an experiment; however, in this case we will make an exception. Remember, we want to answer the question, “Does frozen milk contain crystals?” Open the quart bags and enjoy!

### Part 2: Slow Crystals

#### MATERIALS

- Epsom salts
- Dark construction paper—black, blue, green, brown

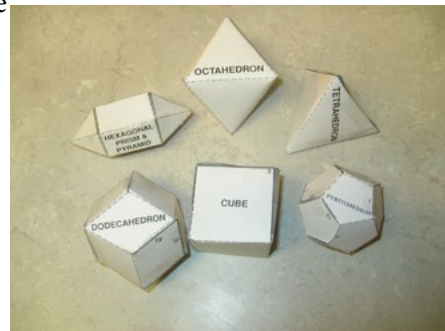


Photo 5





For each learner:

- Paper cup half full of warm water
- Spoon
- Scissors
- Empty half-pint milk carton, rinsed, with the top removed
- Hand lens

### PROCEDURE

Before beginning, explain to learners that this is not an experiment they should try to taste.

Have each learner cut a piece of construction paper to fit the bottom of the milk carton. Stir Epsom salts in the cup of warm water until they will no longer dissolve. Spoon the Epsom salt mixture over the paper in the milk carton until it forms a thin layer of liquid. Place the milk cartons in a warm location where they will not be disturbed for at least 24 hours. Ask learners what they expect to happen. Compare the crystals that form (Photo 4, page 31) with the dry Epsom salts directly from the box.

Observe the crystals with a hand lens. What do the learners notice? How is the Epsom salt demonstration similar to the processes that produced the dripstones of the Oregon Caves?

### Part 3: Cardboard Crystals

The following lesson was adapted from the “Shapes of Mineral Crystals” activity, which is reprinted from the Great Explorations in Math and Science (GEMS) teachers’ guide titled *Stories in Stone*, copyrighted by The Regents of the University of California, and used with permission.

### MATERIALS

- One set of copies of the crystal model sheets, copied onto card stock for each learner (found following this lesson). For young learners, use only the cube, tetrahedron, and octahedron models.

For each pair of learners:

- One pair of scissors
- One pencil
- One ruler
- Transparent tape

If learners will be constructing a crystal mobile, the following will be needed:

- Coat hanger, one per learner
- A supply of string (colored embroidery floss is nice)
- A supply of crayons
- Hole punch

### FYI

A limited number of crystal shapes have been found in nature. There are only seven main groups or “crystal systems,” into which all naturally occurring crystals can be placed. This suggests that there is a limited number of ways in which atoms may be arranged together to form these shapes. Because a single crystal represents the smallest component of a mineral, careful observation and analysis of distinctive crystal shapes has proved to be one of the best ways to classify and distinguish between different minerals.



### PREPARATIONS

Gather all the materials to be used in the activity. Construct one of each of the crystal models to become familiar with the construction process, and so you can show learners what the models will look like when completed (Photo 5, page 32). Have one additional flat copy of the cube available to use in a construction demonstration.

Prior to beginning the activity, read the “Extension” suggestion at the end of the “Procedure” section. If you plan to have students color their crystals, have them do so before they cut them out of the cardboard and fold them.

### PROCEDURE

Prior to passing out the materials, explain and demonstrate to learners how to construct the cube model, one step at a time, as follows:

- a. Write your name on the shape, somewhere not too visible.
- b. Use scissors to carefully cut the cube pattern along the solid lines.
- c. Use the sharp edge of a desk or table to make a fold along all dashed lines of the cutout. In making the folds, learners should make sure the dotted lines and any words (such as “CUBE”) are on the outside of the shape being formed.
- d. Fit the faces of the crystal shape together, tucking tabs as needed, and matching corresponding numbered comers. If making a mobile, use a hole punch to make holes as needed to tie a string on each model. Tape the edges.

### OPTIONAL

- e. Tie a different length of string on each of the models, and tie the string to the coat hanger to form a pleasing pattern.

The same procedure applies to all the crystal shapes. Have learners begin constructing their models, beginning with the cube. For younger learners, use only the cube, tetrahedron, and octahedron models.

Save the cardboard crystals for use again in Activity 4B, Identifying Rocks and Minerals.

### EXTENSION

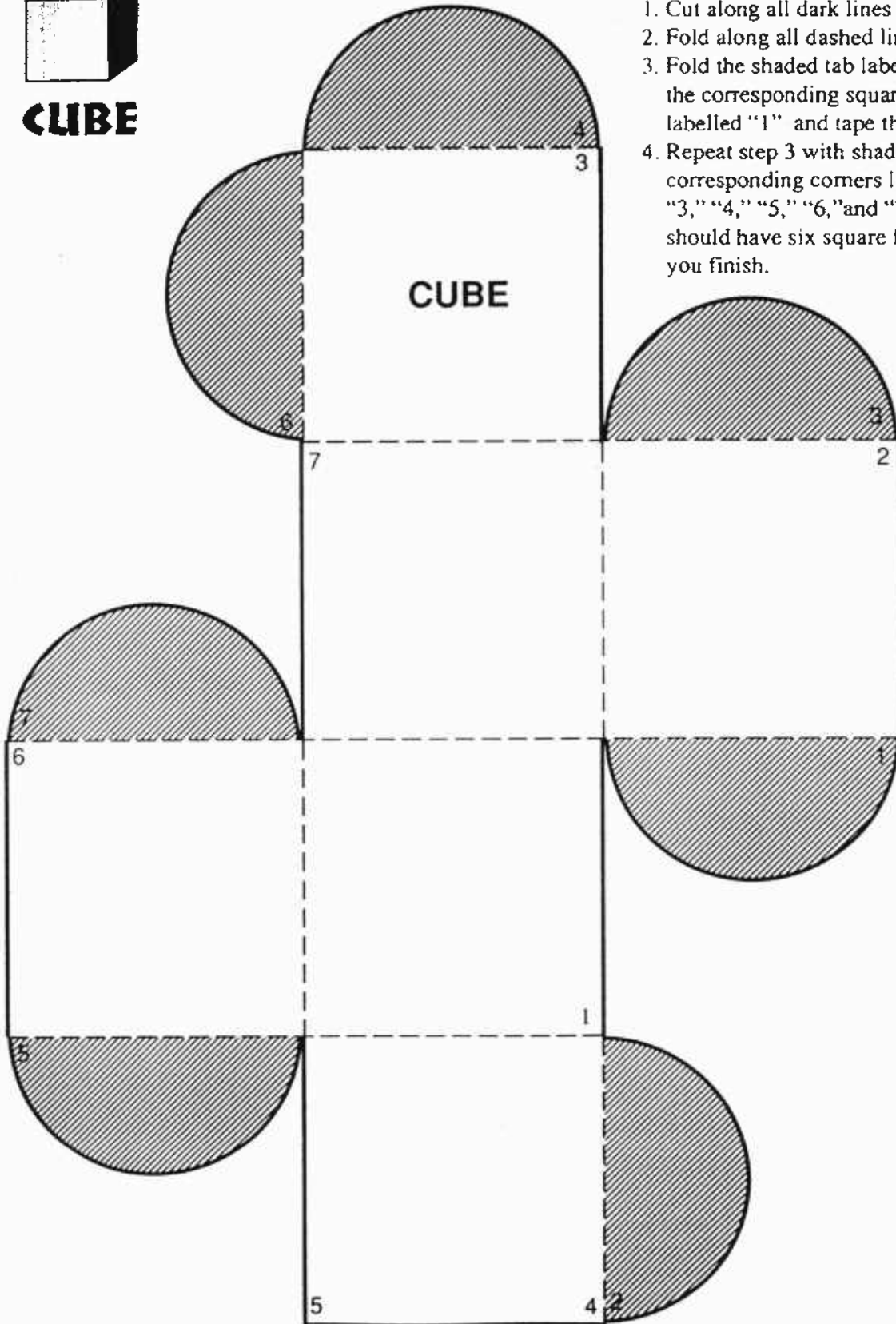
Before learners tape their cardboard models together, ask them to research the colors of the minerals being represented by the crystal shapes. Color the models to match the minerals represented.

Examples of the colors of some crystal shapes and their minerals are:

Cube: salt, galena, platinum	Tetrahedron: chalcopyrite
Pyritohedron: pyrite fool's gold	Dodecahedron: gold
Hexagonal prism: quartz	Octahedron: gold, platinum, magnetite, diamond



**CUBE**



**Directions for Building Cube:**

1. Cut along all dark lines with scissors.
2. Fold along all dashed lines.
3. Fold the shaded tab labelled "1" under the corresponding square corner labelled "1" and tape the edge.
4. Repeat step 3 with shaded tabs and corresponding corners labelled "2," "3," "4," "5," "6," and "7." You should have six square faces when you finish.

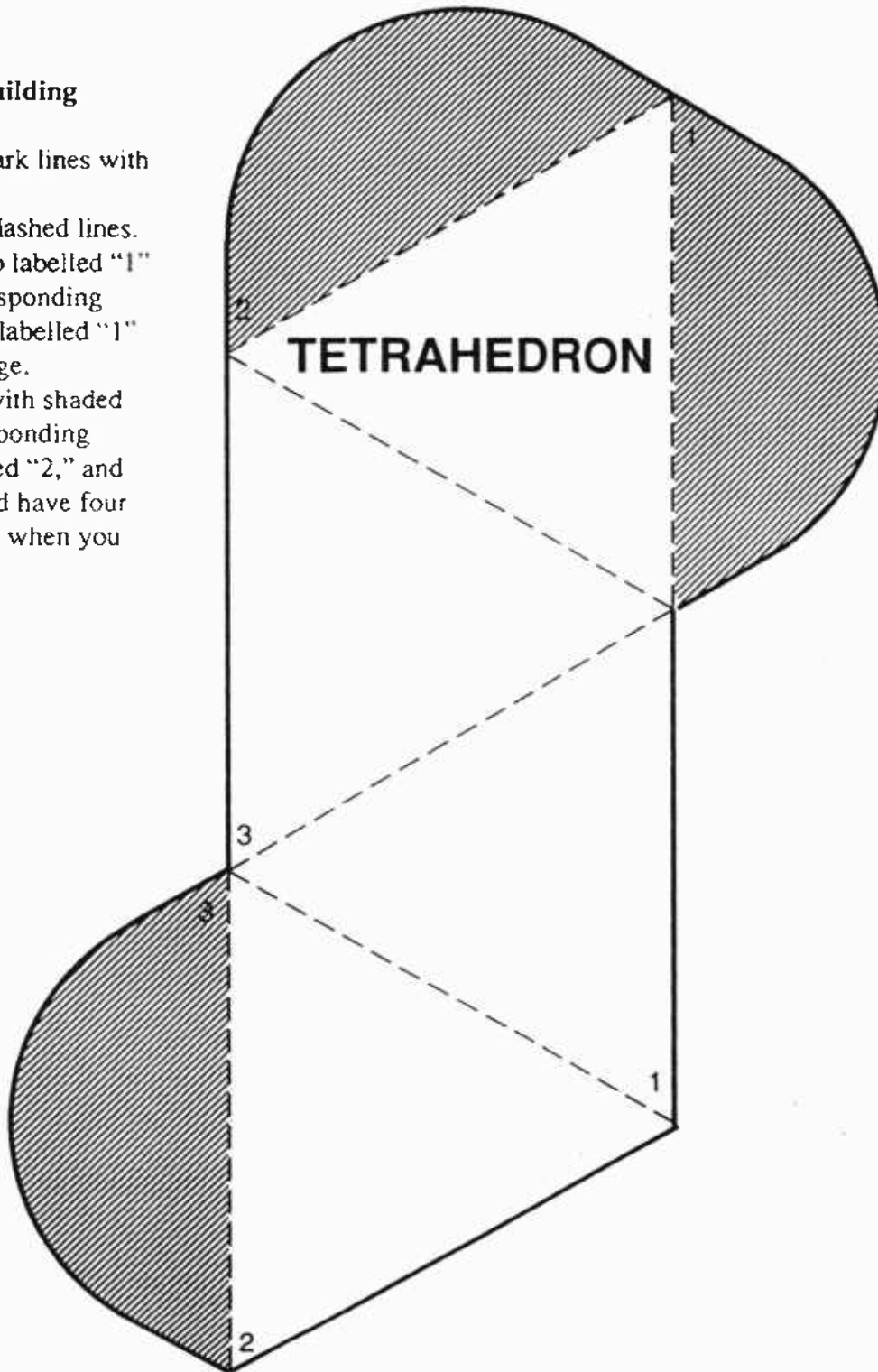


# TETRAHEDRON



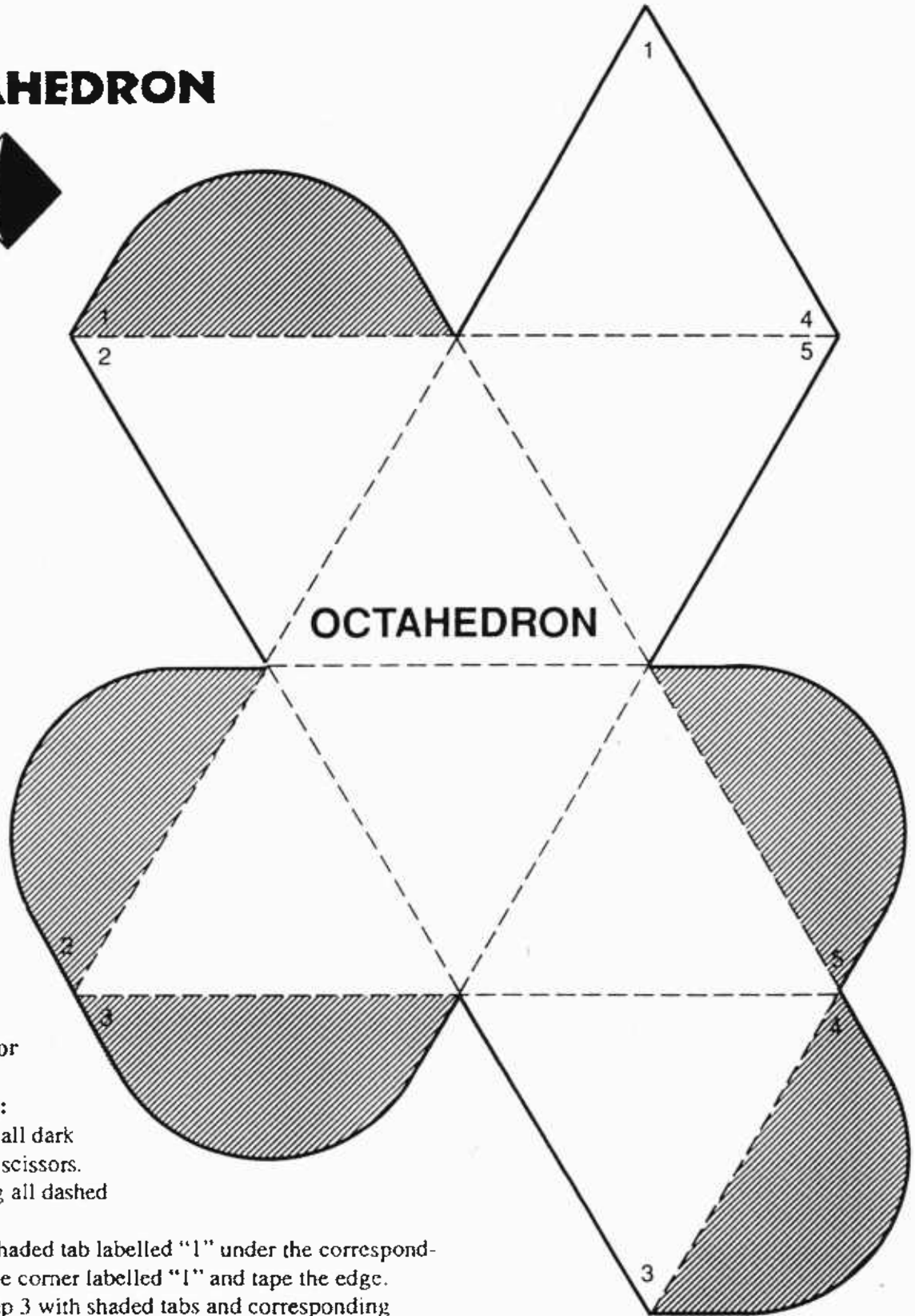
## Directions for Building Tetrahedron:

1. Cut along all dark lines with scissors.
2. Fold along all dashed lines.
3. Fold shaded tab labelled "1" under the corresponding triangle corner labelled "1" and tape the edge.
4. Repeat step 3 with shaded tabs and corresponding triangles labelled "2," and "3." You should have four triangular faces when you finish.





# OCTAHEDRON

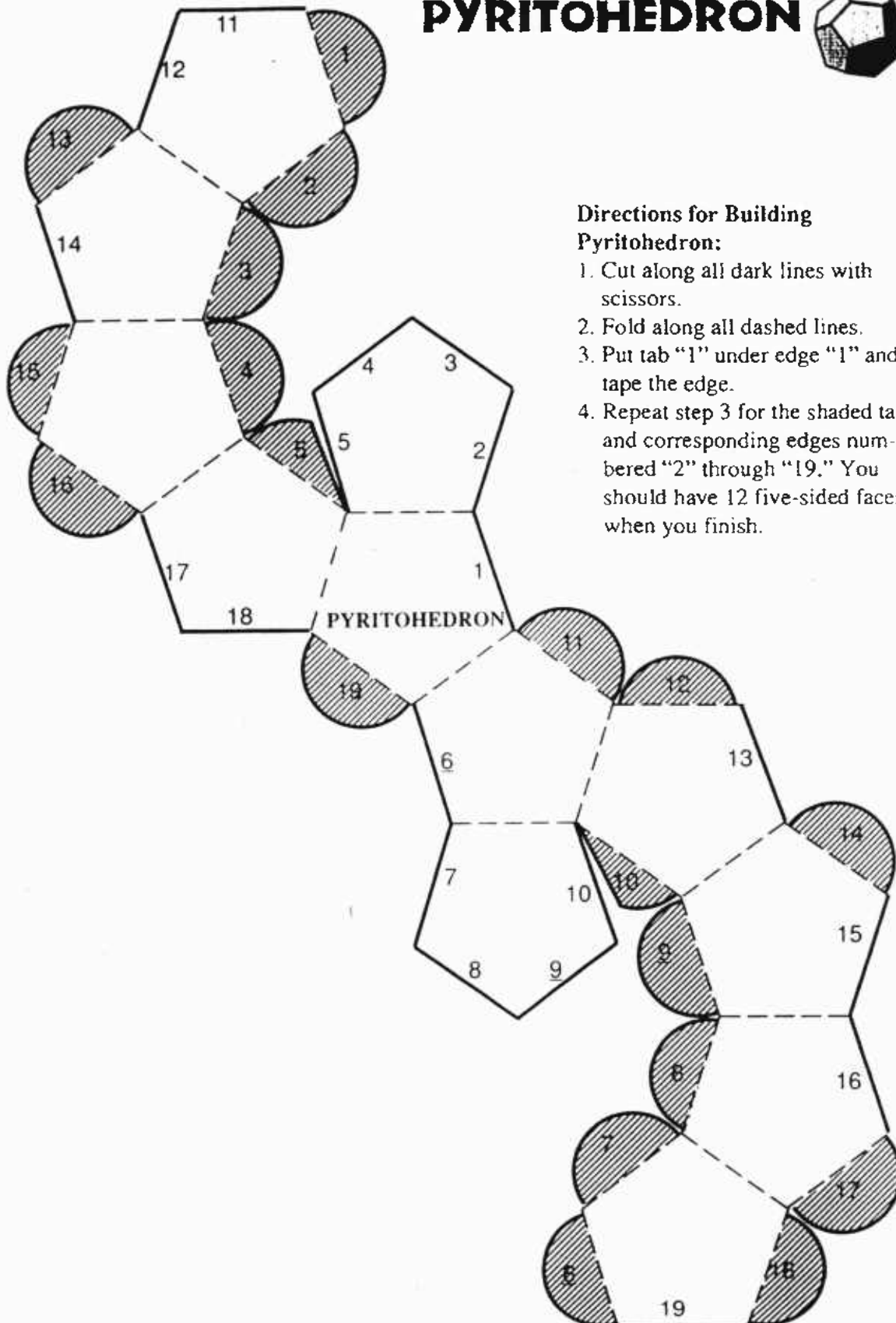


## Directions for Building Octahedron:

1. Cut along all dark lines with scissors.
2. Fold along all dashed lines.
3. Fold the shaded tab labelled "1" under the corresponding triangle corner labelled "1" and tape the edge.
4. Repeat step 3 with shaded tabs and corresponding triangles labelled "2," "3," "4," and "5." You should have 8 triangular faces when you finish.



# PYRITOHEDRON



## Directions for Building Pyritohedron:

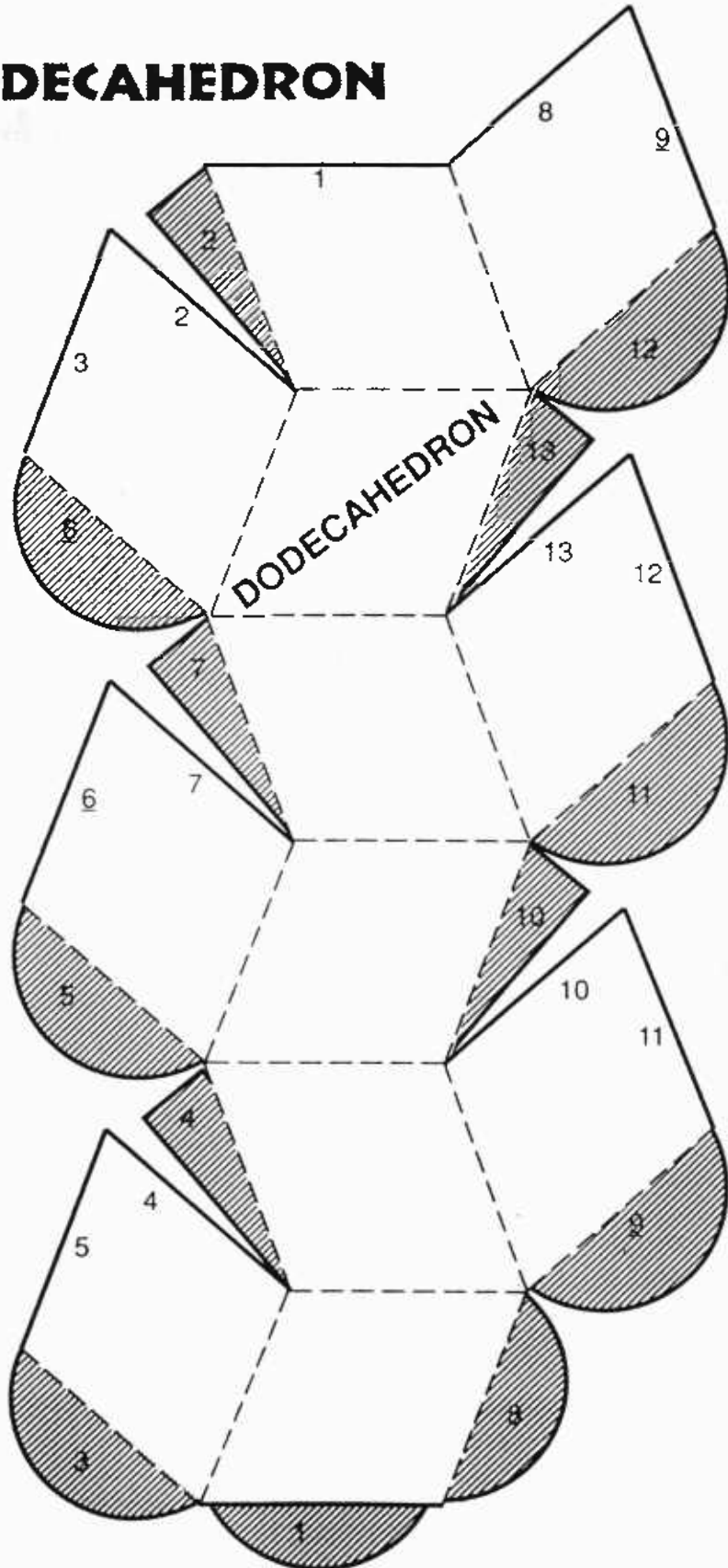
1. Cut along all dark lines with scissors.
2. Fold along all dashed lines.
3. Put tab "1" under edge "1" and tape the edge.
4. Repeat step 3 for the shaded tabs and corresponding edges numbered "2" through "19." You should have 12 five-sided faces when you finish.



# DODECAHEDRON

## Directions for Building Dodecahedron:

1. Cut along all dark lines with scissors.
2. Fold along all dashed lines.
3. Put shaded tab "1" under edge "1" and tape the edge.
4. Repeat step 3 for each shaded tab and corresponding edge. You should have 12 parallelogram-shaped faces when you finish.

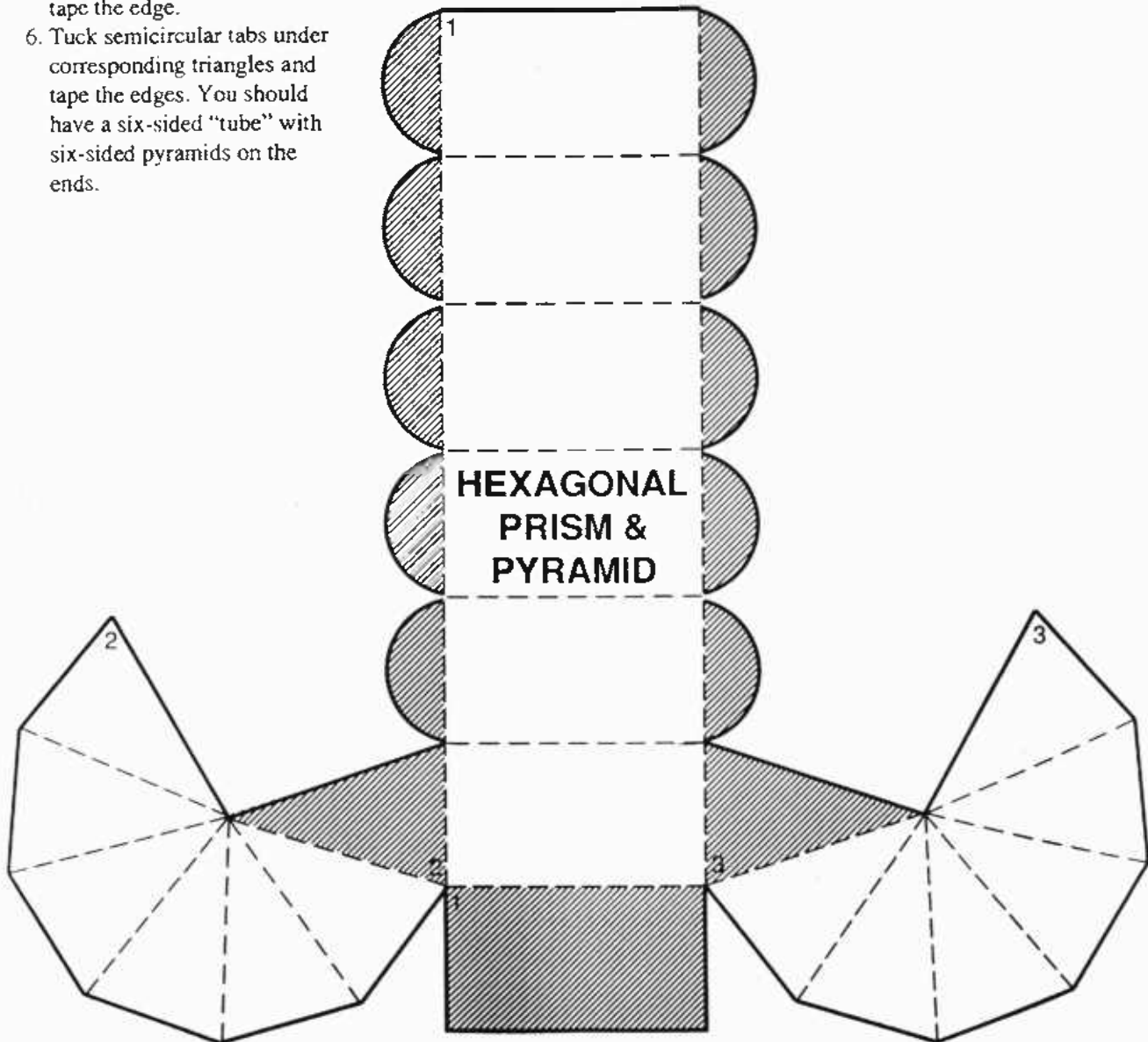




### Directions for Building

#### Hexagonal Prism & Pyramid:

1. Cut along all dark lines with scissors.
2. Fold along all dashed lines.
3. Fold the shaded rectangular tab labelled "1" under the corresponding rectangle corner labelled "1" and tape the edge.
4. Cover triangle labelled "2" with corresponding shaded triangle "2," and tape the edge.
5. Cover triangle labelled "3" with corresponding shaded triangle "3," and tape the edge.
6. Tuck semicircular tabs under corresponding triangles and tape the edges. You should have a six-sided "tube" with six-sided pyramids on the ends.





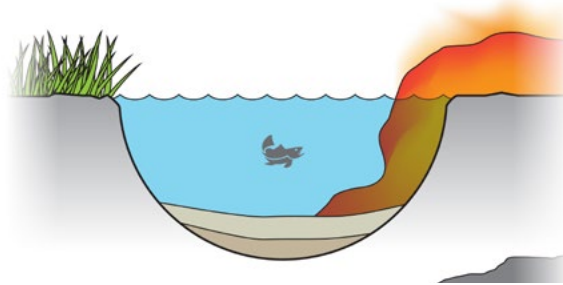


## 4. Creations of the Cretaceous

### Objectives

#### LEARNERS WILL BE ABLE TO:

- Distinguish between metamorphic, igneous, and sedimentary rocks
- Explain the relationship of sedimentary rocks to fossils
- Explain how a fossil is formed and some conditions needed for formation
- Explain where dinosaur fossils are found and why they are NOT found in Oregon
- Define a mineral
- Explain the relationship of minerals to rocks
- Explain (and demonstrate) some of the tests which may be used to distinguish among different minerals



#### NEXT GENERATION SCIENCE STANDARDS (NGSS) PRACTICES:

1. Asking questions
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data

### Field Trips

1. Mitchell Basin—from Mitchell to approximately 2.5 miles west on Highway 26, Gable Creek Road. Gable Creek Formation, a 9,000-foot-thick sequence of Cretaceous material interfingering with Hudspeth Formation marine shales containing abundant ammonites in some localities. Pterosaur and ichthyosaur remnants have been reported.
2. Dinosaur National Monument—Park Headquarters, Dinosaur, Colorado.

### Background

The movie series Jurassic Park was a huge success because children and adults are endlessly fascinated by “classic dinosaurs,” such as the Stegosaurus and the fearsome Tyrannosaurus rex. To find the fossils of “classic dinosaurs,” we must leave Oregon behind. If we travel east to the Utah-Colorado border we can find fossils of the vegetarian Apatosaurus, Diplodocus, and Stegosaurus at the Dinosaur National Monument. Fossils of the bones of the sharp-toothed carnivore Allosaurus are found here, too. These fossils are preserved in a layer of sediment called the Morrison Formation. A geologic formation is a layer (or unit) of rock with a similar composition, age, and origin.

It is believed that the fossil dinosaur bones found at Dinosaur National Monument were preserved when the dinosaurs, along with turtles, crocodiles, and clams, were washed by a huge flood onto a sandbar in an ancient river bed. When animals and plants are

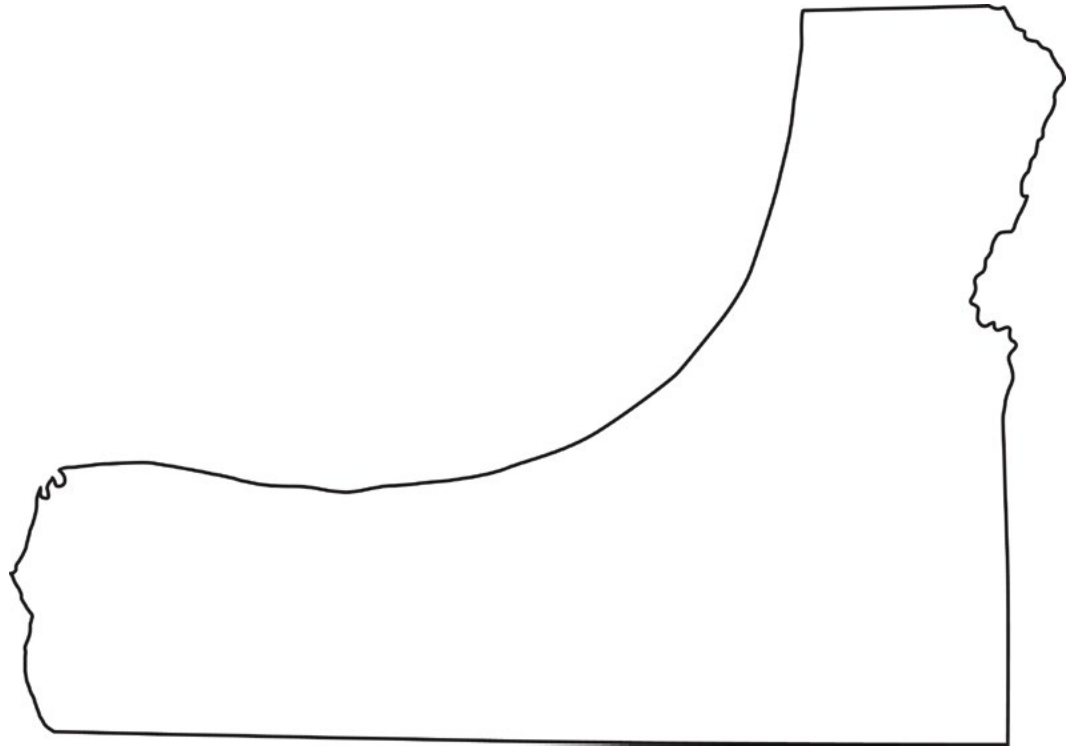


Figure 8. Cretaceous Oregon map shows hypothetical representation of Oregon in the Eocene Epoch.

buried quickly by sediment, their bones do not decay. They remain in the sediments to be mineralized and preserved. Over millions of years, thousands of feet of sediment layered on the bones, perhaps carried by the river and the ebb and flow of the sea. The sea that carried some of this sediment covered much of Oregon during the Jurassic and Cretaceous periods. Slowly, silica and calcium carbonate that was dissolved in water percolated through the sediment layers. Some of the silica-rich water was absorbed by the porous bones and shells. The silica hardened, turning the ancient river bed into sandstone and the bones and shells buried within to fossils.

By the Cretaceous period, 80 million years ago, Central Oregon was just beginning to show evidence of low-lying, marshy, nearly solid land. Much of Oregon still was covered by a bay or inland sea (Figure 8). Sediments being washed from the existing continent and the Blue, Willamette, and Klamath mountains were deposited in silty layers (Figure 4, page 12, and Figure 7, page 28). These conditions proved ideal for the formation of some of Oregon's own early fossils. The sandstone of the Hudspeth formation shows evidence of ammonites and fragments of a fishlike reptile, the ichthyosaur; and a flying reptile, the pterosaur, with a 10-foot wingspan. Plant fossils found include cycads and palm. These types of plants are found today in tropical climates, leading paleontologists to theorize that the climate of cretaceous Oregon was tropical.

Paleontologists are scientists who study fossils. Fossils generally are found in sedimentary rocks. They also may be found in the frozen ground in Arctic life zones or preserved in the resin of cone-bearing trees. Syrupy tree resin may flow over and cover insects or plant parts. When the resin hardens, it forms a translucent, rock-like material called amber. In Activity 4A, learners will create their own model of a fossil-rich conglomerate formation.

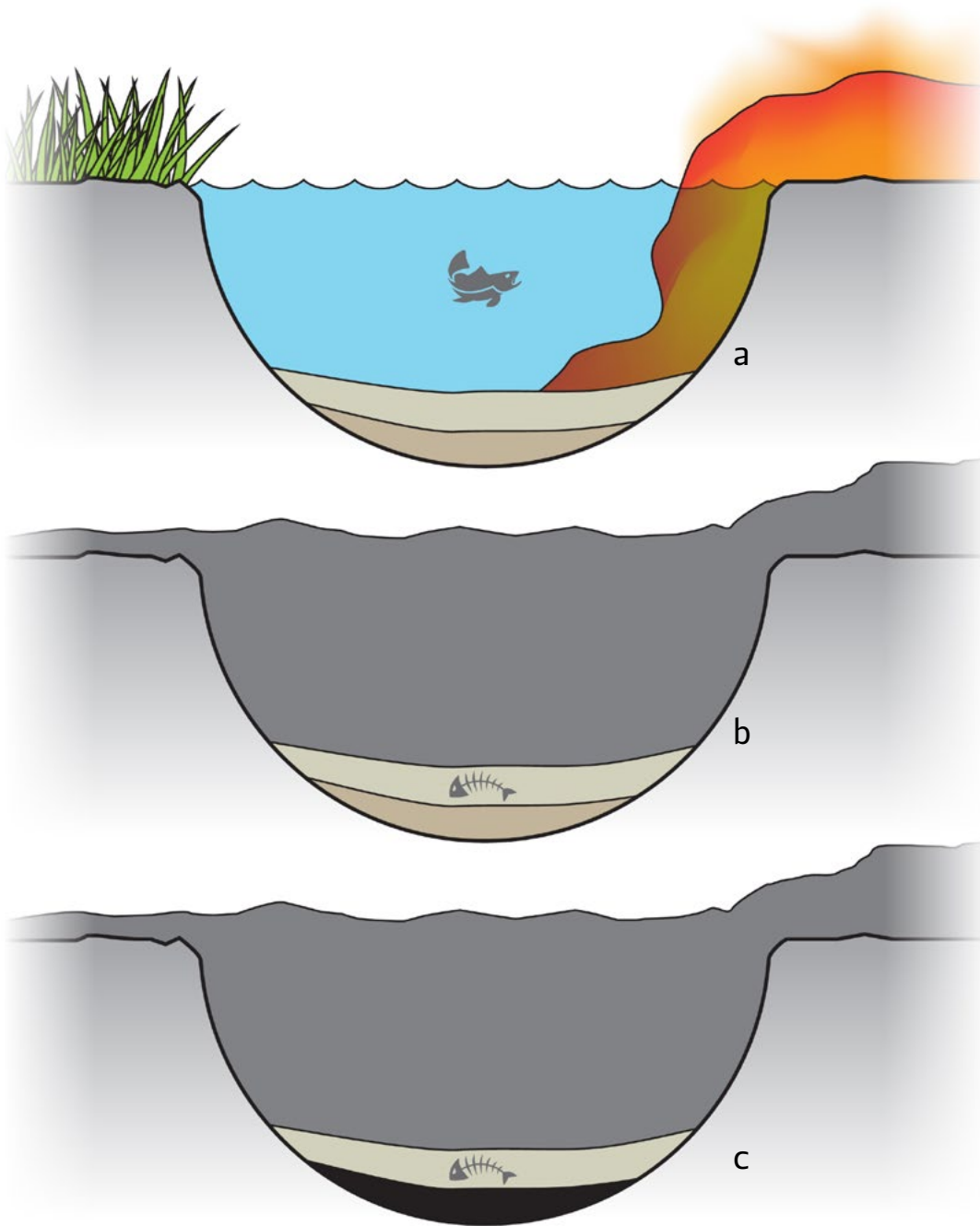


Figure 9. A pond over geologic time.



When paleontologists look for fossils, they begin by looking for sedimentary rock. Sedimentary rocks are composed of a variety of minerals and particles of gravel, sand, clay, and silt, which are carried by water into low-lying areas generally associated with rivers, lakes, and oceans. When layer upon layer of material is deposited, the pressure on the lower layers increases with the weight of each succeeding layer. Eventually, with the help of cement from silica, calcium carbonate, or clay, sedimentary rocks are formed. This creates an excellent environment for preserving fossils.

Over geologic time, a pond may be covered and completely buried by a lava flow that hardens into basalt (Figure 9a, page 43), an igneous rock. Igneous rocks result from hot, melted magma that originates deep within the Earth. The word “igneous” comes from the Latin “ignis” for fire. The word “ignite” has the same root. As more time passes, the sediments of the former pond, which are now under a layer of basalt, are compressed into sandstone. Fish skeletons and snail shells are mineralized. A fossil-rich layer of rock is created. This tiny layer of sedimentary rock may be sitting on top of a layer of black shale. Shale is a sedimentary rock that develops from fine-grained deposits in deep, quiet, water environments (Figure 9b).

More time passes. The shale is metamorphosed into slate. Metamorphic rocks, such as slate, are created when the characteristics of sedimentary or igneous rocks are changed primarily by heat and pressure (Figure 9c).

As you can see, identifying the origin of rocks is not always simple. If a road were cut through the layers of rock described above, we would see a small, tan stripe of sedimentary rock sandwiched between a layer of black metamorphic slate rock on the bottom and black igneous basalt rock on top. Rocks are divided into one of the three classes—sedimentary, metamorphic, or igneous—based on the process that created them. Not all rocks are solid. Oil and natural gas, two of the most economically important geologic materials, occur as a liquid and a gas. Oil and natural gas usually are trapped in sedimentary rocks. Additional classification of rocks requires identification of the types of minerals they contain. To identify the characteristics of minerals, a mineral test kit is helpful, as learners will see in Activity 4B.

See also “Oregon: A Geologic History, Oregon’s First Coast” at <http://www.oregongeology.org/sub/publications/IMS/ims-028/unit03.htm>



## Activity 4A—Sedimentary Rocks and the Preservation of Fossils

### MATERIALS

- Plaster of Paris (NOTE: Use the real product, not a craft plaster.)
- Sand (can be sandbox sand, available from a toy store or home-improvement store)
- Water
- Earth color (brown, gray, black) liquid acrylic craft paints (optional)
- Supply of seashells or other items to become “fossils.” Fossil model casts made from plastic can be ordered from an educational science supply company.

One set per team of two learners:

- Clear plastic disposable “party” cups
- Dental picks (obtain used from a dentist’s office)
- A set of small chisels, or nails modified on a grinder to have a chisel surface.
- Stiff toothbrush
- Small craft paintbrush

### PREPARATION

Create a dry mixture of two parts sand to one part Plaster of Paris. For young learners, you may wish to make the Fossil Formation cups prior to the activity. Small aquarium gravel can be used in one or more of the formation layers to create a model conglomerate.

Mix several small batches of sand-plaster mix with water and the selected color of acrylic paint. The colored sandy plaster is then ready to be poured, one layer at a time, representing layered rock formations, into the clear cups. Press seashells or model fossils into one formation layer of wet plaster. Be sure that the “fossils” are resting inside a formation layer and not in the contact between different formations. Cover the items with a thin layer of sand; the layer should be thin enough to still see the outline of the items. This makes it easier to separate the layers and locate the fossils when the time comes.

After the plaster layers are poured, the models should sit at least 1 day to harden completely before learners dig out their fossils. (Photo 6)



Photo 6



## PROCEDURE

Using the information presented in the Background section, lead a discussion about how fossils are formed: Where are fossils likely to be found? Why are they important to our understanding of how animals, plants, and climates have changed over geologic time? Have learners seen rocks that look like they were layered? Review how sedimentary, igneous, and metamorphic rocks are formed by referring learners to the Rock Cycle worksheet on page 31.

Older learners will make their own Fossil Formation cups by layering the sand-plaster and shells in the clear cups, following the directions in the “Preparation” section. As you pour the succeeding layers of plaster, ask learners how many millions of years each layer took to be deposited. A layer of rock of similar age and composition may be given a formation name. For example, the dinosaur fossils at Dinosaur National Monument are found in the Morrison Formation. Learners may want to name the formation layers they are creating in their cups. The “sediment” (Plaster of Paris mixture) in the model hardens very quickly. Be sure that learners understand it takes millions of years for sediments to harden into rock and for fossils to be preserved—even though the original animal or plant may have been covered very quickly.

When it is time for learners to “dig up” their fossils, cover the work table with newspapers to collect the sediment. Each team should take their plaster model out of the clear cup to work on finding their fossils. Learners will need the tools, brushes, and a lot of patience to dig out their fossils without breaking them. Ask learners how long they think it takes to dig up something like a dinosaur bone.

## DISCUSSION

Ask learners how this activity was similar to the preservation of fossils in nature. How was it different?

## EXTENSION

Fossil-collecting locations of various ages are located across Oregon. Plan a day trip to a fossil location near you. Check with landowners or resource managers to see if fossil collecting is allowed.

## Reference

*Oregon Fossils* (Second Edition), Elizabeth Orr & William Orr. Oregon State University Press, 2009



## Activity 4B—Identifying Rocks and Minerals

### MATERIALS

For each team of learners:

- One mineral test kit—check your school or ESD supplier or order from an educational supply company such as Acorn Naturalist. Kit should include: for hardness test, a nail, a copper penny, and a piece of glass; vinegar; a magnet; a streak plate; and a hand lens.
- A supply of rocks and minerals to be investigated—can be ordered from a scientific supply company. Should include samples of igneous, metamorphic, and sedimentary rocks.
- A copy of the Rock and Mineral Data Sheet for each two specimens to be identified (pages 49 and 50)
- Egg boxes, cigar boxes, shoe boxes, or Ziploc® bags for storing rocks
- Labels
- Hand lens
- Rock and mineral field guides and reference books

### FYI

To learn to identify rocks, learners must study the physical properties of minerals and geologic processes that form rocks. Rocks are divided into three main groups, called “classes,” based on the three geologic, rock-forming processes. By now, the names of these three classes should be familiar to learners. The three classes are sedimentary, metamorphic, and igneous rock. Refer to the Rock Cycle worksheet on page 31 in Activity 3A.

Sedimentary rocks have round grains that may look layered; the silt, sand, and/or clay is compacted and cemented to create the rock. Sandstone and shale are examples of sedimentary rock.

Metamorphic rocks have a sheet-like texture; they may be compact and banded, and are very hard. Marble and slate are examples of metamorphic rock.

Igneous rocks have interlocking grains with angular, sharp shapes. Igneous rocks that cool slowly have large crystals. Examples of igneous rock are basalt and granite. Faster cooling may cause the formation of tiny crystals or no crystals at all, as in basalt (see Activity 7B).

Rocks are a mixture of minerals. A single rock may not have the same mixture of minerals all the way through, and the size of the mineral crystals may change, too.

Characteristics that define minerals include:

- 1) The elements in a mineral are bound together in a repeating pattern that determines the specific shape of a mineral crystal.
- 2) Minerals have a distinct inorganic chemical composition. Most minerals are compounds of several elements.
- 3) Minerals are nonliving.
- 4) Minerals occur in a solid state at room temperature.
- 5) Minerals occur naturally on Earth.
- 6) Minerals have distinct physical properties.

The identification of minerals is like being a detective. Through a series of basic tests, the properties of the mineral are determined, and possibilities are eliminated one by one until the mineral is identified. Minerals are commonly tested for color, luster, shape



(crystallization), hardness, specific gravity, streak, cleavage, and any additional unusual properties with a mineral test kit.

*Hardness*—Most mineral test kits use the Mohs Hardness Scale. Friedrich Mohs was a German scientist who invented a scale for comparing hardness among minerals. The Mohs scale runs from 1 (talc) to 10 (diamond).

Common testing tools for the Mohs Hardness Scale include:

- fingernail = 2.5
- penny = 3.0
- nail = 5.0
- glass = 5.5
- steel file = 6.5

*Color*—some minerals have a characteristic identifying color.

*Streak*—This is the color a mineral makes when scratched on a rough surface. In the test kit, a rough ceramic plate is used to test streak color.

*Shape*—The specific shape of a mineral crystal is characteristic of its component elements (Activity 3B).

*Luster*—A description of the way a mineral's surface looks in reflected light. Is it pearly, metallic, dull?

*Specific gravity*—This is the comparison of a mineral's weight to the same volume of water. Specific gravity does not change. Quartz has a specific gravity of 2.6. That means it weighs just over 272 times the weight of the same volume of water.

*Cleavage*—The shape a mineral takes when it is broken.

Unusual properties include taste, such as in salt; odor, such as in sulfur; fluorescence under an ultraviolet light; or magnetism. Vinegar is used for testing lime minerals such as calcite.

### PREPARATION

Order a supply of rocks and minerals for learners to investigate in this activity. If possible, provide one set for each team of four learners. A set might include:

- minerals—halite, quartz, and galena
- igneous rocks—basalt, granite, and obsidian
- sedimentary rocks—limestone, shale, and conglomerate
- metamorphic rocks—slate and schist.

This set also will be needed in Activity 7B.

### PROCEDURE

Learners should investigate the rocks and minerals provided until they are all identified. If a full set of rocks and minerals is not available for each team, teams may be assigned to identify a few at a time and then exchange with another team. The teams can report on their investigation techniques and results with the full group.

Learners should record their research results on a Rock and Mineral Data Sheet for each sample. Remind learners that in Activity 1B, the action of vinegar on limestone and basalt was compared. What happened? Try placing some vinegar on a seashell. What happens? Why?





## Rock and Mineral Data Sheet

The sample is a/an:

\_\_\_\_\_ Sedimentary rock

\_\_\_\_\_ Metamorphic rock

\_\_\_\_\_ Igneous rock

\_\_\_\_\_ Mineral (*continue below*)

### CHARACTERISTICS OF SAMPLE MINERAL

Hardness—the sample can be scratched with:

- |   |     |    |
|---|-----|----|
| <input type="checkbox"/> a fingernail, hardness 2.5 | Yes | No |
| <input type="checkbox"/> a penny, hardness 3.0      | Yes | No |
| <input type="checkbox"/> a nail, hardness 5.0       | Yes | No |
| <input type="checkbox"/> glass, hardness 5.5        | Yes | No |
| <input type="checkbox"/> steel file, hardness 6.5   | Yes | No |

Color: \_\_\_\_\_

Streak: \_\_\_\_\_

### Additional Unusual Properties

Is it magnetic? Yes No

Bubbles with vinegar? (Contains lime) Yes No

Crystal shapes visible—use cardboard crystal models to compare:

\_\_\_\_\_ Cube

\_\_\_\_\_ Hexagonal Prism

\_\_\_\_\_ Tetrahedron

\_\_\_\_\_ Octahedron

\_\_\_\_\_ Dodecahedron

\_\_\_\_\_ Pyritohedron



## Rock and Mineral Data Sheet

The sample is a/an:

\_\_\_\_\_ Sedimentary rock

\_\_\_\_\_ Metamorphic rock

\_\_\_\_\_ Igneous rock

\_\_\_\_\_ Mineral (*continue below*)

### CHARACTERISTICS OF SAMPLE MINERAL

Hardness—the sample can be scratched with:

- |   |     |    |
|---|-----|----|
| <input type="checkbox"/> a fingernail, hardness 2.5 | Yes | No |
| <input type="checkbox"/> a penny, hardness 3.0      | Yes | No |
| <input type="checkbox"/> a nail, hardness 5.0       | Yes | No |
| <input type="checkbox"/> glass, hardness 5.5        | Yes | No |
| <input type="checkbox"/> steel file, hardness 6.5   | Yes | No |

Color: \_\_\_\_\_

Streak: \_\_\_\_\_

### Additional Unusual Properties

Is it magnetic? Yes No

Bubbles with vinegar? (Contains lime) Yes No

Crystal shapes visible—use cardboard crystal models to compare:

\_\_\_\_\_ Cube

\_\_\_\_\_ Hexagonal Prism

\_\_\_\_\_ Tetrahedron

\_\_\_\_\_ Octahedron

\_\_\_\_\_ Dodecahedron

\_\_\_\_\_ Pyritohedron

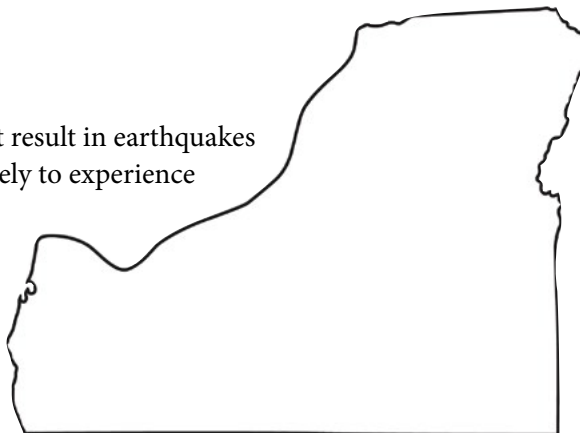


## 5. The Exciting Eocene

### Objectives

#### LEARNERS WILL BE ABLE TO:

- Explain some geologic processes that result in earthquakes
- Explain why some areas are more likely to experience earthquakes than others
- Understand relationships of earthquakes to mountain building, faults, and folding
- Explain the tectonic relationship to some mountain building
- Name one or more types of faults



#### NEXT GENERATION SCIENCE STANDARDS (NGSS) PRACTICES:

1. Asking questions
2. Developing and using models
6. Constructing explanations
8. Obtaining, evaluating, and communicating information

### Field Trips

1. Mary's Peak—Oligocene pillow basalt, Mary's Peak Road, USFS 30. Information at Alsea Ranger District (USFS).
2. Cape Perpetua to Heceta Head—Hwy 101, rocky coastline of headlands and coves, lava flows that erupted underwater in the Eocene.
3. John Day Fossil Beds National Monument—Clarno Unit. Information from Cant Ranch Visitors Center.

### Background

In Oregon, geologic time seems to have flowed directly from the Cretaceous Period to the Eocene Epoch, skipping the Paleocene epoch altogether. It has been suggested that during the Paleocene period, the erosion of rocks was more prevalent than any building processes. Whatever was happening between 54 and 60 million years ago, little record of it is preserved in Oregon. The Eocene epoch ushers in the start of some significant changes in Oregon's geology and topography that in turn created changes in the climate, plants, and animals. The North American plate continued moving slowly westward. In the early Eocene, there was a wide coastal margin. Moist air from a warm, tropical Pacific Ocean moved east over land without the barrier of the Coast Range or Cascade Mountains (Figure 10, page 52).

Off the continental coast, where the Coast Range is today, a chain of underwater seamounts was building. These volcanic mounts released lava into the water. The lava quickly chilled and solidified, forming characteristic balls with glassy exteriors and interiors marked by radial cracks called pillow basalt. These pillow basalts are the foundation of the Coast Range. The growth of the seamounts off the coast created a shallow sea floor area where sediment eroding from the continent slowly collected.

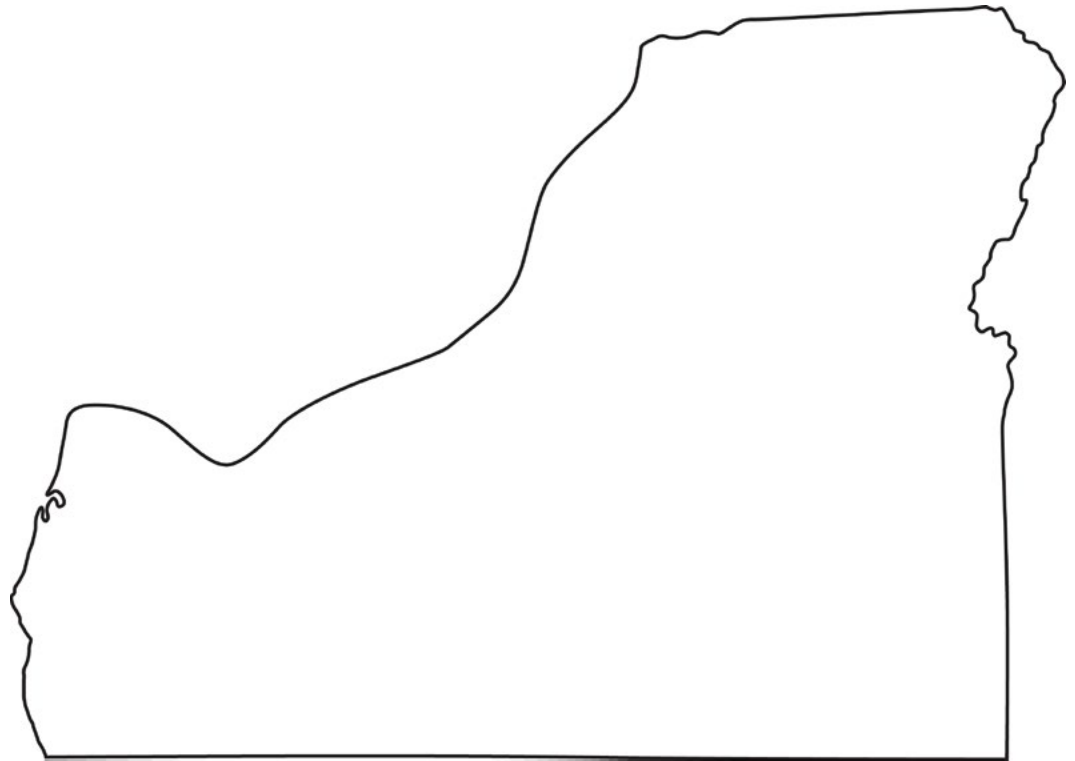


Figure 10. Eocene Oregon map: A hypothetical representation of Oregon in the Eocene Epoch.

In the western Blue Mountain Province (Figure 4, page 12), the Clarno volcanoes developed in a curving line that was about 70 miles inland from the Eocene coastline. These volcanoes erupted andesitic and rhyolitic lava that produced fine-grained, light-colored igneous rocks. Vast quantities of loose ash also erupted from volcanic vents. The ash mixed with water, forming mudflows that poured down slopes with the consistency of syrup. Some Clarno mudflows solidified into sandstone and claystone deposits more than 1,000 feet thick. The liquefied ash provided perfect conditions for preserving a fossil record of the plants and animals that were unlucky enough to be in the mudflow's path. The fossils tell of grasslands and wet subtropical forests of avocados, pecans, figs, and palm trees. Animal bones were preserved, including alligators, tapirs (*Protapirus*), brontotheres (*Telmatherium*), rhinoceros (*Hyrachyus*), and tiny, four-toed horses (*Orohippus*).

In the late Eocene, the coastline shifted farther west, closer to the present-day coastline. This shift was the result of complicated tectonic activity, with plates rotating in a northerly as well as westerly direction. A shift in the location of the subduction zone ended the activity of the Clarno Mountain volcanoes. Learners will be introduced to the geologic processes involved in folding, faulting, and earthquakes in Activities 5A and 5B.

See also "Oregon: A Geologic History, Early Volcanic Arc: Oregon's tropical volcanoes" at <http://www.oregongeology.org/sub/publications/IMS/ims-028/unit05.htm>, and "Cascadia Subduction Zone Earthquakes" at <http://www.oregongeology.org/sub/publications/IMS/ims-028/unit20.htm>



## Activity 5A—Mountain Building: Folds and Faults

### MATERIALS

- Purchase a supply of craft foam sheets, 11½ inches x 17½ inches. This is sold under brand names such as Fun Foam or Flexi-Foam. Any brand will do. Sheet colors to purchase: one light green, two brown, four blue, four yellow, and three red. NOTE: If only dark Christmas green foam is available, purchase one yellow (instead of light green) and four dark green (instead of yellow) sheets. It is important that the top sheet of foam in the models be light enough to write on with felt pens.
- Craft glue
- Scissors or craft knife
- Permanent, fine-point felt pens, assorted colors
- Pair of chopsticks
- World atlas

### PREPARATION

Gather all the materials listed above. The instructions that follow are for the construction of the fold-and-fault models to be used in Activity 5A and the base of the earthquake model to be used in Activity 5B. If the supplies budget allows, make additional sets of models, one for each team of four learners. Set aside one sheet each of the blue, brown, and yellow foam. Learners will use these to create buildings for the earthquake model in Activity 5B.

Cut each of the remaining 11 sheets for the earthquake, fold, and fault models, following the measurements below. NOTE: These measurements are designed for foam sheets measuring 11½ inches x 17½ inches. If your foam sheets are a different size, adjust the cutting lines to maximize use of the material.

From each foam sheet, cut:

- One large rectangle, 5½ inches x 17½ inches. This is the Earthquake Model.
- One long rectangle, 2 inches x 17½ inches. This is the fold model.
- Set aside the remaining material and complete these first two models.

Sort the foam pieces by size. Begin with all the large rectangle pieces (5½ inches x 17½ inches) for the earthquake model. Stack the foam rectangles as follows: Three red, three yellow, three blue, one brown (simulated soil), one green (simulated grass) (Photo 7, page 54).

Glue the rectangles together in the order listed. Set the model aside to dry for at least 48 hours. This completes the base for the earthquake model used in Activity 5B.

To create the fold model, select the set of long rectangular pieces (2 inches x 17½ inches). Stack them and glue them in the order given above for the earthquake model. Set the model aside to dry for 48 hours. No further work is needed on the fold model.

To create the fault models, cut 6-inch x 4-inch pieces from the 11 sheets of foam. There should be enough material to make two sets of fault models. Repeat the procedures as for the other two models, stacking the 6-inch x 4-inch pieces in the same order as before. Glue the stack together.

When the glue has dried on the fault models, you will need a table saw or power saw to cut them into two pieces. The cut will be at an angle to the upper and lower surfaces of the model. One side should measure approximately 3½ inches on the green layer to 2½ inches on the final red layer. The other side should measure approximately 2½ inches on the green layer and 3½ inches on the final red layer. (Photo 8, page 54)



Photo 7: How to stack the rectangles

Once the fault models are cut, place the two foam blocks on a solid surface with the angle cut sides together. Write a 1 on the blue strip on the left. Write a 2 on the yellow strip on the right (Photo 8). On the opposite end of the blocks, write a 3 on the blue strip on the left. Write a 4 on the yellow strip on the left (Photo 12, page 57).

On the light green top of both blocks, draw a river in blue and a road in black. With the ends of the two blocks joined, the river and road should proceed continuously across both. Write the number 5 on the left block approximately a half-inch from the short edge of the



Photo 8: How to measure the layers



model. Write a number 6 on the right block approximately 3 inches from the short edge of the model (Photo 14, page 58).

## Part 1: Folds

### FYI

The world's greatest mountain ranges are fold mountains that were created when the Earth's crust responded to enormous forces. Remind learners what they learned about the causes of continental movement and the four types of tectonic plate boundaries in Chapter 2.

When two tectonic plates collide at a convergent boundary, the kind of lithosphere involved determines how the plates and crust react to pressure. The Andes Mountains are created by the oceanic plate pushing into the South American plate. The oceanic plate is being subducted under the continent and, at the same time, the overriding South American plate is being uplifted. Strong, destructive earthquakes and the rapid uplift of mountain ranges are common in this region. When the subducting plate stops sinking smoothly, it may be locked in place for long periods before suddenly moving to generate a large earthquake.

Oceanic-continental convergence also sustains many of the Earth's active volcanoes, such as those in the Andes Mountains and Oregon's Cascade Range. The eruptive activity is associated with oceanic subduction (Figure 6, #5, page 19). The Himalaya Mountains are created by two continental plates meeting head on; neither is subducting. Instead, the crust is buckling upwards and sideways.

Folds do not always create huge mountains. Sometimes, more modest folds create hills. In addition to being pushed up in an arch, called an anticline, rocks also may fold down, creating valleys. These downfolds are called synclines. (Photo 9)

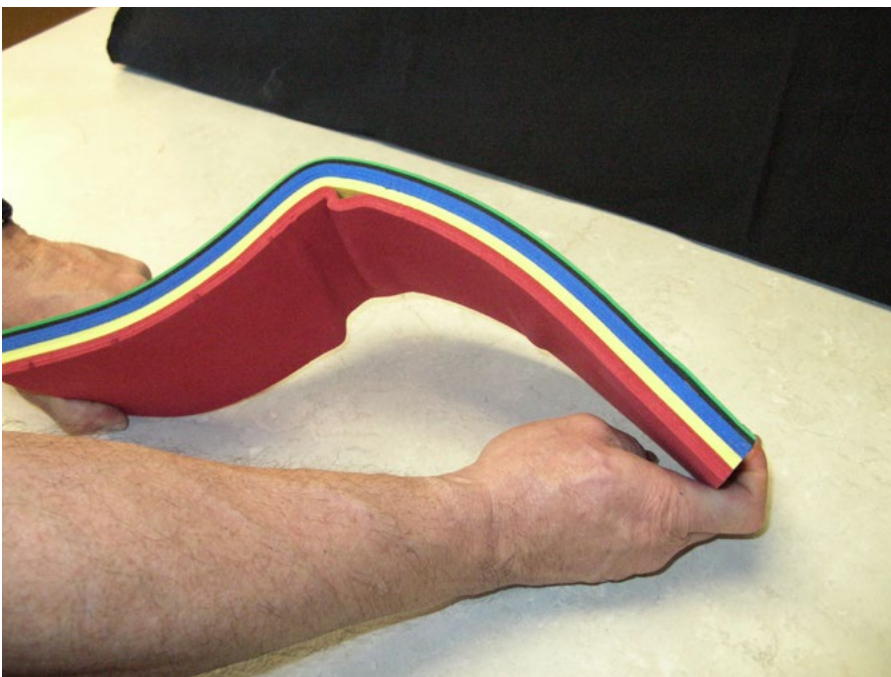


Photo 9: Modest folds create hills or valleys.



## PROCEDURE

Use the fold model to demonstrate how rocks respond to pressure. Place the fold model on a flat surface. Hold about 2 inches of each end down firmly against the surface. At the same time, press the ends toward each other. An anticline will be created. Ripples may be created in the foam layers as they respond to the various pressures. Notice how much pressure is needed to move the model into the arch position. Have pairs of learners try creating anticlines. Use the world atlas to locate fold mountain ranges.

## Part 2: Faults

### FYI

Sometimes the Earth's crust does not bend in response to the gradually accumulating energy of the plates. Sometimes it breaks. Faults are fractures in the Earth's crust where two blocks of rock move relative to each other. Once the Earth's crust has cracked, a zone of weakness is created. Additional motion, experienced as earthquakes (Activity 5B), may be expected on known fault lines.

Strike-slip faults occur where two tectonic plates are sliding horizontally past one another. These transform plate boundaries are most commonly found on the ocean floor, where they offset active spreading (crust-producing) ridges, creating zigzag plate margins (Figure 6, #1, page 19). On land, the most famous example of action by transform plate boundaries is the strike-slip San Andreas fault in California. It is actually a series of faults that extend from the Gulf of California to north of San Francisco. In a few million years, if movement continues as it is now, Los Angeles will be located directly west of San Francisco. A few more million years later, it will be north of San Francisco.

Normal faulting generally is associated with spreading zones and divergent plate boundaries. Thrust faulting is associated with subduction zones, convergent plate boundaries, and volcanic activity (Figure 6, #3a, #5, page 19).

## PROCEDURE

Use the Fault models to demonstrate how blocks of rock can move in relation to pressure. Using these modes, a strike-slip fault, normal fault, and thrust fault can be demonstrated.

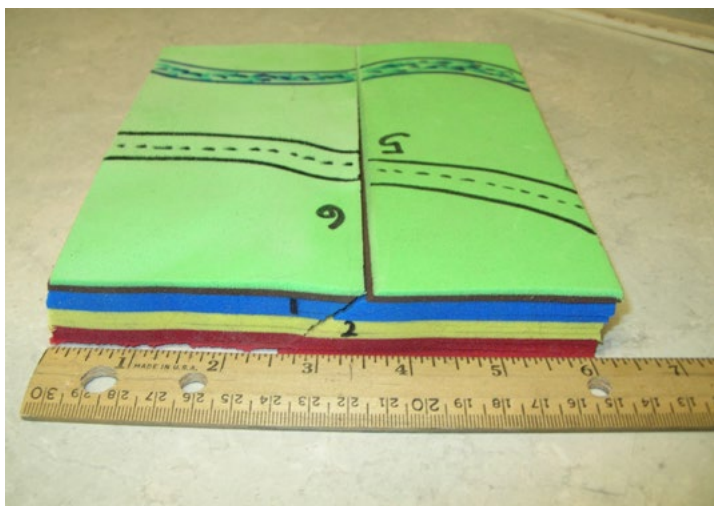


Photo 10. Set the folds on a flat surface.

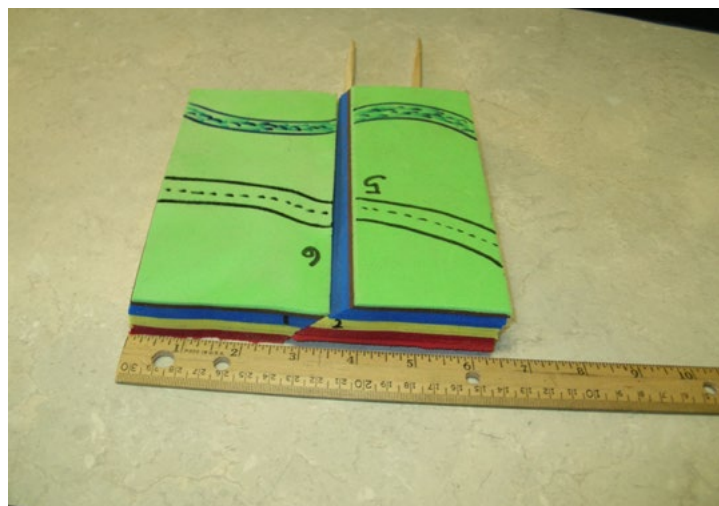


Photo 11. Use chopsticks to raise the right block so that point 2 and 1 are opposite each other. This is a normal fault.



- a) *Normal Faults*. Set the models on a flat surface. (See Photo 10.) Learners should notice that the models together are approximately 6 inches wide. Use the chopsticks to raise the right block so that points, 2 and 1 are opposite each other. (See Photo 11.) Notice that the model is now wider than before. This demonstrates a normal fault. Normal faults occur when rocks are pulled apart in response to tension.

The Owyhee Uplands and Basin and Range physiographic provinces in southeastern Oregon are in the northwest corner of the Great Basin (Figure 4, page 12). In this area, the Earth's crust is being stretched. In Oregon, this stretching may have reached as much as twice the original width of the land surface. In response to these forces, faulting has created the features seen today as Steens Mountain, Owyhee Canyon, Hart Mountain, and Abert Rim. At Steens Mountain, the same Steens Mountain Basalt layer that caps the mountain underlies the Alvord Desert's playa sediments. The east face of Steens Mountain rises 9,774 feet above the floor of the Alvord Desert.

Ask learners to discuss the model. What has happened to the road and river? What happened to the rock layers? Are the layers still continuous?

- b) *Thrust Faults*. Set the models on a flat surface. (See photo 12.) Learners should notice that the models together are approximately 6¼ inches wide. (Because the models are handmade, these measurements may differ.) Use the chopsticks to raise the right block so that points 4 and 3 are opposite each other. (See photo 13.) Notice that the model is now more narrow than before.

This demonstrates a thrust or reverse fault. A thrust fault results from rocks compressing in response to stress. Thrust faults can happen in association with subduction zones where two plates are squeezing together.

The volcanic seamounts, pillow basalt, and sediment that originated on the Eocene-Age ocean floor off Oregon now form the top of the Coast Range. The sinking sea floor scraped the seamounts and sediments it carried onto the edge of the continent. In some locations, a large piece of sea floor basalt cropped out in the growing mountains. Through the action of folding and thrust faults at the advancing continental edge, the Coast Range continues to rise today.



Photo 12. The thrust model before the uplift.

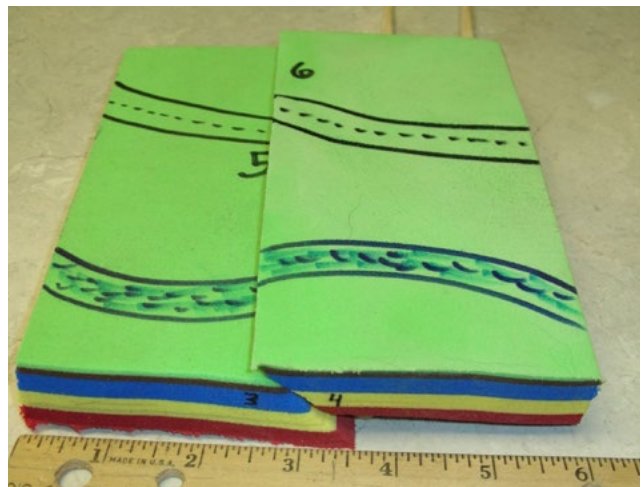


Photo 13. Use the chopsticks to raise the right block so that points 3 and 4 are opposite each other. This is a thrust fault.



c) *Strike-Slip Fault*. Place the two Fault model blocks end to end on a flat surface. The river and road on the green top surface should be aligned (photo 14). Move the blocks until point 5 is next to point 6 (photo 15). This demonstrates a strike-slip, or tear fault.

Ask learners: What happened to the road and the river? What happened to the green, brown, blue, yellow, and red rock layers? Are the layers still continuous?

Ask learners to discuss the model. What has happened to the road and river? What happened to the rock layers? Are the layers still continuous?

## Reference

*This Dynamic Earth—The Story of Plate Tectonics*, U.S. Department of the Interior, U.S. Geological Survey.

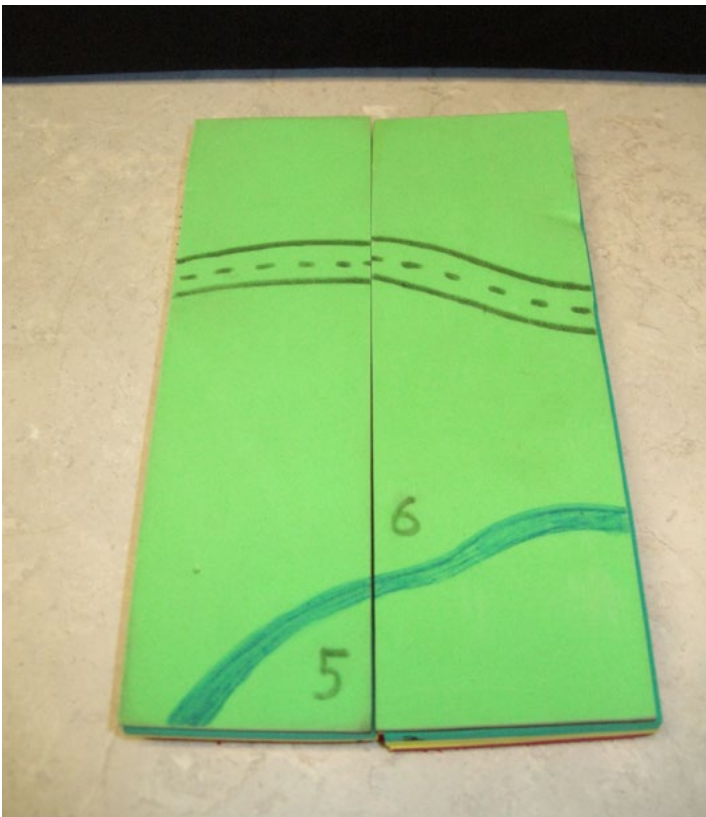


Photo 14



Photo 15



## Activity 5B—Earthquakes!

### MATERIALS

- Earthquake model, large rectangle craft foam stack (5½ inches x 17½ inches) constructed in Activity 5A
- One sheet each of blue, brown, and yellow craft foam. These are in addition to the earthquake model's sheets
- Permanent, fine-point felt pens, assorted colors
- Box of sewing straight pins
- Hammer
- Large, coil-type spring or “Slinky” toy
- One copy per team of the individual maps specified below:
  - From the online resources at Portland State University's (PSU) Center for Geographic Information, purchase copies of the *Student Atlas of Oregon* (available in English and Spanish) from <https://www.pdx.edu/geography-education/instructional-materials-0> or
  - Download and print maps from <https://www.pdx.edu/geography-education/student-atlas-of-oregon>, click on the Table of Contents link.
- or
- PowerPoint slides can also be created from the maps to project as needed throughout the activity. Take a screen print of your computer screen, paste it onto a PowerPoint slide and crop out any unwanted areas.
  - a. Pacific Northwest Plate Tectonics, page 17
  - b. Natural Hazards: Earthquakes, page 18

### FYI

When the Earth's crust responds to pressure by folding or faulting, a huge amount of energy is released. The crust may move suddenly when previously stuck tectonic plates build up enough pressure to suddenly move past each other. The *Student Atlas of Oregon* Pacific Northwest Plate Tectonics map has arrows indicating how the plates are moving in relation to each other.

When plates slip and faults occur, shock waves of energy are sent out in all directions through the Earth. These are called seismic waves. On the surface, these waves are felt as earthquakes. The epicenter of an earthquake is the point on the surface directly above the focus. The focal depth is the depth from the Earth's surface down to the focus, the area where the earthquake's energy originated.

Earthquakes generated beneath the ocean floor can cause massive sea waves called tsunamis. The waves can travel at speeds up to 600 miles per hour. They generally are not destructive at sea. As they reach the shallow water along coastal margins, they can reach heights of 100 feet, engulfing coastal areas when they reach land.

The severity of an earthquake can be expressed in terms of both magnitude and intensity. Scientists use the Richter Magnitude Scale to measure and compare the amount of energy released by an earthquake. The Modified Mercalli Intensity Scale is being used in the United States to quantify the observed effects of ground shaking on people, buildings, and natural features.

A Richter Magnitude Scale measurement of 4.5 or above probably means damage will



have occurred to roads and buildings. However, an earthquake's destructiveness depends on factors such as the focal depth, the distance from the epicenter, the type of rock or soil material at the surface, and how buildings and other structures are designed. The Modified Mercalli Intensity value assigned to a specific site after an earthquake is a more meaningful measure of severity to a nonscientist than the magnitude, because intensity refers to the effects actually experienced at that place.

Earthquakes produce two classes of seismic waves: surface waves and body waves. Surface waves travel through the rock near the Earth's surface. They are slower than body waves, have the strongest vibrations, and probably cause most of the damage associated with an earthquake. The vibrations of body waves precede the surface waves to reach the surface first. They travel at high speed through deeper, denser rock within the Earth. There are two types of body waves: compressional waves, also called primary (P-) waves; and shear waves, also called secondary (S-) waves.

### **PREPARATIONS**

It will be helpful if learners have completed Activity 5A before beginning this activity. The construction of the earthquake model to be used in this activity was explained in the Preparations section of Activity 5A.

### **PROCEDURE**

Provide one copy per team of the Pacific Northwest Plate Tectonics map and the Natural Hazards: earthquakes map or create PowerPoint slides to project for the discussion. Present the relevant information from the Background and FYI sections. Note where tectonic plates meet and where earthquakes occur. What is the relationship?

### **Part 1: Shake**

Use the earthquake model to demonstrate how buildings and roads may respond to earthquakes. Draw a line across the short width of the model, 3 inches from one end. Have learners work together to create a community on the large section of the model (the 5½-x 14½-inch area). Using the additional brown, blue, and yellow foam, cut out parts to create buildings. Hold the buildings together with the straight pins. Cut roads from brown foam.

When the "community" is completed, place the earthquake model on a solid, flat surface with the 3-inch tab sitting off the edge of the surface. Explain to learners that you are going to strike the bottom of the tab with the hammer. What do they expect to happen? Strike the model; discuss what happens. How was it different or similar to learner's expectations?

Place the model completely on the solid surface. Explain to learners that you are going to strike the tab from above with the hammer. What do they expect to happen? Strike the tab from above this time; discuss what happens. What happens? How was it different or similar to learner's expectations? What part of the model is like the epicenter of an earthquake?

### **Part 2: Spring**

Ask two learners to help with a demonstration of waves using the spring. Ask one learner to hold the spring firmly on one end. The second learner will stretch out the spring until there is some tension, then swiftly push the end toward the first learner and bring it back to its starting location without letting go. Learners should be able to see the spring alternately compress and expand as the waves travel through it. A wave created in this manner is like a primary wave.



To demonstrate a secondary wave with the spring, have the second learner give the spring a sharp left-to-right, side-to-side tug without letting go. Secondary waves vibrate at right angles to the direction they are traveling, and often are more destructive than primary waves.

## References

Earthquakes and The Severity of Earthquakes, U.S. Department of the Interior, U.S. Geological Survey.

### EXTENSION

- Use Lesson 12, “Waves and Tsunamis,” in OSU Extension 4-H publication, *Exploring Water Habitats* (4-H 3805-L) at <https://catalog.extension.oregonstate.edu/4-h38051>
- Research Oregon earthquakes such as the March 25, 1993 Scotts Mills earthquake, known in the news media as the “Spring Break Quake,” which caused damage from Woodburn to Salem. This quake had a magnitude of 5.6. This quake was associated with the Mount Angel Fault line. Where does the Mount Angel Fault run? Why is it most likely there?
- Portland’s West Hills are associated with two major fault zones that are pulling the Portland Basin apart. When was the last time Portland experienced an earthquake?



# NOTES

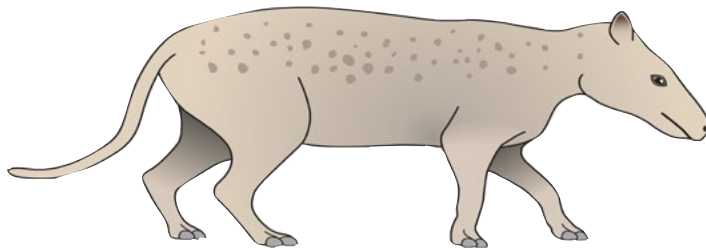


## 6. Where Have All the Oreodonts Gone?

### Objectives

#### LEARNERS WILL BE ABLE TO:

- Define a rock formation
- Explain how a sequence of fossil-containing rock formations can teach us about how life on Earth changed over many millions of years
- Use a model to explain a sample span of geologic time in Central Oregon
- Understand the relationship of an animal's bone structure to its physical appearance and habitat
- Understand that if an animal does not change (or migrate to a different area) to meet its needs in a changing habitat, it will become extinct



#### NEXT GENERATION SCIENCE STANDARDS (NGSS) PRACTICES:

1. Asking questions
2. Developing and using models
4. Analyzing and interpreting data
6. Constructing explanations
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

### Field Trips

1. *John Day Fossil Beds National Monument*—Information: <https://www.nps.gov/joda/planyourvisit/basicinfo.htm> Download maps at <https://www.nps.gov/joda/planyourvisit/maps.htm>. At the Painted Hills Unit, don't miss Painted Cove and Leaf Hill trails. At the Sheep Rock Unit, stop at the Sheep Rock Overlook and the Cant Ranch Visitor Center. In the Foree Area, take the Story in Stone Trail. In the Blue Basin Area, take the Island in Time Trail.
2. *Fossil, Oregon*—John Day Formation leaf bed outcrop of Bridge Creek Flora behind Wheeler High School. These fossil beds probably were formed about 30 million years ago when falling volcanic ash was washed into a lake basin along with leaves, seeds, cones, and other plant material. Level after level of material piled up. The ash preserved the plant material long enough for the beautiful impressions found today to be formed.

**NOTE:** Vertebrate fossils are relatively rare and may not be collected except under permit by qualified individuals. No fossil collection is allowed in the John Day Fossil Beds National Monument. When planning a field trip, check with public or private landowners to determine whether fossil collecting is permitted, and, if so, what types of collection are permissible. Each fossil is an irreplaceable link to the past. Learners should understand that they are responsible for the wise collection, study, and conservation of fossils.

3. *Madras/Prineville-area thunder eggs*—Free site-collecting information from Prineville Ranger District or Prineville, Crook County Chamber of Commerce. Also, fee sites at Richardson's Recreational Ranch in Madras or Judy Elkins Gemstones in Prineville.



#### 4. Museums at which to see fossils:

- Cant Ranch Visitor Center*—John Day Fossil Beds National Monument
- Oregon Museum of Science and Industry*—Lon Hancock Fossil Collection, 1945 SE Water Ave., Portland
- Douglas County Museum of History and Natural History*—1-5 exit 123, Roseburg
- The High Desert Museum*—59800 S. Highway 97, Bend

## Background

This chapter presents information on geologic activity and climate change in the John Day Basin in Central Oregon beginning with the Clarno volcanoes in the Eocene Epoch. Understanding the Background section of Chapter 5 (Exciting Eocene) is essential for continuing with this chapter.

The fossil record of plant and animal life in Central Oregon over 48 million years from the Eocene to the Miocene is remarkably well preserved. The dates for the formations and geologic events used in this chapter are based on the most recent research at the time of this writing. These may change as scientists continue to study this fascinating area.

The Law of Superposition states that in an undisturbed horizontal sequence of rocks, the oldest rock layer will be on the bottom, with successively younger rock layers above these. This means that fossils found in the lowest levels in a sequence of layered rocks represent the oldest record of life in a locality. Layers of rock of the same age and with a similar origin are called formations. Paleontologists read the successive layers of the fossil record to tell the story of how plants and animals changed over time.

In the John Day Basin, there was a very long time for the climate to change and for plants and animals to respond to that change. When a habitat changes, living things will:

1. migrate to a suitable habitat (an option for animals),
2. adapt to the new habitat, or
3. die.

There are no native camels, tapirs, or horses living in Oregon today. According to the fossil record, they did once live here. Where did these animals go? It is believed that the horse evolved in what is now North America, and then migrated across the land bridge to Asia. This may also be true of the ancestors of the cheetah. Scientists are still working today to answer these questions. Some of these answers may help us understand the consequence of our changing global climate today.

The story of geologic time, preserved in fossils in the John Day Basin, begins with the Clarno Formation as the “bottom layer” and continues over 40 million years through the John Day, Mascall, and Rattlesnake formations. In Activity 6A, learners will create a timeline to help them understand the changes taking place in climate, plants, and animals.

The Western Cascade volcanoes began building about 40 million years ago. This was near the end of the period in which the Clarno Formation was being deposited by volcanic activity in the late Eocene. Today the Western Cascade volcanoes are low, forested foothills west of the High Cascades. Once the Western Cascades probably stood as tall as the present-day High Cascade Mountains. As these mountains rose they created a new barrier to moisture traveling in clouds from the ocean. The High Cascades do this today. The reduced volume of rain on the east side of the mountains is called a rain shadow. An average of over 80 inches of rain per year falls on the Western Cascades, resulting in extensive erosion and creating the Middle Fork, McKenzie, Santiam, and Clackamas rivers, which





feed the Willamette River. The *Student Atlas of Oregon* climograph map depicts how the Coast Range and the Cascade Mountains create a rain shadow in Eastern Oregon, as the Western Cascades once did.

Eastern Oregon already was feeling the effects of the Western Cascades rain shadow in the late Clarno and John Day times as the climate changed from tropical to subtropical forests, then to a temperate climate. This climate change is recorded in the plant and animal fossils found in the deposits from the Clarno Formation to the Rattlesnake Formation.

There was a short lull in volcanic activity between the end of the deposition of the Clarno Formation and the beginning of the deposition of the John Day Formation. The new John Day volcanic period began about 39 million years ago. Rapid deposition of volcanic ash and mud in low-lying areas proved ideal for the preservation of fossils.

In addition to producing large quantities of loose ash, the volcanoes also produced basalt and rhyolite. The rhyolite and ash, cemented into tuff deposited in the area around present-day Madras and Prineville, contain geodes and thunder eggs. Some scientists believe that gas bubbles were trapped in the cooling volcanic material, providing a pocket for the creation of these treasures. Not everyone agrees with this theory. The thunder egg was designated Oregon's official state rock by the legislature in 1965. The internal structure of a thunder egg may be a hollow nodule or a solid geode. Thunder eggs are made up of a combination of mineral deposits. They typically have a russet-colored, knobby, or ribbed outer shell lined or filled with quartz crystals, opal, or chalcedony. The variety of patterns and colors from mineral additives is almost endless.

### **THE CLARNO FORMATION—54 MILLION TO 39.7 MILLION YEARS AGO**

Other rock formations in Oregon are older, but the Clarno Formation is the start of an amazingly continuous fossil record. Tropical to subtropical forests mantled the local terrain some 54 million to 39.7 million years ago.

One location, known as the Clarno Nutbeds, is among the finest fossil plant localities on the planet. The fossils found here tell us that 44 million years ago, Central Oregon was a hot, wet, semitropical place filled with a wide diversity of plants. More than 175 species of fruits and nuts preserved in the fossil record suggest a forest more diverse than any modern ecosystem in this part of the world. It contained plants with modern relatives, such as walnuts, chestnuts, oaks, bananas, magnolias, and palms. The forest was dense and moist, receiving an annual rainfall of almost 10 feet. But this semitropical environment was home to more than just trees and plants; the forest echoed with the buzzing of insects, the calls of birds, and the footfalls of mammals.

Most of the mammalian beasts that thrived during this time period are only vaguely familiar to us now: creodonts, large meat-eaters similar to wolves or hyenas but related to neither; hyrachyus, a distant relative of the tapir; and brontotheres, large rhino-like plant eaters. In addition to the mammals, reptiles such as crocodiles and tortoises lived alongside large catfish relatives.

### **THE JOHN DAY FORMATION—39.7 MILLION TO 18.2 MILLION YEARS AGO**

The middle to upper portions of the extensive John Day Formation have been divided into four major fossil-bearing units deposited between 30 million and 18 million years ago. From the oldest to the youngest, they are the Bridge Creek Flora; Turtle Cove Member; and, in the Upper John Day Formation, the Kimberly and Haystack Valley assemblages.



The Bridge Creek Flora documents major changes in the Earth's climate around 33 million years ago. At that time, the regional climate became 3°C to 6°C cooler and precipitation fell in a seasonal (wet season/dry season) pattern that differed from the more consistent subtropical precipitation of the Clarno. The ultimate sources of these gradual climate changes are likely attributable to several global-scale events, including a global drop in carbon dioxide (CO<sub>2</sub>), changes in the Earth's obliquity, and particularly the separation of Antarctica from Tasmania and South America, which set up the Antarctic circumpolar current and led to the formation of persistent Antarctic continental ice sheets.

Eastern Oregon gradually became drier with more seasonal changes in the weather. The area was covered with hardwood forests, lakes, and swamps that resembled the balmy parts of the southeastern United States or Southeast Asia. Many of the trees in the ancient forest are related to modern alders, elms, maples, and oaks. They lived alongside the “dawn redwood” (metasequoia), a conifer species that is still living in eastern Asia. In the Bridge Creek Flora, we find the remains of leaves, fish, amphibians, birds, and insects preserved like pressed flowers in a book. Because it was a lakebed environment, few mammals, other than the occasional bat, are preserved.

In contrast to Bridge Creek, the distinctive 29-million-year-old Turtle Cove beds contain a remarkable number of mammal fossils. In fact, the vast majority of localities and museum specimens from the John Day Basin are from the Turtle Cove fauna. During the Turtle Cove Member, the climate continued to cool and dry. Hardwood forests were sometimes flooded with ash and pumice from nearby volcanoes. Grasses were beginning to appear, but they were not yet a major part of the landscape. Given the span of time preserved in the Turtle Cove Member (about 5 million years), it is not surprising that the fauna is not homogenous; as the regional environment changed, so did the mammals, and that evolutionary progression is depicted in the fauna.

Three-toed horses, mouse-deer, beavers, and oreodonts—a strange family of sheep-sized creatures—browsed on the still-prevalent leafy plants. They were stalked by carnivores such as bear-dogs, nimravids (fierce, cat-like animals) and the giant, pig-like entelodont. Paleosol evidence from this interval indicates a change in habitats, with forests opening up as the global climate became cooler and drier. The co-occurrence of Oregon's first burrowing animals, running mammals, and clearly arboreal species (tree squirrels like protosciurus and miosciurus, and the primate ekgmowechashala) supports the reconstruction of Turtle Cove as a heterogeneous environment, with a mixture of wooded forests and open areas.

Above the striking blue-green beds of the Turtle Cove are the buff-to-pink volcanic sediments of the 24-million-year-old Kimberly Assemblage and the fluvial sandstones and conglomerates of Haystack Valley. With similar flora and fauna, the two youngest assemblages of the John Day Formation (Kimberly and Haystack) are commonly grouped together.

Many taxonomic groups persist from Turtle Cove into the upper John Day, but the overall fauna suggests more open habitats. The habitat was forest and field, with elm, birch, oak, maple, fir, spruce, and smaller plants and shrubs. Grasses are more abundant, and the most abundant mammals from the Kimberly fauna are gophers. Burrowing beavers, another specialized, tooth-digging animal, which would have preferred open habitats, are common as well. The greater abundance of running-adapted herbivores, like camels and ‘stilt-legged’



horses (kalobattius), and the presence of daphoenodon, the first running-adapted predator in Oregon, support the interpretation of more open environments at this time.

In general, the climate became cooler and drier. The appearance of bunch grasslands and the spread of sagebrush steppe occurred at the expense of forests, woodlands, and swamps, which had previously dominated the area. Ecosystems changing to more open habitats correspond with the appearance of burrowing and running animals. Paleosol evidence indicates that the ecosystems continued to evolve, with short-sod grasslands appearing by the end of the Upper John Day Assemblage.

### **PICTURE GORGE BASALTS—16.5 TO 16 MILLION YEARS AGO**

The Picture Gorge Basalt flows separate the John Day Formation from the Mascall Formation. Beginning in the middle Miocene, about 20 million years ago, a succession of basalt flows began to cover Oregon. They came from volcanic vents, cracks, and calderas along the Columbia River, at Picture Gorge in the John Day Basin, Steens Mountain, Mahogany Mountain in the Owyhee, and from the Cascade and Smith Rock volcanoes.

### **MASCALL FORMATION—16 TO 12 MILLION YEARS AGO**

The Mascall formation caps the Picture Gorge Basalts with a sequence of ashy layers and paleosols. This formation records a gradual yet influential climate change event that took place over millions of years—the mid-Miocene climatic optimum. Paleosol evidence from the Mascall formation indicates a period when forests returned, outcompeting the sagebrush steppe.

These wooded environments were similar to modern temperate forests found in the eastern United States, filled with swamp cypress along bodies of water, deciduous forests in the lowlands, and coniferous forests in upland habitats. Though forests dominated the area, the decline in shrubland allowed for the growth of short-sod grasslands. Grazing animals such as giraffe-deer and three-toed horses (merychippus, parahippus, archaeo-hippus) lived alongside the more common, larger mammals such as Gomphotherium (a trunked, four-tusked elephant relative) and Aphleops, a rhinoceros relative.

### **RATTLESNAKE FORMATION—10 TO 7 MILLION YEARS AGO**

The last major episode of deposition and fossil preservation in the John Day Basin was the Rattlesnake Formation. This formation contains fewer well-preserved fossils than the earlier formations.

Seven million years ago rivers chewed down into the soft, ashy soils of large floodplains, carving out river channels and creating lush riparian zones. These riparian woodlands and meadows were the home to grazing ungulates (horses and camelids) and burrowing mammals (moles, gophers, and ground squirrels). Aridification through time caused a shift from mixed hardwood forests to tall grasslands and semi-arid wooded shrubland, similar to what is seen in the current John Day River Valley. Life in the valley was dangerous, with predators about like short-faced bears, coyote-like dogs, and multiple species of saber-tooth cats.

Life in the Rattlesnake came to an abrupt end approximately 7 million years ago as a stratovolcano in the Harney Basin (near current-day Burns) erupted. In many places in Wheeler County and western Grant County, the Rattlesnake Formation is capped by the



Rattlesnake Ignimbrite Tephra that was expelled from the mouth of the volcano, coming down like a fiery hail on the land. The eruption created a pyroclastic flow, which attained speeds over 400 miles per hour and spewed hot, ashy gas that reached nearly 1,800°F. This event caused nearly 13,000 square miles of Eastern Oregon to be covered in an ashy tuff that destroyed everything in its path.

See also “Oregon: A Geologic History, Rattlesnake Tuff: Oregon’s Largest Eruption” at <http://www.oregongeology.org/sub/publications/IMS/ims-028/unit11.htm>

## References

- Dillhoff, R.M., T.A. Dillhoff, R.E. Dunn, J.A. Meyers and C.A.E. Stromberg. 2009. *Cenozoic Paleobotany of the John Day Basin, Central Oregon*. (2009). The Geological Society of America
- O’Connor, J., R. Dorsey, I. Madin, editors. 2009. *Volcanoes to Vineyards: Geologic Field Trips through the Dynamic Landscape of the Pacific Northwest*. Portland, OR. U.S. Geological Survey
- John Day Fossil Beds National Monument website <https://www.nps.gov/joda/learn/nature/fossils.htm>
- Orr, E., W. Orr. 2009. *Oregon Fossils* (Second Edition). Corvallis, OR. Oregon State University Press.



## Activity 6A—John Day Basin Timeline

### MATERIALS

- <https://www.nps.gov/features/joda/b> Visit this link for the John Day Fossil Beds National Monument
- One copy of the John Day Basin Timeline Cards (pages 71 and 72) for each learner
- Three sheets of 8½- x 11-inch blank paper per learner
- Two empty toilet paper tubes, or one empty paper towel tube cut in half, per learner
- Transparent packing tape
- Assorted colored felt pens, pencils, or crayons
- Scissors
- Rulers
- Paper clips
- PowerPoint slide of the General Reference Map and Climographs from: <https://www.pdx.edu/geography-education/student-atlas-of-oregon>, click on the Table of Contents link. Take a screen print of your computer screen, paste it onto a PowerPoint slide and crop out any unwanted areas.
- PowerPoint slide of the John Day Fossil Beds Monuments locations in the John Day Basin from <https://www.nps.gov/joda/planyourvisit/maps.htm>. Take a screen print of your computer screen from this website, paste it onto a PowerPoint slide and crop out any unwanted areas.

### PREPARATION

Visit this link for the John Day Fossil Beds National Monument website to determine which videos and slide shows to present to learners: <https://www.nps.gov/joda/index.htm>

### PROCEDURE

Project the PowerPoint slide of the PSU *Student Atlas of Oregon* General Reference map. Show learners the John Day River basin. Geologic formations discussed in this chapter cover a large area of Oregon from John Day to Madras. Show the climograph to explain how the Coast Range and the Cascade Mountains create a rain shadow in Eastern Oregon, as the Western Cascades once did. Show the PowerPoint slide of the map of the John Day Fossil Beds National Monument.

Show video and/or slide shows from the John Day Fossil Beds National Monument website and discuss the information presented using the additional information in the Background.

Learners will create a timeline of the John Day Basin beginning with the Clarno Formation on the left edge of the scroll and ending with “TODAY” on the right end of the scroll following these steps:

1. Cut the three sheets of blank 8½- x 11-inch paper in half down their length. Lay them end to end on a work surface. Tape the six pieces together, overlapping a half inch on each end. This will create a continuous paper scroll five segments long.
2. Wrap about 1 inch of the paper on one end of the scroll onto a paper tube. Tape in place. Repeat on the other end of the scroll. If the timeline scroll is too long for your working surface, roll some of the paper onto the right-hand tube until it will sit on the table. Use a paper clip to keep the paper rolled on the tube.
3. In this timeline, 1 inch equals 1 million years. Learners will use a ruler to draw



a straight line  $\frac{1}{2}$  inch from the bottom edge of the scroll in colored segments as described below. This will leave the upper  $3\frac{1}{2}$  inches for the John Day Basin Timeline cards from the copy page.

**Clarno Formation**, 54 million to 39.7 million years ago. Draw a line 15 inches long starting on the left of the scroll.

**John Day Formation**, 39.7 million to 20 million years ago. Draw a line of a DIFFERENT COLOR than the Clarno formation line. Measure this line 19 inches long from the end of Clarno time.

There are three subunits of the John Day Formation

- Bridge Creek Flora 33 million years ago (mya)*. Make a mark 6 inches from the start of the John Day Formation's line
- Turtle Cove Beds (29 mya)*. Make a mark 10 inches from the start of the John Day Formation's line
- Upper John Day Formation: Kimberly and Haystack Assemblages (24 mya)*. Make a mark 15 inches from the start of the John Day Formation's line

Skip a space 4 inches long.

**Picture Gorge Basalt**, 16.5 million to 16 million years ago. Draw a line  $\frac{1}{2}$  inch long. Use a different color than any previous lines. Use arrows to connect the Picture Gorge Basalt label to its  $\frac{1}{2}$ -inch length of the timeline.

**Mascall Formation**, 16 million to 12 million years ago. Draw a line 4 inches long. Use a different color than any previous lines.

Skip a space 2 inches long.

**Rattlesnake Formation**, 10 million to 7 million years ago. Draw a line 2 inches long. Use a different color than any previous lines.

**Rattlesnake Ignimbrite Tephra**. Draw an arrow to the 7-million-year mark. Place the label on the timeline for the arrow.

Skip a space 6 inches long.

Draw a star and write, "TODAY"

4. Give each learner a copy of the John Day Basin Timeline Cards. Ask learners to cut out the cards and tape them in place along the timeline at the formation they represent.

## DISCUSSION

Discuss the many changes in climate that have occurred in Oregon. What are the options for humans around the Earth to respond to the climate change taking place today?

## EXTENSION

Research the early paleontologists who studied fossils in Oregon.

Oregon's first state geologist was Thomas Condon. Before becoming a geologist, Condon was a minister. What led him to change careers?

Edward Drinker Cope and Othniel Charles Marsh studied fossils in the Blue Basin, in an area now part of the John Day Fossil Beds National Monument. They were rivals in seeking large dinosaurs. What other locations were studied for dinosaur fossil remains by Cope and Marsh?



## John Day Basin Timeline Cards Copy Page

NOTE: These cards are sized to fit in the length of the designated space on the timeline. Cut off the extra blank paper to the right of the text on some cards.

**Clarno Formation, 54 million to 39.7 million years ago.** The habitat was hot, wet, and semitropical, receiving an annual rainfall of almost 10 feet. More than 175 species of fruits and nuts are preserved in the fossil record. The forest was more diverse than any modern ecosystem in this part of the world. The dense forest contained plants with modern relatives such as walnuts, chestnuts, oaks, bananas, magnolias, and palms. Most of the mammalian beasts that thrived during this time period are only vaguely familiar to us now: the creodont, a large meat-eater similar to wolves or hyenas but related to neither; the hyrachyus, a distant relative of the tapir; and the brontotheres, a large rhino-like plant eater.

### **The John Day Formation, 39.7 million to 18.2 million years ago**

**John Day Formation: Bridge Creek Flora 33 mya.** Climate 3°C to 6°C cooler. Precipitation changes to a seasonal (wet season/dry season) pattern. The area was covered with hardwood forests, lakes, and swamps and resembled the balmy parts of the southeastern United States. Trees in the ancient forest are related to modern alders, elms, maples, and oaks. The remains of leaves, fish, amphibians, birds, and insects are preserved like pressed flowers in a book. Because it was a lakebed environment, few mammals, other than the occasional bat, are preserved.

**John Day Formation: Turtle Cove Beds 29 mya.** As the global climate became cooler and drier, forests opened up and a mixture of wooded forests and open areas emerged. Grasses were beginning to appear, but they were not yet a major part of the landscape. Three-toed horses (miohippus), mouse-deer, beavers, and oreodonts (a strange family of sheep-sized creatures) browsed on the still-prevalent leafy plants. They were stalked by carnivores, such as bear-dogs, nimravids (fierce, cat-like animals) and the giant pig-like entelodont.

**Upper John Day Formation: Kimberly and Haystack Assemblages 24 mya** The habitat was forest and field, with elm, birch, oak, maple, fir, spruce, and smaller plants and shrubs. Grasses are more abundant. The most abundant mammals are gophers. The greater abundance of running-adapted herbivores, like camels and stilt-legged horses (kalobattipus), and the presence of daphoenodon, the first running-adapted predator in Oregon, support the interpretation of more open environments at this time.

**Picture Gorge Basalts, 16.5 million to 16 million years ago**

**Mascall Formation, 16 million to 12 million years ago**

Mid-Miocene climatic optimum. Evidence indicates a period when forests returned, outcompeting the sagebrush steppe. These wooded environments were similar to modern temperate forests found in the eastern United States, filled with swamp cypress along bodies of water, deciduous forests in the lowlands, and coniferous forests in upland habitats. Though forests dominated the area, the decline in shrubland allowed for the growth of short-sod grasslands. Grazing animals, such as giraffe-deer and three-toed horses (Merychippus, Parahippus, Archaeo-hippus) lived alongside the more common, larger mammals such as Gomphotherium (a trunked, four-tusked elephant relative) and Aphleops, a rhinoceros relative.

**Rattlesnake Formation, 10 million to 7 million years ago**

Another period of drying climate through this time caused a shift from mixed hardwood forests to tall grasslands and semi-arid wooded shrubland. Riparian woodlands and meadows were the home to grazing ungulates (horses and camelids) and burrowing mammals (moles and gophers). Life in the valley was dangerous, with predators like short-faced bears, coyote-like dogs, and multiple species of saber-tooth cats.

**Rattlesnake  
Ignimbrite  
Tephra, 7  
million years  
ago**





## Activity 6B—Be a Fossil Detective

### MATERIALS

- Collection of Zoobooks® or similar animal encyclopedias, or access to a library
- Large box of craft sticks
- Supply of modeling clay

### FYI

Learners can examine the fossil record and use actual data to put together pieces of evidence to answer questions about the past. This is the process of science. To answer questions about past life on Earth, paleontologists must study the whole organism. This study can involve anatomy, comparative morphology, biometrics, pathology, botany, ecology, biology, and paleoenvironmental reconstruction. What stresses did the environment place on the animal? What type of skin, hair, or feet was most likely to help it survive? What type of teeth did it need to eat the predominant plants available? Is the animal extinct? If so, why? If not, where is it found on Earth today? Did the climate change? Was a new predator introduced? Was a food supply lost?

The principle of uniformitarianism tells us that the present is a key to the past. This means,

when studying the evolution of horses, a scientist would begin with an understanding of the characteristics of today's horses, such as habitats, food sources, defenses, and reproduction.

Othniel Marsh of Yale University and a group of Yale students came to Oregon in 1871 to look for mammal fossils. Marsh was able to demonstrate a complete lineage of the evolution of horses from the Eocene *Orohippus* (dog sized) to the modern *Equus* with specimens from the John Day Basin (See Figure 2, page 7). For more information, see *Oregon Fossils* (page 190) and the American Museum of Natural History's Horse Evolution (<http://www.amnh.org/exhibitions/horse/the-evolution-of-horses/>).



Othniel Marsh

Photo: Library of Congress Prints and Photographs Division. Brady-Handy Photograph Collection



## PROCEDURE

Ask the learners to work in pairs or teams to choose an animal to investigate. Choosing mammals will make the activity easier for younger learners. They may want to research one of the animals listed on the timeline in Activity 6A or other examples from the John Day Fossil Beds National Monuments website. With the group, create a list of information they need on each animal, such as habitats, food sources, defenses, and reproduction.

- Habitats:** desert, mountain meadow, plains or grasslands, forest, wetland, river
- Food source:** plants, live animals, dead or dying animals, both plants and animals, insects, worms, grubs, fish, and shellfish
- Defenses:** flying, hiding, fighting; size; running, speed; burrowing under the ground, swimming, camouflage, play dead, taste bad, and smell bad
- Reproduction:** eggs, live birth, dependent young, independent young, location of nests/nurseries

Each team should gather all the information they can about their animal. This can be an assignment to complete before the next session. Once the teams have gathered information about their animal, have them create a model or set of models with the craft sticks and clay. The models should show the characteristics of the animal that most clearly indicate how and where it lives. Have each team take turns showing the models of their animal to the group. The other teams are to use their science question skills to ask questions to help them determine what type of animal is being displayed. Teams take turns asking yes or no questions, such as, “Does your animal have cutting-tearing teeth?” If the answer to this question is yes, a follow-up question might be, “Is your animal a carnivore?”

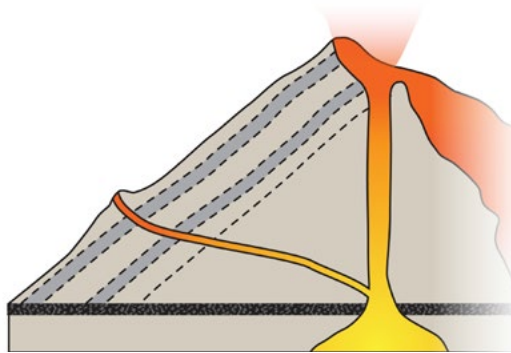


## 7. Growing Mountains and Pouring Lava

### Objectives

#### LEARNERS WILL BE ABLE TO:

- Explain where in Oregon volcanic events were responsible for Earth surface changes from the Miocene through the Pleistocene
- Diagram a composite volcano and explain the three types of volcanoes in Oregon and the types of eruptions that create them
- Understand how and where igneous rocks are formed
- Understand the relationship between speed of cooling and the size of crystals formed in igneous rock



#### NEXT GENERATION SCIENCE STANDARDS (NGSS) PRACTICES:

1. Asking questions
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
6. Constructing explanations
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

### Field Trips

1. Lava Lands Visitor Center—Highway 97, Bend; Lava Butte, Lava River Cave, Lava Cast Forest
2. Dee Wrote Observatory—Highway 242, McKenzie Pass; information from Deschutes National Forest
3. Newberry National Volcanic Monument—Paulina Peak, Big Obsidian Flow, Paulina and East lakes
4. Crater Lake National Park—Information from superintendent, Crater Lake National Park
5. Silver Falls State Park—Silverton; Miocene Columbia River basalt on Oligocene marine sediment; information from Oregon State Parks and Recreation Department
6. Smith Rock State Park—Terrebonne (6 miles north of Redmond); spectacular canyon of multicolored rock formations carved from 17-million-year-old volcanic ash and tuff; information from Oregon State Parks and Recreation Department

### Background

In the Miocene and Pliocene epochs, volcanic mountain building and huge outpourings of flood basalt dominate the geologic story across Oregon. Volcanic mountain building continued through the Pleistocene into the Holocene Epoch (Figure 11). Both Mount Hood and South Sister still show intermittent volcanic activity. Mount St. Helens in Washington State erupted catastrophically on May 18, 1980.



Oregon's coastline was being lifted and folded to its current location about 5 million years ago as the continental edge rose up over the subducting oceanic plate (see Chapter 2, Background).

The Columbia River's path cut through the old Western Cascades to reach the ocean. The Willamette Valley also was rising, completing the transition from inland bay to dry land with the help of basalt lava from the Western Cascade volcanoes. In eastern Washington and Oregon and western Idaho, massive flood basalt flows were erupting from cracks in the Earth's crust. These thin, hot lavas flowed in wave after wave between 17 million and 12 million years ago. The size of the area covered and the volume of lava produced is difficult to comprehend. The lava followed the Columbia River's channel toward the ocean.

Many coastal features, including Tillamook Head, Cape Mears, Cape Kiwanda, Yaquina Head, Depoe Bay, and Seal Rocks, originated as Columbia River basalt lava deposits. In the Willamette Valley, pockets of Columbia River basalt flowed from the old Columbia River channel, creating the South Salem, Eola, and Amity hills.

The story of human interpretation of the origin of coastal headlands is an example of how scientific knowledge can change. Geologists once believed that many large coastal basalt features were the remnants of local Miocene volcanoes.

In Central Oregon, the volcanoes that created Smith Rock were active between 10 million and 17 million years ago. These small volcanoes produced multiple ash and sticky tuff eruptions. Weathering over millions of years by wind, rain, and the Crooked River produced the fantastic rock shapes visible today.

In the High Lava Plains, the volcanic activity began about 10 million years ago in the east near Steens Mountain. This activity moved west along a 140-mile line of vents that ends at Newberry Caldera on the west (Figure 11). Throughout this area, the diversity of lava types

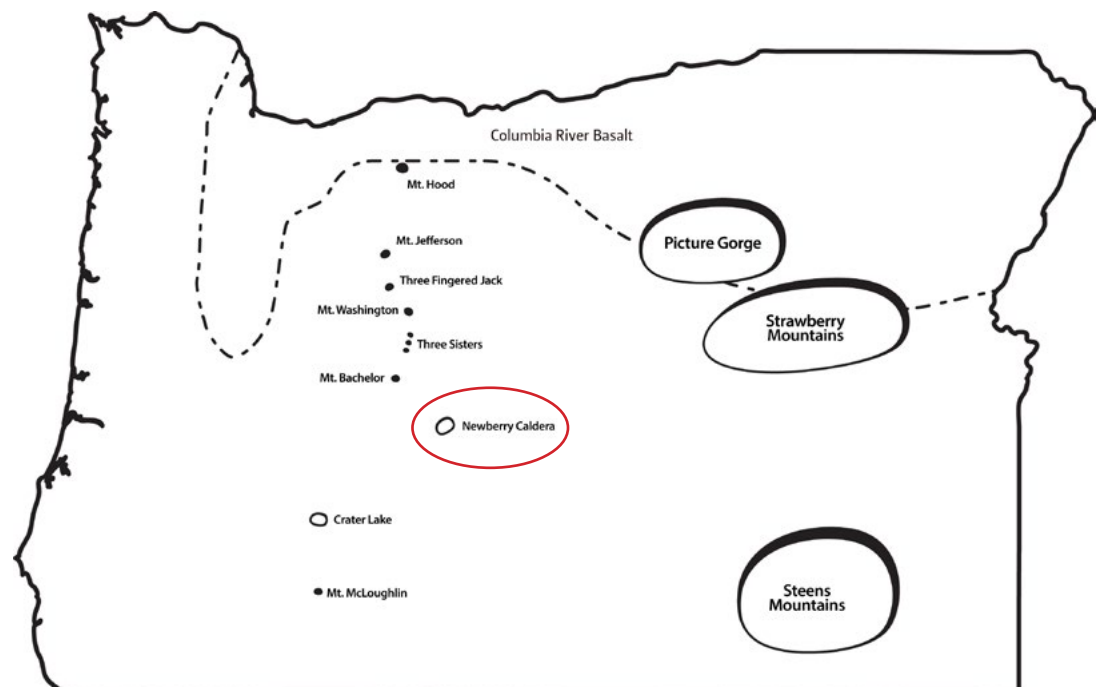


Figure 11



and features—such as cones, buttes, lava tubes, and tree casts—is amazing. Scientists classify volcanoes into three main types: shield volcanoes, composite (stratovolcanoes) volcanoes, and cinder cones.

**Shield volcanoes** are low-profile mountains with the gently curving slope of a warrior's shield laid on the ground. Their very fluid lava flows spread out over large areas to produce a mountain with broad, gentle slopes. Their eruptions generally are not explosive. Shield volcanoes are very common in Oregon, but because they don't form dramatic mountain peaks, few are well-known. Larch Mountain, east of Portland, is a shield volcano. Millican Butte, east of Bend, is another. The most famous shield volcanoes are Mauna Loa and Kilauea in Hawaii. Shield volcanoes are the largest of all volcanoes.

**Composite volcanoes** are more explosive and dynamic than shield volcanoes. The thick lavas that build the typical steep-sided, symmetrical cones of composite volcanoes also contribute to their explosive nature.

The name “composite volcano” comes from the material produced by alternating explosive eruptions of ash and rhyolite and quieter basalt and andesite lava eruptions. Composite volcanoes pose considerable danger to nearby human and animal habitats. In Activity 7A, learners will label a diagram of a composite volcano.

**Cinder cones** are the smallest volcanoes. They are formed by the piling of ash, cinders, and rocks, all of which are called pyroclastic (“fire-broken”) material that has been explosively erupted from the vent of the volcano. As the material falls back to the Earth, it piles up to form a symmetrical, steep-sided cone around the vent. Lava Butte, at Lava Lands Visitor Center on Highway 97 near Bend, is a classic cinder cone volcano.

A few volcanic mountains combine characteristics from all three types of volcanoes. Oregon's Newberry Volcano is one of the best, and largest, examples of this kind of volcano in the world. Newberry has a shield shape, but actually is a composite volcano having erupted fluid basalts, thick rhyolites, and enormous quantities of pumice and ash. Its flanks are peppered with more than 400 cinder cones. Newberry covers more than 500 square miles. The summit of Newberry Volcano is a caldera—a large, volcanic crater that forms when a volcano explodes and/or collapses into itself as lava drains out of underground chambers. Paulina and East lakes are found in Newberry's 5-mile-wide caldera. The Big Obsidian Row, which partially fills Newberry's caldera, is dated to 1,300 years ago, making it the youngest volcanic rock in Oregon.

The final major stage of Oregon's mountain building, about 5 million years ago, gave rise to the High Cascade peaks stretching from Mount McLoughlin to Mount Hood (Figure 11). Even as these composite volcanoes were rising, the Pleistocene Epoch glaciers were wearing them down. The largest Cascade composite volcanoes in Oregon include Mount Hood, Mount Jefferson, the Three Sisters, and Mount Mazama.

Around 6,600 years ago, in the Holocene Epoch, Mount Mazama erupted in a violent cataclysmic event typical of composite volcanoes. When it was done, the eruptions had left a caldera 4,000 feet deep, known today as Crater Lake. The highest point at Crater Lake is Hillman Peak at 8,156 feet. Scientists believe that before its eruption, Mount Mazama stood 10,800 to 12,000 feet tall. Ash from the eruption that blew the top off the mountain was deposited across eastern Oregon in layers that can be used today to date older and younger deposits.



Mount Hood is Oregon's most accessible composite volcano. The mountain is seismically active today. There is thermal activity in the fumarole fields near Crater Rock and Devil's Kitchen, between the head of White River Glacier and the Summit Ridge. When Mount Hood erupts again, it will have a catastrophic impact on the environment and economy of Oregon.

See also "Oregon: A Geologic History, Coast Range Volcanoes" at <http://www.oregongeology.org/sub/publications/IMS/ims-028/unit07.htm>; "Columbia River Basalt" at <http://www.oregongeology.org/sub/publications/IMS/ims-028/unit08.htm>, High Cascades Volcanoes <http://www.oregongeology.org/sub/publications/IMS/ims-028/unit12.htm>

## Activity 7A—Volcano Anatomy

### MATERIALS

- One copy of the Volcano Anatomy worksheet for each learner

### PROCEDURE

Work with the learners to label the diagram of the composite volcano on the Volcano Anatomy worksheet. Use the information in the Background section to discuss the three types of volcanoes found in Oregon. Use the pictures on the worksheet to assist with a discussion of how the physical and eruptive characteristics of cinder cone, composite, and shield volcanoes differ. How are they alike?

Where are active composite and shield volcanoes found on Earth today? Use an atlas to assist learners to answer this question, and questions 7 and 8 on the worksheet.

## References

- Kious, J.W., and R.I. Tilling. 1996. *This Dynamic Earth: the Story of Plate Tectonics*. Washington, D.C. U.S. Geological Survey.
- Tilling, R.I., L.J. Topinka, and D.A. Swanson. 1990. *Eruptions of Mount St. Helens: Past, Present and Future*. Washington, D.C., U.S. Geological Survey.
- Tilling, R.I., C. Heliker, and D.A. Swanson. 2010. *Eruptions of Hawaiian Volcanoes: Past, Present and Future*. Washington, D.C., U.S. Geological Survey

### ANSWERS FOR THE VOLCANO ANATOMY WORKSHEET

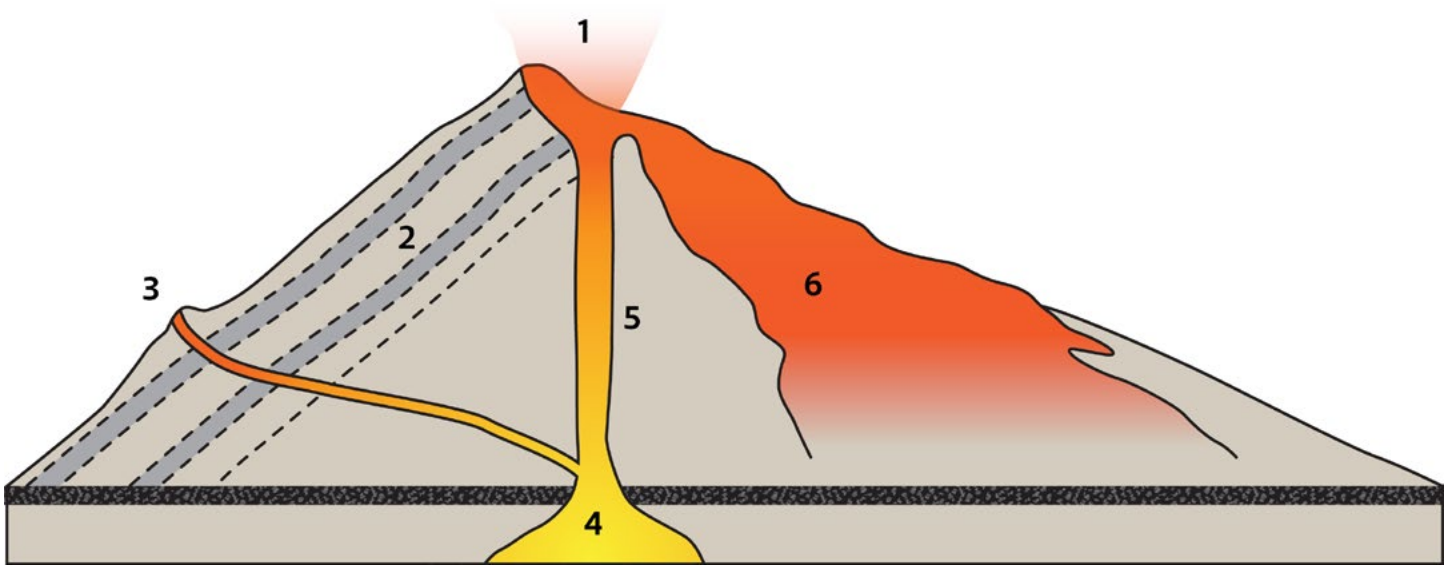
1. Crater
2. Alternating layers of ash and rhyolite with lava from previous eruptions
3. Parasitic cone, may be a cinder cone
4. Magma chamber
5. Central vent
6. Lava flow
7. Composite, Washington
8. Shield, Hawaii, Hawaii

### EXTENSION

Order and show the DVD *Fire Mountain: Eruption and Rebirth of Mount St. Helens* from the Discover Your Northwest website (<http://www.discovernw.org/mm5/merchant.mvc?Screen=SFNT>).



### Volcano Anatomy worksheet



1. \_\_\_\_\_

2. \_\_\_\_\_

3. \_\_\_\_\_

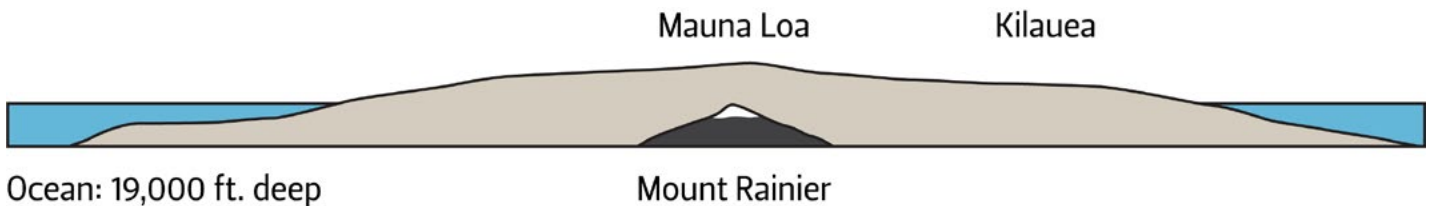
4. \_\_\_\_\_

5. \_\_\_\_\_

6. \_\_\_\_\_

7. Mount Rainier is a \_\_\_\_\_ volcano located in \_\_\_\_\_ State.

8. Mauna Loa and Kilauea are \_\_\_\_\_ volcanoes located in the state of \_\_\_\_\_  
on the island of \_\_\_\_\_





## Activity 7B—Formation of Igneous Rocks

Properties of rocks, such as the characteristics of their minerals and crystals, provide important clues about how they were formed. Rocks are formed through the actions of powerful geologic processes. Volcanism, sedimentation, and metamorphism are three of the most important processes that shape the Earth's crust and create different kinds of rocks and minerals.

Each of these processes leads to the formation of a different type of rock, and rocks are accordingly classified into three major categories: igneous, sedimentary, and metamorphic. This session is about igneous rocks, formed through volcanism—in which molten material (Activity 4B) from the Earth's mantle rises up through the crust, where it later cools and solidifies.

In this session, to simulate the formation of igneous rocks, the learners melt phenyl salicylate (salol) and observe the formation of crystals as the salol cools. They will compare crystals formed when the salol is cooled at two different temperatures. The learners apply what they've learned to identify three igneous rock samples from their sets, inferring the relative rates at which the crystals cooled.

### A Note about Candles and Classroom Safety

This activity uses candles, and some teachers have understandably been concerned about safety. Yet teachers who tested the unit have told us that, when presented in the step-by-step fashion described below, this activity not only could be conducted safely, it was the highlight of the unit for many students. It has been done safely and successfully in many classrooms, and we have seen learners as young as fourth grade use the candles and clearly focus on the experiments. While playing with the partly melted candle wax is also a temptation, no accidents or injuries have been reported. Obviously, the use of a candle in the classroom necessitates care, and you know best how to convey this to your learners and how to structure classroom activity to ensure safety. Caution is urged regarding long hair, loose clothing, or other risk factors. If you feel that your learners should not use candles on their own, we suggest that the teacher, classroom aide, or parent volunteer sit at a table with two candles, and to have each team of four come up to do the experiment while the other learners are doing something else.

#### MATERIALS

- One set of rocks and minerals (from Activity 4B)
- One book of matches
- One container of salol crystals (2 oz is adequate for a class of 25)
- One quarter-teaspoon measuring spoon

One set per team of four learners:

- One ice cube
- Two magnifying lenses
- One paper towel
- One tray
- Two paper cups, 2- to 3-oz size
- Two votive candles with holders
- Two metal spoons
- Two lumps of modeling clay, or another method to support the spoons with melted salol in them





- Four pairs of goggles
- Four copies of Observing Crystal Formation data sheets (See page 86.)
- One flashlight

## PREPARATIONS

Before the day of the activity:

1. Purchase salol (phenyl salicylate) from a science supply company
2. To become familiar with the experiment procedure, carry out the following steps:
  - ❑ Prepare the materials you will need. Light a votive candle. Set two metal spoons, a lump of clay, and a magnifying lens in front of you.
  - ❑ Place no more than  $\frac{1}{8}$  teaspoon (even  $\frac{1}{16}$  teaspoon is plenty) of salol crystals on a silverware-type tablespoon. The reason to use a very small amount is to decrease the time it takes the mass of melted salol to cool down to the temperature at which crystals start forming.
  - ❑ Heat the salol crystals by holding the spoon above a votive candle flame. When almost all the crystals have melted, forming a clear liquid, remove the spoon from the flame. It's best to remove the spoon from near the flame a little before the last crystals melt. Enough heat will remain in the spoon to melt the remaining crystals. (If the melted salol gets too hot, it will take much longer before it cools down and starts forming crystals.)
  - ❑ Add a pinch of salol grains to act as "seed crystals." These will help start the crystallization process.
  - ❑ Place the spoon with the melted salol on a table, and position the lump of clay beneath the end of the spoon's handle, so it does not spill the liquid salol. Observe the melted salol with a magnifying lens as it cools.
  - ❑ Repeat the entire process a second time using a different spoon. This time, hold the spoon containing the melted salol on top of an ice cube on a paper towel, and carefully observe crystallization using a magnifying lens.
  - ❑ When near-total crystallization has occurred, place the ice-cooled spoon on the table next to the one containing crystals that are forming at room temperature, using the same support for the handles of both spoons. Compare both sets of crystals with the naked eye and with a magnifying lens.
3. You probably will notice that the salol placed on the ice cube cooled faster and formed smaller crystals than the room temperature salol. If you have time, remelt the salol in the spoons and try the experiment again to become more familiar with the variables that affect the outcomes.

Just before the activity:

1. Place the materials you will use to demonstrate the experiment in a place where the learners can easily see you.
2. Put aside the ice and sets of rocks and minerals for use later.
3. Place all other supplies for teams of four learners (working in pairs) on trays. For each small cup, measure out a level  $\frac{1}{4}$  teaspoon of salol crystals.

## FYI

It's difficult to remove salol from metal spoons, so obtain old spoons that you can keep permanently and use repeatedly with this activity. Any salol left on a spoon will melt during the next experiment.



It's ideal if you can acquire a spoon for every learner, plus two for the leader. Sometimes very inexpensive metal spoons can be obtained from a flea market or secondhand store.

Salol, more technically known as phenyl salicylate, is an organic compound ( $C_6H_4OHCOOC_6H_5$ ) that is produced synthetically—that is, through processes that do not occur in nature. Since minerals are defined as inorganic solids that occur naturally, salol is not a mineral. However, just like natural mineral crystals, salol crystals possess regular geometric form and structure, resulting from three-dimensional internal order.

Salol also has other properties that make it an excellent choice for experiments. Due to its relatively low melting point (108°F) and generally safe nature, salol is often used to illustrate fairly rapid crystal formation. In addition, salol is used in the manufacture of various plastics, lacquers, waxes, polishes, suntan oils, and creams.

Sometimes a large, fan-shaped cluster of tiny, whitish crystals forms when the salol cools very quickly. Occasionally, learners see the larger shape and jump to the mistaken conclusion that it represents one large crystal. In this activity, the salol is used to demonstrate the difference in crystal size at different cooling speeds.

Crystals in igneous rocks tend to have angular shapes, more so than crystals in sedimentary or metamorphic rocks. This can be one clue in identification. While all crystals are angular when they form, those in sedimentary or metamorphic rocks usually have been subjected to other forces that tend to blunt and distort the edges of the crystals.

## PROCEDURES

### PART 1: INTRODUCING IGNEOUS ROCKS

1. Remind learners how they observed properties when they began classifying the rock and mineral samples (Activity 4B) and how they also have constructed models of different crystal shapes (Activity 3B). Explain to the learners that another way to classify rocks is to study the minerals within them and their other properties to determine how they were formed. One kind of rock is formed when a batch of hot liquid and crystal mush, called magma, cools and solidifies. Ask, “Who knows what landforms of the Earth’s crust produce magma?” (Volcanoes.) “What do we call magma that actually reaches the Earth’s surface?” (Lava.)
2. Remind learners that when magma cools it forms igneous rocks. Igneous rocks are one of the three major classes or types of rock found in the Earth’s crust. The other two classes are sedimentary and metamorphic rocks.
3. Emphasize that some igneous rocks form when magma cools slowly inside the Earth. Other igneous rocks form when hot lava comes out of the Earth and cools very quickly. The challenge for today is for the learners to work in pairs to create their own batches of hot liquid and crystal mush to investigate the effect that fast and slow cooling has on the formation of crystals.



Teachers may want to introduce the activities in this session with a brief story, such as the one below.

*Deep within the Earth, batches of molten magma stir. When a volcano erupts, some of the magma reaches the Earth's surface, on land or sea. When this lava cools, it forms igneous rocks.*

*Meanwhile, still inside the Earth, other magma also cools, but it cools more slowly because it is warmer inside the Earth. This magma that cools more slowly also forms igneous rocks.*

*Let's suppose that the molten substance we're going to work with in this activity is magma, and let's see for ourselves what might happen when it cools at different temperatures.*



Photo 16

## **PART 2: OBSERVING CRYSTAL FORMATION AT ROOM TEMPERATURE**

1. Tell the learners that in this first part of the activity, each team of four learners will work in pairs. Each pair of learners will use one metal spoon to grow salol crystals and observe them as they form at room temperature. Demonstrate the procedure, one step at a time, following the directions on the learner data sheet, Observing Crystal Formation. In your demonstration, do NOT actually light the candle or melt the salol, but go through the motions of each step.
2. Caution the learners to do their experiments over the tray so that if the hot salol spills it will go onto the tray. Tell the learners that each pair of learners should pour less than half of the salol crystals from the cup into their spoon. Tell them that they will need leftover crystals in their cups to use as “seed crystals.” Remind them how you added a few grains as “seed crystals” in your demonstration.
3. Show the data sheets and explain that you want each learner to complete his or her own data sheet during the experiment.
4. Distribute the trays with materials. When both partners are ready, light the candles for them. Remind them to hold the spoon well above the candle flame. Tell the students that they should try to get as much light as possible on their spoons for best viewing. The flashlights will help illuminate the crystals for better viewing.
5. Circulate around the class, making sure the experiments are proceeding and encouraging close observation. Allow time for the learners to draw the crystals on the data sheet.



6. As you circulate, ask questions to focus their observations, such as: “Does the salol seem to be forming one big crystal, or several smaller crystals?” “Do the crystals seem to have sharp edges or smooth ones?” “How would you describe the shape of each crystal?” (It is nearly impossible to get a large single crystal to grow from multiple seed crystals. So, if the learners think that they have observed one big crystal, ask them to re-examine it carefully and look for flat faces and sharp edges dividing smaller crystals.)
7. Ask the learners to describe how the crystals grew. “Did the crystals form all at once or a few at a time?” “Were you able to see the faces and edges moving as the crystals grew?”
8. Explain that in the next part of the experiment, one of the spoons will be left with the crystals that formed at room temperature, while the salol in the other spoon will be melted again to find out what happens when the melted salol is cooled at a lower temperature.

### **PART 3: COMPARING CRYSTAL FORMATION AT DIFFERENT TEMPERATURES**

1. Tell the learners that now they will see what happens when the hot liquid and crystal mush cools more quickly in a cold environment.
2. Give one ice cube to each team of four, and have them place it on the paper towel. Tell them to melt the crystals in one of the spoons again, leaving the other spoon with the crystals formed at room temperature for comparison.
3. Again, the spoon should be held above the candle until almost all the salol melts. Then the bowl of the spoon should be held so that it touches the ice cube. Remind learners to add a few “seed crystals” to the spoon as it cools.
4. Encourage close observation through questioning as you circulate among the groups. “Are crystals forming?” “Do the crystals seem to be forming more quickly than before?” Each learner should draw the crystals that are forming in the salol over ice on the data sheet. Remind learners to look very closely at the crystals so they do not misinterpret large multicrystal clusters as one big crystal. After drawing the results on the data sheet, learners are asked to briefly describe in writing the differences they’ve observed between the crystals that formed at different temperatures.
5. If you have time, the learners can repeat the experiment and time how long it takes for crystals to form at room temperature and in a cold environment. Doing this or other experiments can help all learners have a chance to do all the tasks involved, and can confirm that their results are repeatable. If learners disagree about their results, or conclusions from group to group vary widely, be sure to ask learners for their ideas on this in the discussion that follows.
6. When groups have finished their experiments, have them blow out their candles. Collect the candles and other materials.

### **PART 4: OBSERVING IGNEOUS ROCKS**

1. Ask the learners to imagine that the melted substance in their spoons is volcanic magma. Ask, “Which of your magma batches completely crystallized fastest—with ice or without ice?” “What other differences did you observe in the two experiments?” Help them articulate that larger crystals formed with slower cooling.
2. Ask the learners to consider how their findings might apply to igneous rocks in the Earth’s crust. Say, “Imagine mineral crystals in igneous rocks that formed from magma. Suppose some cooled slowly and some cooled quickly. Which ones do you



think would have the biggest crystals?” (The ones that cooled more slowly.)

3. Explain that, as modeled by the experiment they did, geologists have noticed that magma that cools very slowly deep inside the Earth tends to form igneous rocks with large crystals; lava that erupts at the surface of the Earth, or under the ocean, cools very quickly, and is likely to form igneous rocks with very tiny crystals or even no crystals at all; and whether cooled slowly or quickly, all the crystals in igneous rocks tend to have angular, sharp-edged shapes.
4. Distribute the sets of rocks and mineral samples to each group. Ask the learners whether they can tell which of the rocks are igneous. After learners have had a chance to predict, point out that granite, basalt, and obsidian are igneous rocks. They all formed from the cooling of magma.
5. Invite the learners to examine each of these rocks closely, and to put them in order according to how fast they think the magma or lava cooled.
6. Lead a discussion of their results. Inform the learners that obsidian—“volcanic glass”—cools so fast that crystals have no time to form.
7. Lead the learners in a brief discussion of landforms on the surface of the Earth’s crust where one might expect to find igneous rocks. Ask, “Where might igneous rocks be forming?” (Wherever magma reaches or comes close to the surface. Refer to the Field Trip and Background section of this chapter for more specific information.)
8. You might want to challenge older learners to think about the process involved in the formation of the Epsom salt (Activity 3B) and salol crystals. You could ask, “How was the process that created salol crystals similar to the process that created Epsom salt crystals?” “How did the two processes differ?” (In both cases, crystals were formed. The Epsom salt crystals formed from the evaporated solution of Epsom salt and water. In this case, water was added to dissolve the salt. The salol crystals formed from melted salol. In this case, the heat was added to melt the salol.) These differences have an interesting connection to rock classification. Rocks that contain crystals formed by evaporation are considered sedimentary, while rocks that contain crystals formed from a melting process are considered igneous.



## Observing Crystal Formation worksheet

Name: \_\_\_\_\_

Date: \_\_\_\_\_

### CRYSTAL FORMATION AT ROOM TEMPERATURE

1. Place a very small amount of salol on a metal spoon.
2. Melt the salol by holding the spoon more than an inch above the candle flame.
3. Remove the spoon from the flame.
4. Add a few grains of salol as “seed crystals.”
5. Use a small lump of modeling clay to prop up the handle so the spoon stays level.
6. Look at the crystals with a magnifying lens, and draw what you see.

### CRYSTAL FORMATION AT LOW TEMPERATURE

1. Working with a partner, remelt the crystals in one of the spoons.
2. Add a few grains of salol as “seed crystals.”
3. Rest the bowl of the spoon on an ice cube.
4. Draw the shapes of the crystals that result when the salol cooled at a low temperature. Use the magnifying lens to compare the crystals at both temperatures.
5. Describe how the shapes and sizes of the crystals differ when they cooled at room temperature and when they are cooled by ice.
6. What other experiments would you like to try? What would you like to know more about?

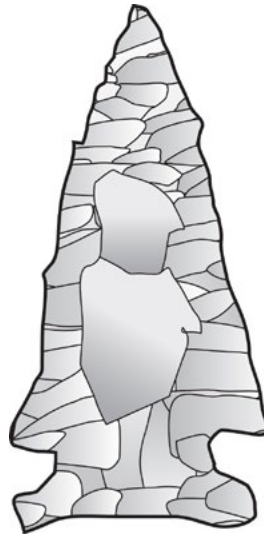


## 8. Glacial Ice and Giant Floods

### Objectives

#### LEARNERS WILL BE ABLE TO:

- Understand the relationship of Paleo-Indians to large prehistoric mammals
- Explain why early Oregonians selected specific types of rocks for different tools
- List three components of soil
- Explain soil's relationship to the Rock Cycle and how soils are different from rocks



#### NEXT GENERATION SCIENCE STANDARDS (NGSS)

##### PRACTICES:

1. Asking questions
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

### Field Trips

1. Erratic Rock State Park—3.4 miles west of McMinnville on Highway 18 to junction of Oldsville Road, turn right and go 0.3 miles, bearing left at the fork. Continue 1.4 miles and park on the shoulder. A quarter-mile path leads to the boulder.
2. Mount Hood—Zigzag, Ladd, and White River glaciers. Where Highway 35 crosses White River, a lateral moraine is prominent just upstream from the bridge.
3. Kiger Gorge—at Steens Mountain. Shows U-shape of a previously glaciated valley.
4. Fort Rock State Park—This tuff ring erupted as an island in a Pleistocene lake that covered an area of more than 500 square miles. Erosion by water created wave-cut terraces. Information from Fort Rock State Park.

### Background

The Pleistocene Epoch, from 2 million to 10,000 years ago, is sometimes called the Ice Age. Large continental glaciers formed, followed by periods of glacial melting and floods. These alternating periods of expanding and retreating ice sheets created a series of ice ages. These were global events. At times, continental glaciers covered 30 percent of the Earth's surface. They covered northern Europe, Russia, Canada, and parts of the northern United States. Remember from our discussion of the Water Cycle in Activity 1A that the supply of water on Earth is finite. Today, polar ice and mountain glaciers store 2.15 percent of the water on Earth. During the Pleistocene, so much water was frozen into continental glaciers that the sea level was lowered along the continental coastline.

Glaciers are created where more snow falls than is melted off each year. Over time, the collecting snow turns to ice. Continental glaciers or ice sheets cover large land masses.



Antarctica is covered with glaciers that are more than 2 miles thick in places. Mountain or valley glaciers are rivers of ice that flow very slowly through mountain valleys. Beginning in high-altitude snowfields, these glaciers may cover great distances.

As a glacier moves over land, it carries sand, rocks, and boulders with it. This “sandpaper” ice leaves characteristic marks on the land. Glacial valleys are worn to have broad U-shaped floors. Mountain tops are worn to horn shapes, cut from all sides by glacial action. The Matterhorn in the Swiss Alps and Mount Washington in Oregon are famous examples of ice’s ability to sculpt rock.

The huge weight of continental glaciers can leave behind shallow basins that fill with meltwater to create lakes. The Great Lakes are a result of glacial depressions that filled with water.

Large rocks may be carried hundreds of miles from their source by glaciers. When they are deposited, they are called glacial erratics. Deposits of unsorted sediment left at the sides and front of a melting glacier are called moraines.

When a glacier reaches the ocean, it may form an ice shelf over the water. Large masses of ice can break away from the front of the ice shelf, creating icebergs. An iceberg is a floating island of ice. Less than 10 percent of an iceberg is visible above the water’s surface.

During the Pleistocene, the closest a continental ice sheet approached Oregon was probably northern Washington. Mountain glaciers formed at high altitudes in the Cascade Mountains and moved toward the valley floors, rounding the foothills in their path. The North and South Santiam, Calapooia, and McKenzie rivers carried glacial debris into the Willamette Valley.

At Steens Mountain, at the southeastern margin of the Basin and Range Province, glacial ice carved the U-shape of Kiger Gorge and sculpted lake basins.

The most spectacular geologic events in Oregon in the Pleistocene were caused by water, not ice. Massive floods occurred repeatedly over a period of 2,500 years. The floodwaters came from an enormous lake that formed behind an ice dam on the Clark Fork River in the Idaho Panhandle.

As the continental ice sheet was retreating, meltwater backed up into western Montana. Various accounts hypothesize that the huge lake was 500 to 900 feet deep.

When the ice dams failed, unimaginably large amounts of water suddenly were released. All that water poured across eastern Washington, creating the Channeled Scablands, and followed the channel of the Columbia River toward the Pacific Ocean. The torrent widened and deepened the Columbia Gorge and deposited gravel across areas of eastern Oregon and Washington.

Floodwater backed up and filled the entire Willamette Valley. Before it drained out, the water dropped much of its sediment load of tons of lake silt, sand, and large blocks of ice. This sediment contributed to the creation of the rich soil that supports agriculture and forestry in the Willamette Valley. In Activity 8B, learners will explore soil as a stop along the rock cycle.

In addition to soil components, the icebergs also had carried with them boulders that were widely deposited across the Willamette Valley as glacial erratics. Some of these boulders are composed of native Montana granite.





The Pleistocene also marks the beginning of the habitation of Oregon by people. In Activity 8A, learners will learn about some of the tools Oregon's first people made from rocks.

See also "Oregon: A Geologic History, Pluvial Lakes" at <http://www.oregongeology.org/sub/publications/IMS/ims-028/unit15.htm>, "Glacial Deposits" at <http://www.oregongeology.org/sub/publications/IMS/ims-028/unit16.htm>, "Ice Age Floods" at <http://www.oregongeology.org/sub/publications/IMS/ims-028/unit17.htm>

## Activity 8A—Oregon's First People: Climate and Stone Tools

"Oregon's First People: Climate and Stone Tools" was adapted from Section 2, "Oregon's People," in *Exploring Oregon's Past* teacher's activity guide for fourth through seventh grades, developed by the Bureau of Land Management Oregon State office and used with permission.

### MATERIALS

- Copy the essay "Oregon's First People" on learner reading pages 1—4 (see page 92), one per learner.

### FYI

The living descendants of the prehistoric people originally on this continent are the American Indians; four recognized Indian tribes and five recognized confederated (grouped) tribes live in Oregon. There are also nonfederally recognized tribes in Oregon that continue as distinct tribal entities.

People have a tendency to develop erroneous concepts about the past. One misconception is that past people were primitive, backward, or simple, or, conversely, that they were noble savages living perfectly in tune with nature, or as heroic pioneers and idealists living an idyllic, uncomplicated life with high-minded values. A second misconception is that archaeologists are interested only in "valuable" or "mystical" artifacts or works of ancient art.

The first misconception can be addressed by stressing that all people everywhere, past and present, exhibit an array of talents and personalities. As a group, people in the past possessed incredible skill and understanding of their world. Prehistoric people had knowledge that enabled them to live successfully in environments that today seem inhospitable to most of us.

The second misconception can be remedied by emphasizing that archaeologists study the past cultures of all peoples. They seek to learn how the people lived their lives and how the culture of people changed over time. Archaeologists come to understand people by studying the artifacts and other remains that they left behind or that occur naturally in the occupied environment.

### PROCEDURE

Discuss with learners what they know about Indians in Oregon. They may be aware of Indian cultures only as they relate to Oregon's settlement by Euro-Americans in historic



times, or worse, may only associate them with casinos. Pass out the essay “Oregon’s First People” for learners to read. You may choose to send the essay home prior to this activity so that learners already will have read the essay and are ready for the discussion and the Small Group Activity: A Mammoth Dinner.

## Discussion

### PART 1: VOCABULARY

**Artifact**—any item made, modified, or used by humans. In common usage, it normally refers to portable items.

**Atlatl (AT-ul-AT-ul)**—a tool used to throw spears. The atlatl consists of a flat shaft, often with a groove down the middle and typically with a hook at the back end. A spear (dart) was held in the groove and thrown with an overhand motion.

**Clovis point**—type of large, stone, projectile point made by early Paleo-Indians for use as a spear tip on a thrusting spear, characterized by a short, shallow channel on one or both faces.

**Core**—a prepared nodule of stone that a flintknapper strikes to remove thin flakes of stone; also the remnant chunk of stone left after flintknapping.

**Culture**—a set of learned beliefs, values, and behaviors generally shared by members of a society or group. Culture includes thought, knowledge, language, habits, art, actions, beliefs, and artifacts.

**Diagnostic artifact**—an item that is indicative of a particular time and/or cultural group.

**Flake**—a thin piece of stone removed from a core by striking it with a hammer or pressing with a flaker. The hammer or flaker may be made of bone, antler, or stone. Flakes have sharp edges and can be used as 5-cm cutting implements. Flakes may be further shaped into tools. Flakes also are left as waste byproducts of flintknapping.

**Flintknapping**—the technique of making stone tools from natural stone.

**Mammoth and mastodon**—Ice Age animals related to the modern-day elephant.

**Paleo-Indian**—the name given to the oldest known cultural group in North America. This is also the oldest known cultural group in Oregon.

**Prehistoric**—information about past events prior to the recording of events in writing.

**Projectile point**—the point attached to the end of spears, darts, and arrows. The point may be made of stone, bone, antler, glass, or metal. Often erroneously termed “arrowheads.”

**Rock shelter**—a shallow cave or sheltered area covered by a rock.

**Tradition (archaeological usage)**—different types of tools occurring together over a long span of time and/or a specific geographic area, and usually associated with a particular type of lifeway. For example, the Clovis tradition includes characteristic fluted points and the hunting of large game animals.

**Tundra**—a treeless plain that is characteristic of arctic and subarctic regions, consisting of black soil with a permanently frozen subsoil. Plants in this environment may be dense and often include conspicuously flowering dwarf herbs.



## PART 2: IDEA REVIEW

- Review the concept of habitat (Activity 6B). In the reading, what changes were taking place in the habitat of the mammoths, giant bison, camels, and giant ground sloths that lived in Oregon in the Ice Age? How are the survival needs of animals and people different? How are they similar? What would it be like to have our climate in Oregon change to a tropical environment? How would this affect the clothes we wear, the food we grow, or the houses we live in?
- The reading tells learners the names of five different stone projectile points found in Oregon. How did the projectile points' design change over time? How did the tools they were used on change? Why were these changes important to the survival of the people?
- Why were stone tools important to the Paleo-Indians and later the people of the Great Basin? In addition to the projectile points, what other tools would have been made of stone?
- Chert is a type of quartz that was used to make some projectile points found in Oregon. Chert is harder than a knife (hardness group 7, Activity 4B) and fractures with a shell-like edge pattern that produces an edge that can be used for cutting. Unlike some metals, chert does not rust and maintains a sharp edge with longer use. Other types of stone used for tools include obsidian (volcanic glass), nephrite (jade or jadeite), basalt, schistose sandstone, agate, quartz crystal, steatite, jasper, chalcedony, serpentine, and siltstone. Each type of rock has particular characteristics for meeting particular needs. Look up the properties of some of the rocks in a rock-and-mineral reference book. How would tools made from these materials compare to tools we might use today?

### Small Group Activity: A Mammoth Dinner

After the learners have read the essay “Oregon’s First People,” divide them into teams of three or four learners each. The team is to prepare a presentation on how Paleo-Indians would have captured and used a huge mammoth for dinner. The teams are to use a variety of techniques to present the information. They may use charts, pictures, demonstrations, or dioramas, or write and present a skit. The presentation can be based on the essay and on additional research. Learners will need to infer some of the ideas they present on the humanity and lifeways of past people.

During problem solving, learners should give some consideration to the size and weight of the mammoth; the large quantity of meat it will provide; how the meat is to be stored and used; how the meat will be transported; how the meat will be shared among the group; what special skills or knowledge is needed to prepare a mammoth; what tools will be needed; who will make the tools and what will they be made from; what does the toolmaker need to know about rocks; who will know all these needed skills, and how they will be passed on to other members of the group; and what types of situations would cause these people to worry, or be frightened, surprised, or joyful.



## Oregon's First People

Thirty thousand years ago, large herds of animals lived in the Ice Age tundra lands of northern Asia. Tundra is cold, flat land where trees do not grow. The soil of tundra never completely thaws out. Tundra plants include many kinds of grass and moss. These plants grow thickly, but they are small in size.

People had learned to live in these harsh, cold lands also. Mammoths, mastodons, caribou, musk oxen, and other large animals lived near the huge Ice Age glaciers. People hunted these animals for food.

During the Ice Age, much of the Earth's water was frozen into huge glaciers. This caused the oceans to be lower. Today the Bering Sea is a shallow sea between Alaska on the North American continent and Siberia on the Asian continent. During the Ice Age, the lower ocean level left dry land where the Bering Sea is today. Scientists call this area the Bering Land Bridge or Beringia. The Bering Land Bridge connected the continents of Asia and North America.

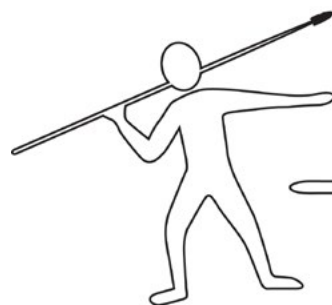
Much of Alaska was not covered by glaciers. Tundra stretched across northern Asia, Beringia, and Alaska without a break. Scientists believe that people first came to North America from Asia by walking across Beringia, following the large animals they hunted. Archaeologists call the earliest known people living in North America the Paleo-Indians.

During the Ice Age, the mountains of Oregon were covered by large glaciers. Huge lakes filled the valleys and basins of eastern Oregon. Archaeologists have discovered evidence of people living in Oregon 13,200 years ago. One group lived in a cave that was near a lake at Fort Rock in Lake County.

By 11,500 years ago, people were living all over North America. Many of these people used a large spear point with a shallow groove (flute) on each side of the point that has been named a Clovis point. Archaeologists do not know why the grooves were made, but they have inferred several ideas. Perhaps the groove made it easier to attach the point of the spear to a spear shaft. Perhaps it made the spear easier to remove from an animal that had been killed.

People using Clovis tools hunted big game animals, including mammoths, mastodons, and a giant bison. Clovis points have been found in all parts of Oregon.

Clovis Point



Spear



Clovis Point



## Oregon's First People *(continued)*

When Paleo-Indians first arrived in Oregon, much of Oregon was covered by a cold tundra environment. Around 12,000 years ago, the world's climate began to change from the cold of the Ice Age to a warmer, drier climate. In Oregon, the climate changed, too. Glaciers in Oregon's mountains began melting and became smaller and smaller. Many floods swept down the Columbia River as ice dams formed and broke in the mountains far to the northeast in Idaho. Sometimes the floodwaters rushed up the Willamette River almost as far as Eugene. Granite boulders from Montana were carried by icebergs in these huge floods and can now be seen near Eugene, Salem, and McMinnville. Floods also came from glaciers melting in the Cascade and Coast Range mountains.

Oregon's plants and animals changed in response to the climate change.

The very large herd animals that the Paleo-Indians relied on became extinct or moved out of the area. Deer, antelope, bear, coyote, cougar, mountain sheep, elk, small mammals, birds, reptiles, and fish remained.

Meltwaters from the glaciers formed large lakes and marshes that did not completely dry up for several thousand years. Groups of people could still live around the lakes. These people knew which wetland plants were good to eat. The ducks, geese, and animals that came to the lakes for water were hunted. Because the lakes and marshes provided much food, the people did not need to move often, and they made permanent homes around the lakes. This way of life lasted from about 9,000 to 7,000 years ago.

About 7,000 years ago, the weather became drier and warmer than today's climate. The weather did not change much again until about 4,000 years ago when it became much like it is today. How much longer today's climate will stay as it is now is not known. What is known is it will change.

The Great Basin covers the southeastern corner of Oregon, in addition to parts of Idaho, California, Nevada, Utah, and Arizona. It is called a "basin" because the rivers in the region do not flow to an ocean. The Great Basin's climate today is a cool, dry desert ideal for preserving artifacts left by Indian people thousands of years ago.

A little before 7,000 years ago, Great Basin people began to make two points that were smaller than Clovis points. Archaeologists call these two point types the Cascade point and the Northern Side-notched point. The smaller points were used on light darts that were thrown with a spear-throwing tool called an atlatl (AT-ul-AT-ul). The atlatl was a new kind of hunting weapon. Instead of a thrusting spear, hunters were now using an atlatl to throw a spear or dart. Using the atlatl, hunters could throw a dart farther and more accurately than they could throw a spear by hand.

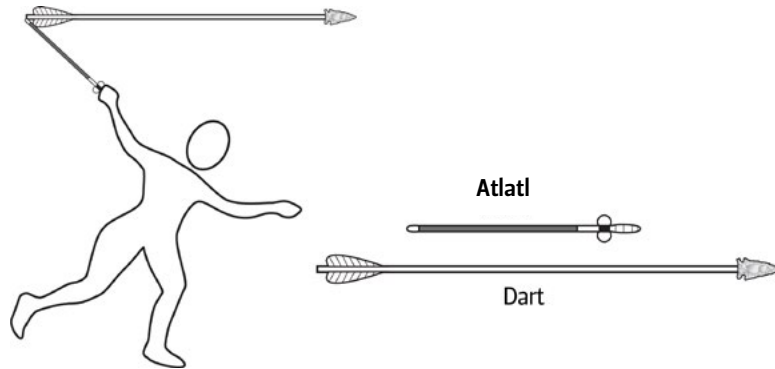
About 3,000 years ago, the climate began to cool again. More rain fell. There was more snow in winter. Bows and arrows first came into use during this time. The people began making a different type of point for the arrows.

These points were smaller. Archaeologists call the most common types of points found from this period the Rosegate and the Desert Side-notched point.



**Oregon's First People** *(continued)*

Northern Side-notched point

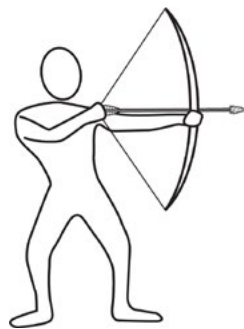


Northern Side-Notched Point



1/2 real size

While many things are known about Oregon's first people, much remains to be learned or understood. People can help archaeologists learn more about early people's lifeways by leaving artifacts where they find them and not digging in any sites. Sites that are left undisturbed tell a complete story about how people lived and how their culture changed over time. Leave artifacts where you find them and report your find to an archaeologist, university, or public land management agency.



Desert Side-notched point



1/2 real size



## Activity 8B—Soil: A Stop Along the Rock Cycle

### MATERIALS

- 1 copy of the Soil worksheet per soil sample per learner
- From 3 to 5 soil samples. Collected samples should include the material on the surface and down to about 4 inches deep into the horizons. Number the soil samples.
- Newsprint or flip-chart paper, one sheet per soil sample
- Clear jars with lids, one per soil sample
- Two, 2-cup glass measuring cups
- Access to water
- Roll of paper towels
- Small wire mesh sieve or tea ball sieve

### FYI

Organic matter is anything that is, or once was, part of a living plant or animal. Material that is recognizable as animal or plant parts is called litter or duff. The mixture of decayed organic matter found near the surface of the soil is called humus. Humus does not include living animals and plants, or recognizable parts of dead animals or plants.

When scientists study soil, they divide it into layers from the surface downward. These layers are called horizons. A set of horizons that describes a particular soil type is called a soil profile.

The surface, humus-rich horizon of most soils is called the A horizon.

Some soils, especially in forests, have thin layers of plant litter on top of the mineral soil. These layers are called O horizons. O horizons consisting of peat or muck also may occur in swampy or boggy soils.

Subsoil horizons beneath the surface soil are called B horizons. B horizons contain less organic matter than A horizons. Colors of B horizons, along with their clay contents and shapes of soil aggregates, record the maximum effects of processes that change rocks into soils. Beneath the B horizons, we find either C horizons, which are weathered but not fully altered into soil B horizons, or R horizons, which are hard bedrock.

Parent material refers to the original materials from which A, B, and C horizons have developed. In some soils, the A and B horizons have formed from materials like those in the C or R horizon beneath them. In many other soils, however, new parent materials have been deposited on top of older C or R horizons, and we cannot say that the C or R horizon is the parent material of the soil above it.

There are tremendous variations in soils and their development from parent material due to differences in temperature, rainfall, vegetation, and slope. Soils do not always develop profiles with all five horizons.

### PROCEDURE

Just as a glacier might be a stop along the water cycle for a water drop, so might soil be considered a stop along the rock cycle for small fragments of weathered rock. Have learners refer to their copy of the Rock Cycle worksheet from Activity 3A. Ask learners which processes depicted in the diagram contribute to the formation of soil.



In Activity 1B, learners rubbed rocks together to make sand. They compared the sand to a sample of soil. Leaders may want to revisit this activity. What does soil contain that weathered rock fragments alone do not?

Bring out the soil samples. Now learners will do an investigation of soil themselves following the steps on the worksheet. Read over all the procedures on the worksheet with learners before they start. Distribute the materials to each team. You will pour each numbered sample onto a large sheet of paper in turn. Ask learners to look through the samples. Look quickly! There may be insects, snails, earthworms, or nematodes who will try to hide. The learners should be able to find and identify some pieces of plant material, parts of invertebrates, hair, feathers, and other bits of organic matter. They can list what they find in the worksheet section Who's at Home?

To determine how much air space is in the soil sample, you will add water from a 2-cup measuring cup into the soil sample in the second cup (Photo 17).

In Part 3: Organic Matter, the organic matter floats to the surface of the water. Be sure to take the organic matter out of the jar before you shake it for Part 4: Weathered Rock (Photo 18).

### DISCUSSION

Review the makeup of soil with learners. Were there any components in soil that surprised anyone? What additional experiments would learners like to try with soil?

### EXTENSION

Order and show the DVD *The Great Ice Age Flood* from Discover Your Northwest's web page (<http://www.discovernw.org/mm5/merchant.mvc?Screen=SFNT>).

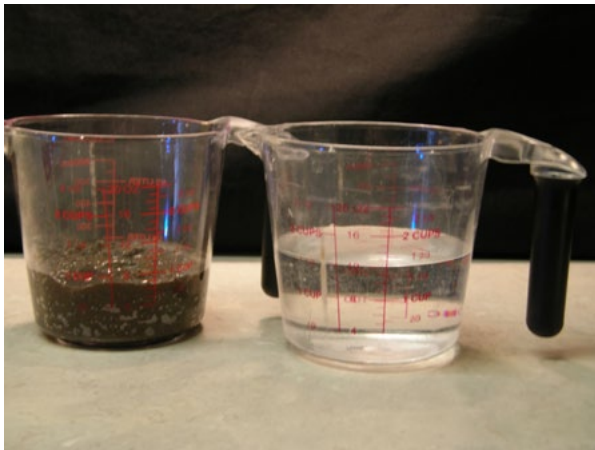


Photo 17



Photo 18



**Soil worksheet sample # \_\_\_\_\_****Part 1: Who's at Home?**

Your leader will pour a sample of soil onto a large sheet of paper. Look through the samples. Look quickly! There may be insects, snails, earthworms, or nematodes who will try to hide. Find and identify pieces of plant material, parts of invertebrates, hair, feathers, and other bits of organic matter. Record what you find here:

---

---

**Part 2: Air Spaces**

Your leader will pour soil samples off the paper into one of the 2-cup measuring cups. Record how much soil is in the cup.

---

Predict how much of the volume of the soil is air space

---

Your leader will use the second measuring cup to pour water onto the soil sample in the first cup. Begin with the lowest air space volume predicted by the learners. Pour this amount of water into the soil.

First amount of water added: \_\_\_\_\_

Second amount of water added: \_\_\_\_\_

Third amount of water added: \_\_\_\_\_

Total amount of water added: \_\_\_\_\_

Discuss: How much of the volume of the soil was air space? Why is air space important in soil?

Pour the soil and water mixture into one of the clear jars and save. Repeat Part 1 with each of the other soil samples, and record results on a Soil worksheet.

**Part 3: Organic Matter**

Add water to the soil in the clear jars from Part 1 until the water is about an inch over each soil sample. Swirl each jar gently to loosen the soil sample. Do NOT shake the jar.

Using a small sieve, scoop out all the material floating in the first jar and dump it onto a stack of several paper towels to drain. This floating material is that portion of the organic matter consisting primarily of dead plant and animal parts from each soil sample. Use a hand lens to compare the samples. How are they the same or different? Record your observations.

---

---

**Part 4: Weathered Rock**

Place the lid securely on the soil-and-water-mixture sample in the jars Parts 1 and 2. Shake the jar vigorously. What happens to the soil? Record your observations.

---

---

Place the jars where they can be observed for an hour or more. The soil particles will settle in layers, with the largest particles settling to the bottom of each jar first. Sand grains, measuring 2 to  $\frac{1}{16}$  millimeters, will settle out first.

Next, the silt content, particles from  $\frac{1}{16}$  to  $\frac{1}{256}$  millimeter, will settle out.

The smallest particles might remain suspended in the water for a long time. These are fine clays with particles less than  $\frac{1}{256}$  millimeter in size.

How might we measure the amount of material in each layer without mixing them again?

---

---

Place the jars where they can remain undisturbed for a week or more. Do you notice any other changes in the material in the jars?



## 9. People on the Landscape

### Objectives

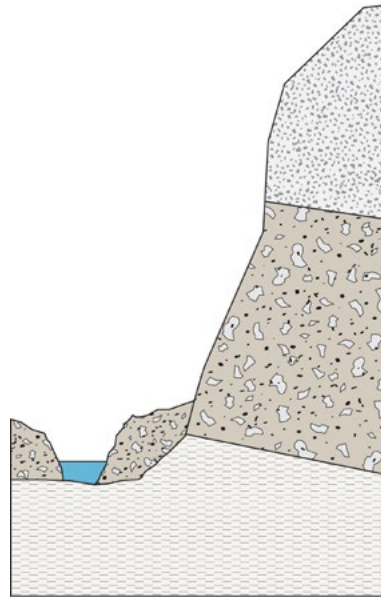
#### LEARNERS WILL BE ABLE TO:

- Understand the relationship between human population movement and population centers and current geological conditions
- Use a model to explain a landslide
- Explain how the discovery of gold in Oregon contributed to early settlements
- Describe early gold mining methods and their impact on local environments and Indian populations

#### NEXT GENERATION SCIENCE STANDARDS (NGSS)

##### PRACTICES:

1. Asking questions
2. Developing and using models
4. Analyzing and interpreting data
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information



### Field Trips

1. Bonneville Dam and the Bonneville Landslide—40 miles east of Portland on I-84, trailhead of Pacific Crest Trail at the base of the Bonneville Landslide
2. Gin Lin Interpretive Trail—Information from Rogue River National Forest
3. Kam Wah Chung Museum—John Day. The business of Chinese miner “Doc” Hay.
4. U.S. Bank—Baker City. A displayed collection of gold nuggets found in eastern Oregon
5. National Historic Oregon Trail Interpretive Center—information and artifacts from the study of the Flagstaff Mine

### Background

The relationship of people with geology is often masked by geology’s enormous size. Most of our largest cities are on the contact point between continental and oceanic tectonic plates (Figure 6, page 19). Other cities are built on major rivers and along lakes carved by glaciers. The productivity of our farmlands is determined by the nature of their soils and their location relative to mountain ranges and oceans that strongly influence rainfall.

The movement of human populations in the past was directed by the nature of the landscapes they encountered. During the Ice Ages, lowering of the sea level allowed people to move onto continents where they had not lived before (Chapter 8, Activity 8A). Oceans and major mountain ranges isolated groups of people, allowing different cultures to develop in different areas. Even the small mountain ranges that bisect Greece caused the people living in the valleys between to become independent city-states 2,500 years ago.

In Oregon, the isolation of different groups from each other by major rivers and mountain ranges resulted in more than 200 different American Indian languages developing over the past 10,000 years. Some of these languages are as different from each other as English is from Chinese.



Geological circumstances also influenced the first Oregonians' technology. For example, the Chinook Indians on the Columbia River used large canoes for transportation, while the Northern Paiute and Tenino Indians in eastern and central Oregon moved on foot and later on horses, which were introduced in the 18th century. Horses were never very useful in the dense forests of the Cascade Mountains or the Coast Range.

People have endured major geological catastrophes, and at times have taken advantage of the conditions left in their aftermath. The eruption of Mount Vesuvius in 79 A.D. killed tens of thousands of people, but the ash that spread across the landscape left behind some of the richest soil in Italy. People farm the slopes of Mount Vesuvius today, even though the volcano is still active.

All of the world's major rivers exist because of the Earth's geological activity. Mountain ranges built by colliding tectonic plates and erupting volcanoes intercept rainfall, creating watersheds. The Columbia River drains both the northern Rocky Mountains (a tectonic range) and the Cascade Mountains (a volcanic range), providing people with water for irrigation, navigation, and hydroelectric power ( Figure 1, page 6; Activity 1A; Activity 5A).

The requirements of human technology and our fascination with rare metals and gemstones have influenced the movement of people, and caused conflicts between them, over tens of thousands of years. During prehistoric times, obsidian, the best material for making most stone tools, was traded over thousands of miles in Africa, Asia, Europe, and the Americas (Activity 8A). The island of Cyprus in the Mediterranean Sea gave its name to a metal common there—copper. Copper is a key component in the manufacture of bronze, the first metal used to replace stone tools. The Spanish conquest of Central and South America was driven by Spain's desire for gold, the principal medium of exchange in Europe during the 16th and 17th centuries A.D. The domination of India and south and central Africa by England, France, and Germany in the 19th century was due in large part to the wealth of diamonds and gold common in those places. World War II was, in part, the result of Germany's and Japan's lack of a mineral resource—oil—critical to industrial nations.

In Activity 9B, learners will study how the discovery of gold in the Blue and Klamath mountains led to the settlement of these areas by immigrant Americans.

Humans also have attempted to change geology to meet their needs and prevent damage from geological events. Some of the earliest human engineering involved the construction of irrigation canals in Mesopotamia, India, and Central and South America to deliver water for farming to areas normally too dry to produce crops. Every large city built near an ocean or a river is protected from flooding by dams and levees.

Humans have even connected oceans naturally isolated from each other by digging huge canals. The two most important to transportation are the Suez Canal, between the Indian Ocean and the Mediterranean Sea; and the Panama Canal, which links the Pacific and



Atlantic oceans. Our attempts to control major rivers by building flood-control levees often have made flooding worse by focusing the floodwater's energy on places that are not adequately protected. Along the Mississippi in 1993, thousands of square miles of farmland, towns, and cities suffered because planners and builders did not fully understand this process.

Recently, countries worldwide have begun planning for major geological catastrophes. The western sides of Oregon and Washington are particularly vulnerable to both major earthquakes and volcanic eruption, since they rest on a subduction zone where North America is overriding two oceanic plates. In this setting, large earthquakes (magnitudes between 8 and 9) occur infrequently, at intervals of 300 to 500 years, but could destroy buildings, bridges, and roads and generate huge tsunamis that might inundate coastal towns and cities (Activity 5B).

Many of the bridges and buildings in Portland and Seattle are being retrofitted to resist these earthquakes. Modern building codes require that new structures in the Pacific Northwest are built to resist earthquake damage. The Cascade Range contains some of the world's most dangerous volcanoes. Mount St. Helens erupted in 1980, killing 57 people and disrupting traffic on the Columbia River and the roads and railroads along it. In the past, Mount Rainier and Mount Hood have produced huge lahars or mudflows that would reach Tacoma, Seattle, and Portland if they occurred today. The unstable geology in much of the Pacific Northwest has caused major landslides in the past. The Columbia River Gorge has been the scene of some of the largest landslides in recent geological history. In Activity 9A, learners will study how the relationship between rock formations can predispose an area to landslides.

It's important for us to study and understand the geology of our planet. We rarely can do anything to predict or prevent geological events, but we can plan for these events and try to limit the loss of life and property. The U.S. Geological Survey, in cooperation with other state and federal agencies, is studying the geological hazards that exist in Oregon. You can learn more about their research on the Internet at [www.USGS.gov](http://www.USGS.gov).

See also *Oregon: A Geologic History* and *Unstable Oregon, Land of 10,000 landslides* <http://www.oregongeology.org/sub/publications/IMS/ims-028/unit19.htm>



## Activity 9A—The Bridge of the Gods: Landslides and People

FYI

The Bonneville Landslide is located in the Columbia River Gorge, 40 miles east of Portland. This landslide is part of the Cascade Landslide Complex that originates in the mountains north of the town of Stevenson, Washington, and is an example of how geology affects human populations.

The geological processes that first formed and then altered these mountains created a very unstable situation. Three geological formations are stacked on top of each other and are exposed on Table Mountain, Greenleaf Peak, and Red Bluff (Figure 12, page 103).

On the bottom is the Weigle Formation, which is made up of sedimentary rocks, mostly mudflows or lahars, along with some river-deposited sediments and volcanic ash (see the Bonneville Landslide worksheet, page 104). The Weigle Formation has been deeply weathered and altered by hot groundwater until most of the minerals in the formation have been converted to clay. Above the Weigle Formation is the Eagle Creek Formation, which also is sedimentary. The Eagle Creek Formation is similar in composition to the Weigle Formation, but the rocks are not as altered. Capping the mountains is Columbia River Basalt, a very dense volcanic rock that is vertically fractured into columns (Chapter 7, Background). In addition, the area is bisected by the Mount St. Helens seismic zone, where earthquakes are common.

During uplift of the Cascade Range over the past several million years, a major fold developed north of the Columbia River, tipping the Weigle, Eagle Creek, and Columbia River Basalt formations toward the river. The contact between the clayey Weigle Formation and the Eagle Creek Formation is like a well-greased skid board. Even a small earthquake could cause landslides under these conditions. Geologists have identified four major landslides in and around Stevenson, Washington. The Bonneville Landslide is the most recent.

The Bonneville Landslide was catastrophic, instantly moving 200 million cubic meters of rock, sand, and mud across the Columbia, coming to rest nearly 400 feet above what is now the town of Cascade Locks, Oregon (Figure 12). The event was recorded in the mythologies of the Klickitat and Chinook Indians and is collectively referred to as the legend of the Bridge of the Gods since people could cross the mighty Columbia on the material deposited by the landslide and not get their feet wet.

When the Columbia River finally breached the landslide dam, it created a large set of rapids, which Lewis and Clark called the Cascades. This name eventually was applied to the entire mountain range in Washington, Oregon, and northern California.

The Cascades of the Columbia River created conditions favorable to people by slowing migrating salmon, making them easier to catch. In the centuries following the landslide, this part of the river was impassable for boats and canoes, which had to be unloaded and carried around the rapids. The Chinook Indians took advantage of the situation by collecting tolls from people using the trails that bypassed the Cascades.

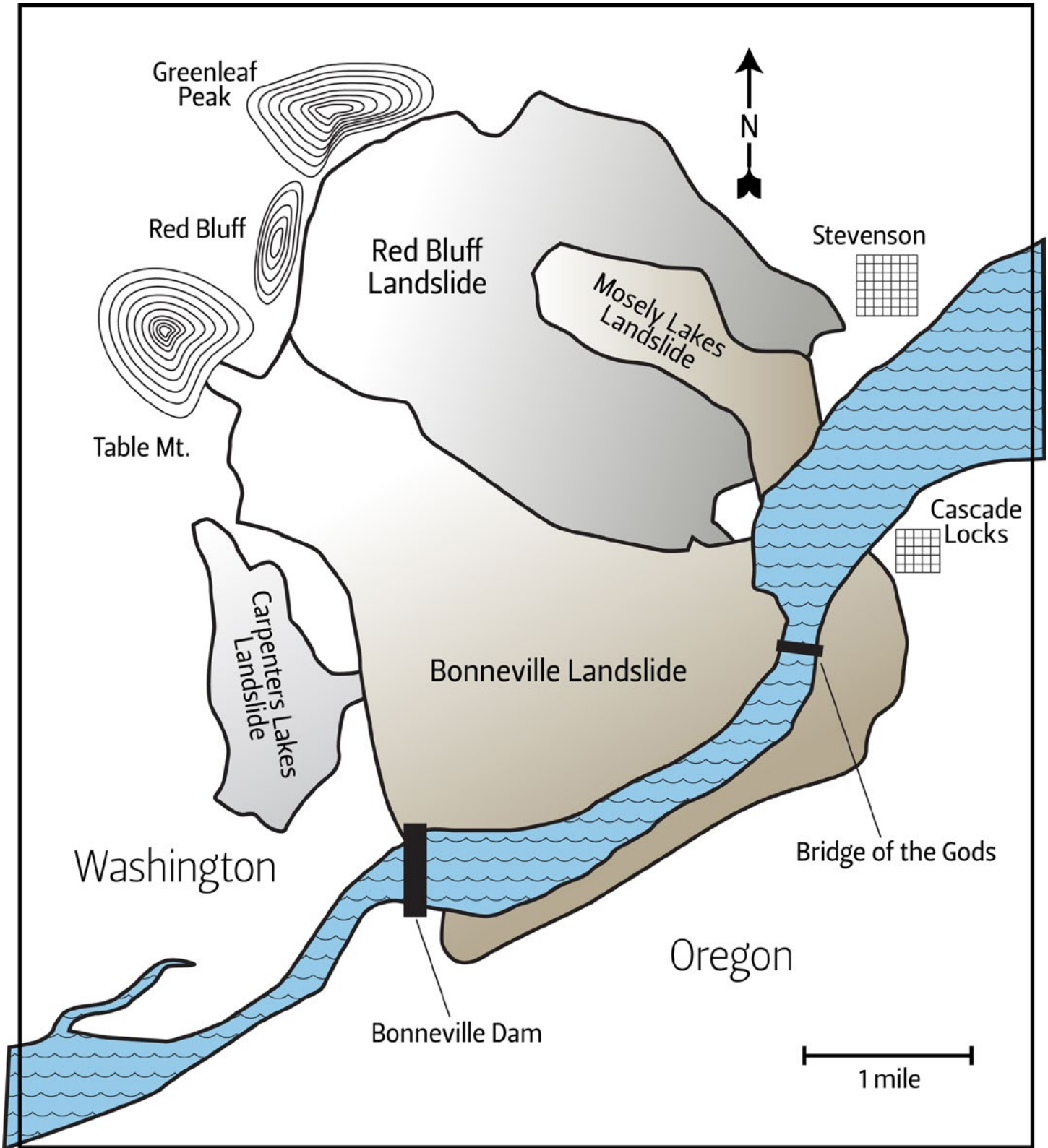
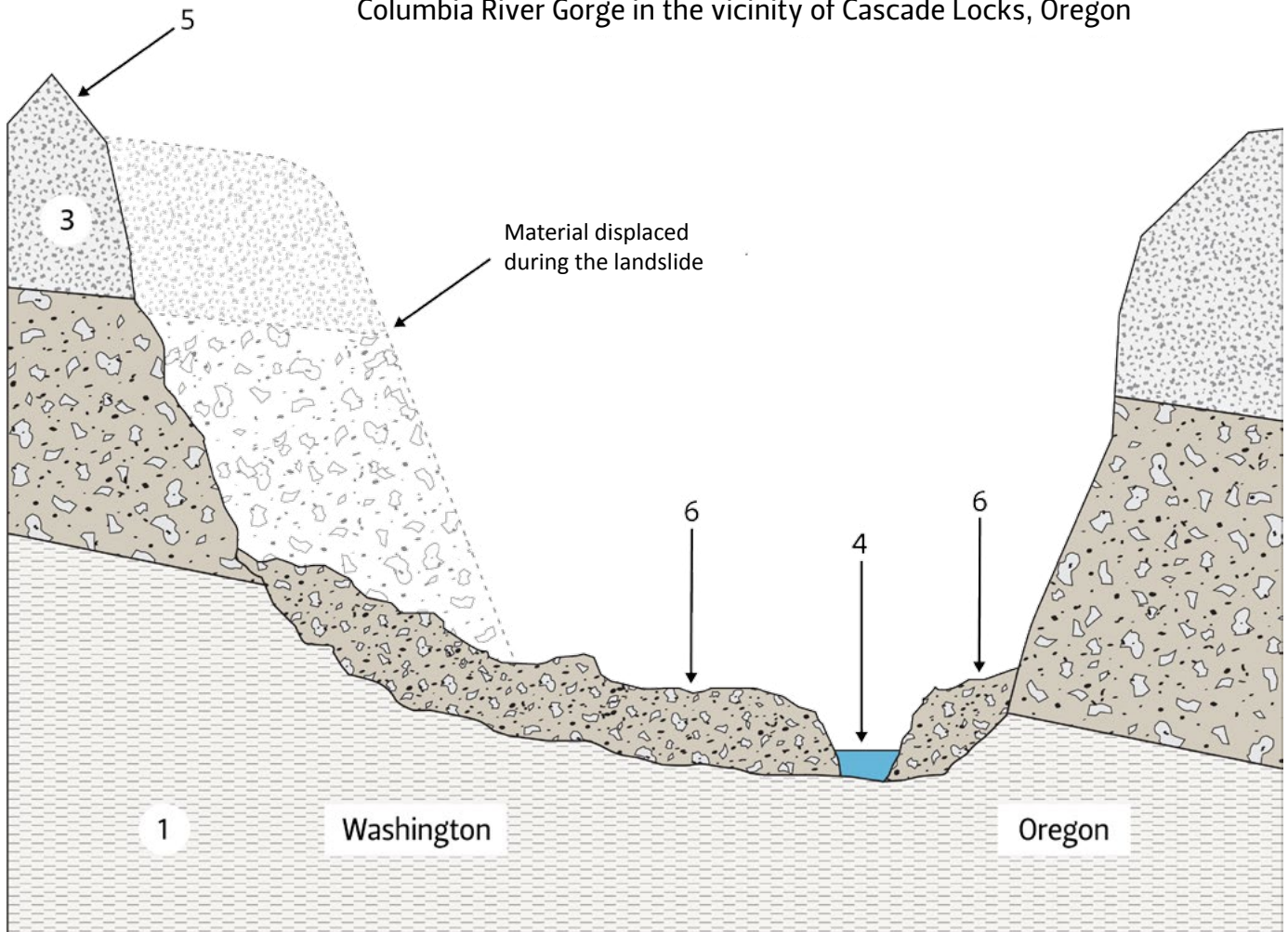


Figure 12. The Cascade Landslide Complex



### Bonneville Landslide worksheet

Bonneville Landslide Profile  
Columbia River Gorge in the vicinity of Cascade Locks, Oregon



- 1. \_\_\_\_\_
- 2. \_\_\_\_\_
- 3. \_\_\_\_\_
- 4. \_\_\_\_\_
- 5. \_\_\_\_\_
- 6. \_\_\_\_\_





Continued from page 102

The landslide formed a constriction in the river that was a key factor in selecting this site for Bonneville Dam, the first hydroelectric dam built on the Columbia. The modern Bridge of the Gods at Cascade Locks, Oregon, was built here for the same reason.

The conditions that produced the Cascade landslide still exist. Table Mountain and Greenleaf Peak, the largest mountains in the area, are seriously over-steepened. Huge cracks, up to 30 meters across, can be seen on the face of Table Mountain. Periodic earthquakes are recorded on the Mount St. Helens Seismic Zone. It's very likely that future earthquakes will trigger landslides in this area. The USGS and the Washington Department of Natural Resources are studying the Cascade Landslide Complex as part of ongoing geological hazards analysis.

## Part 1

### MATERIALS

- One copy of the Bonneville Landslide worksheet per learner
- An Oregon-Washington map that shows features on the north edge of the Columbia River in Washington State
- Make a PowerPoint slide of Figure 12, The Cascade Landslide Complex, to project for discussion. Take a screen print of the page on your computer screen, paste it onto a PowerPoint slide and crop out any unwanted areas.

### PROCEDURES

Using the Background and FYI sections, lead a discussion about the impacts of geology on human activities. Use the Oregon-Washington map to locate Bonneville Dam and Cascade Locks in Oregon and Stevenson, Washington. Work with learners to label the Bonneville Landslide Profile.

Answers to the Bonneville Landslide worksheet

1. Weigle Formation
2. Eagle Creek Formation
3. Columbia River Basalt
4. Columbia River
5. Table Mountain
6. Bonneville Landslide

## Part 2

### MATERIALS

- 1-inch-thick book
- 8½- x 11-inch sheet of corrugated cardboard
- Three sets of plastic building blocks, in three different colors (Legos® or similar)
- Color 1: 16 blocks @ 2 x 4 peg size
- Color 2: 16 blocks @ 2 x 4 peg size
- Color 3: 30 blocks @ 2 x 2 peg size



## PREPARATIONS

Using the set of plastic building blocks specified in the materials list, create a model of the mountains that collapsed, creating the Bonneville Landslide. From Color 1, 2x4 peg blocks, build two stacks of blocks, each eight blocks high. These blocks will represent the Weigle Formation located at the bottom of the stack. These blocks are blue in the photos.

Place these two stacks of blocks horizontally (on their sides) on the corrugated cardboard, across the short width of the board.

From the Color 2 blocks, build two stacks of eight blocks each. These blocks represent the Eagle Creek Formation. The four stacks should be placed horizontally on the “Weigle Formation” blocks at a right angle to the direction the “Weigle” blocks were placed. The “Eagle Creek Formation” blocks should be running the same direction as the length of the corrugated cardboard. These blocks are white in the photos.

From the Color 3 blocks, build 10 stacks of three blocks each. These blocks represent the vertical columns of the Columbia River Basalt formation that cap the hills throughout this area. Place the “Columbia River Basalt” blocks vertically on top of the “Eagle Creek Formation” blocks. These blocks are red in the photos.

CAREFULLY lift one short edge of the corrugated cardboard and rest it on a book (Photo 20).

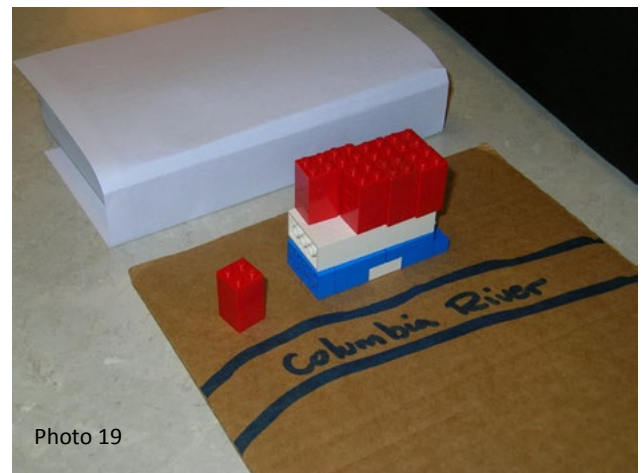


Photo 19

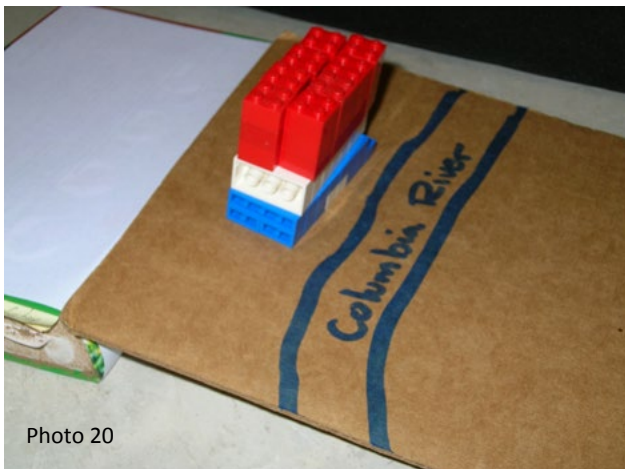


Photo 20

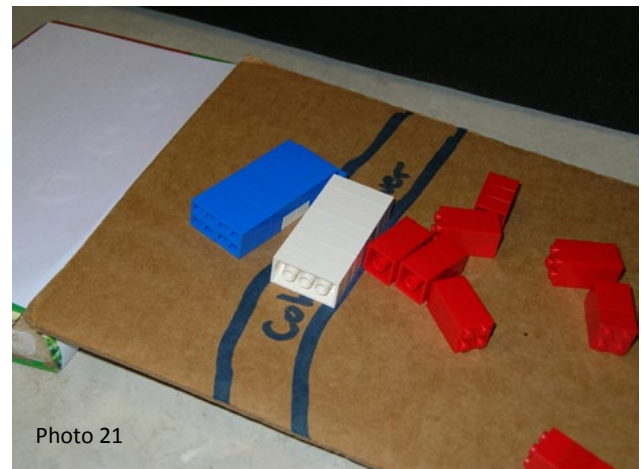


Photo 21



## PROCEDURE

Explain to learners that the three colors of blocks represent the Weigle, Eagle Creek, and Columbia River Basalt formations. The landform is tipped toward the Columbia River. This is a representation of what the Washington side of the Columbia River looked like prior to the landslide.

The Columbia River would be located where the cardboard rests on the table.

Have learners look at their Bonneville Landslide worksheet and note the parts of the Columbia River Basalt and Eagle Creek formations that were displaced during the landslide. Explain that one learner is going to bang firmly on the table surface. What do the learners think will happen? Ask one learner to bang on the table (it might take two good blows if the table is sturdy). The middle layer of “Weigle Formation” blocks should skid off the bottom layer, tumbling the top layer of “Columbia River Basalt” onto the table surface (Photo 21).

## DISCUSSION

The slippery surface between the “Weigle Formation” blocks and the “Eagle Creek Formation” blocks represents the surface on which the Bonneville Landslide moved. The rocks above this surface collapsed into the Columbia River Gorge as seen in the Bonneville Landslide worksheet.

Remind learners that 200 million cubic meters of rock, sand, and mud were moved by this landslide. Measure the distance from Bonneville Dam to Cascade Locks. How much area did the landslide material cover on the Oregon side of the river?

## Activity 9B—Gold Mining in Oregon

The “Gold Mining in Oregon” activity was adapted from *Exploring Oregon’s Past* teacher’s activity guide for fourth through seventh grades, developed by the Bureau of Land Management Oregon state office, and used with permission.

## MATERIALS

- Copy the essay, “Gold Mining in Oregon” (see page 110), one per learner.

## FYI

Gold is the most historically important mineral mined in Oregon. The discovery of gold led to the settlement and development of major parts of the state. Gold mining had negative effects on the native populations and natural environment.

Gold occurs primarily in two regions of the state: the Blue Mountains (see Chapter 2) and the Klamath Mountains (see Chapter 3).

The way of life of the miner evolved from an individual prospector/miner to working in a company. This change involved a change in lifestyle as well, from mostly male mining district communities to more family-oriented towns and settlements.

Gold mining is an industry that is very responsive to outside factors, particularly developments in technology and economic cycles of depression and inflation.

Miners faced a common set of problems in the early days of mining regarding the rules of how to claim and hold land without conflict. There are no right or wrong answers to some of the discussion questions provided below. The problems faced were addressed differently by different groups. One common theme in all mining districts was the belief that a person



who discovered a section of gold-bearing land had the right to exploit it, and that right lasted as long as the person actively mined the claim.

### PROCEDURE

Discuss with learners what they know about gold mining in Oregon. The California and Alaska gold rushes may be more familiar to them. Pass out the essay “Gold Mining in Oregon” for the learners to read. You might choose to send the essay home prior to this activity so that learners already will have read the essay and are ready for the discussion.

### DISCUSSION

#### Part 1: Vocabulary

Dredge—power-operated machine used in streams and rivers to dig, process, and dispose of sand and gravel.

Hydraulic mining—method of mining in which gold-bearing material is washed out by a jet of water into sluice boxes.

Lode—deposit of mineral in a vein of rock.

Ore—rock containing a valuable metal for which the rock is mined.

Placer—deposit of eroded mineral in the rock matrix, sand, and gravel commonly found in stream beds and river-deposited soil.

Sojourner—someone who lives somewhere temporarily; a term applied to Chinese miners.

Tailings—piles of rock and cobbles left from placer and lode mining after the gold has been extracted.

#### Part 2: Idea Review

- The reading tells learners that the two largest areas in Oregon where gold occurs are the Blue Mountains and Klamath Mountains. Remind learners of what they learned in Chapters 2 and 3. What do the two areas have in common geologically that would lead to the formation of gold deposits? (Accreted island arc volcanoes and the associated geological processes.)
- Name one invention that helped mining. How did the invention work?
  - Pans for “washing” sand and gravel to find the heavier gold allowed a miner to work independently using only shovels and picks.
  - Sluice boxes have riffles (raised strips of wood) in the bottom to catch gold nuggets as water carries the lighter sand and gravel over them.
  - Hydraulic mining includes the use of “giants” to wash the dirt off hillsides into sluice boxes.
  - Dredges are machines that dig sand and gravel out of the bottom of streams.
  - Lode mining included blasting, crushing, and processing.
  - Ore crushers (ore-crushing mills) allowed greater recovery of gold from ore.
- What was “Gum San” and why did the “sojourners” come there? What were some of the hardships Chinese miners faced?
  - “Gum San” means the “Mountain of Gold” in Chinese; it was how some Chinese people described America.
  - Chinese “sojourners” came to the mines to make money to send back to their families in China. They planned to return to China when they became rich.
  - Chinese miners faced many hardships. They were not considered equal by whites.



They were not given equal treatment under the law; they paid extra taxes; they were not allowed to own land or mining claims, and many had to work mining claims that had been abandoned by white miners. Chinese miners rarely had families in America, as few Chinese women or children came to America. After the early 1880s, additional Chinese were prevented from entering America, so the Chinese population became smaller and smaller, and many were unable to maintain their customs.

### **Small Group Activity: Mining District Code of Laws**

After discussing the key points of the essay, divide the learners into several small groups. Each group will represent a mining district in Oregon. Ask each district of “miners” to organize themselves and develop a code of laws to regulate mining in their district. Each “miner” must agree to abide by the laws and must sign the code of laws. Each mining district will present their code of laws to the full group.

The following questions may be used to guide “miners” in the small group activity to create a code of laws for their mining district.

- Who may make a claim?
- How large a piece of land can a person claim?
- May a person make more than one claim?
- What happens if a miner gets sick and can't work his claim? Can someone else take it over?
- What happens if a miner dies or leaves the area?
- How is a claim recognized as “abandoned”? How does a claimant relinquish a claim?
- How often or how much does a miner have to work a claim to keep it? When does “claim-jumping” become justifiable?
- How should claims be recorded so that everyone knows what is claimed?
- Does the person (or group) who discovers a new mining area get any special privileges? Can that person or group have more claims than other people in that area?

### **References**

Barlow, J. and C. Richardson. 1979. *China Doctor of John Day*. Portland, Oregon. Binford and Mort.

Brooks, H.C. and L. Ramp. *Gold and Silver in Oregon*. Portland, Oregon. State of Oregon Department of Geology and Mineral Industries.



## Gold Mining in Oregon

Gold! When we think of mining in Oregon, gold immediately comes to mind. Gold was the lure that drew thousands of people to Oregon in the 1850s; gold mining was a main source of money in some parts of the state for 70 years and provided money for many who were out of work during the Depression of the 1930s. For many, gold mining was a way of life as well as a type of work. Though other minerals, including silver, nickel, and mercury, are in the state, gold is the most important mineral in Oregon's history.

### Where is the Gold?

In Oregon, gold occurs mainly in two large areas, located at opposite corners of the state. The Blue Mountains in northeastern Oregon have the richest deposits of gold and silver in the state. Silver occurs with gold in many ores. Ore is rock containing a valuable mineral or metal. The Klamath Mountains in the southwest corner of the state are the second-richest area. In addition to these gold-bearing regions, smaller deposits occur in the Cascade Mountains, which run north-south through the western half of the state, and in scattered places in eastern Oregon.

### Types of Gold Deposits

There are two main types of gold deposits: placer deposits and lode deposits. Placer deposits are made up of sands and gravels containing small bits or nuggets of gold that have eroded out of the original ore. Placer deposits usually are located near the top of the ground, especially in river and stream beds, and in the sand and gravel terraces built up alongside the streams. Placer deposits are mined by using some form of washing action to separate the heavier gold from the lighter sand and gravels.

Lode deposits consist of hard-rock ores that contain gold. These ores often are found deep in the rocks of the mountains. They are mined by digging into the mountains, breaking up the gold-bearing rocks, and then crushing the rocks to separate out the gold.

### Boom and Bust: 100 Years of Gold Mining in Oregon

The 1849 California Gold Rush brought thousands of people from all over the world to the American West. Prospectors then spread out from California looking for gold in other areas of the West. In 1851, two packers, James Cluggage and James Poole, discovered gold in southwest Oregon. In 1862, prospectors discovered the rich deposits of northeastern Oregon.

The first miners in Oregon came as independent prospectors. They brought what they could carry on their backs and on their mules, working sometimes in pairs or small groups, or sometimes alone. One problem the miners faced in these early years was the lack of laws regulating mining. Miners solved this problem by forming mining districts. People who were mining in a certain area, or district, would meet and agree on the mining laws that they would all follow in that district. These laws covered how to make and keep a claim so that no one else had a right to take it ("claim-jumping"), when a miner had given up a right to mine a claim, how much land could be in a claim, how many claims one person could have, how to mark a claim so that others know who has claimed it, what would happen to a claim if a miner left, and many other such problems.



## Gold Mining in Oregon *(continued)*

At first, the early miners worked the easy placer diggings. Their equipment was simple: a pan, a pick, and a shovel. Some used a sluice box. A sluice box is a wooden box with riffles in the bottom that trap the gold as the water carrying sand and gravel runs through it. A sluice box was more efficient than a pan, and more dirt and gravel could be washed. These methods of mining rely on the fact that gold is heavier than most dirt and sand and will settle to the bottom, while the rest of the material washes away.

After the easiest gold placers were mined away, miners had to get the gold out of the deeper placer deposits. Two inventions helped: hydraulic mining, which was developed in the 1860s; and dredging, which became important about 1900. Both hydraulic mining and dredging need expensive equipment with several people to operate it. Hydraulic mining uses large machines called “giants,” which operate like enormous garden hoses, to wash vast amounts of dirt off the mountainsides and into sluice boxes. It’s often necessary to build long ditches to bring water to the “giants.” Dredging uses a machine that can dig sand and gravel out of the bottom of a stream. Both of these ways of mining require more money and work than one miner alone can supply, and so mining becomes a business. No longer able to work as an independent prospector, the miner becomes a company man.

After the easy placer diggings were used up, miners also turned to the hard-to-mine lode deposits. Miners had to dig into the mountainside to get to the gold-bearing vein of rock (the lode), blast or dig out the lode to break up the ore, and get the broken ore out of the mountain.

Then the ore had to be crushed and processed so that the gold could be collected from it. Like hydraulic mining, lode mining requires money to buy equipment and miners working together to get the gold. Like placer mining, too, lode mining was helped by new inventions that made it easier and worth more money to mine and process gold ore. Around the turn of the century, for example, methods of removing gold from ore improved, allowing miners to recover even more gold from the deposits.

The miners had little respect for the land. The hydraulic mining, dredges, and lode mines created huge scars on the land and left great piles of rubble called “tailings.” Larger placer mining operations washed huge amounts of sand and silt into the rivers, destroying fish habitat. Lode mining tore apart hillsides and increased erosion. Over a long time, many of these scars have begun to heal, but the evidence of mining is still present and easy to see on the land.

Gold mining was important to the settlement of Oregon. Oregon settlers first provided food and supplies to the miners in California. When the first miners came to Oregon, they also needed food and supplies. They had to buy them from packers bringing goods from the areas of Oregon already settled. Soon farmers and merchants came to the mining areas, starting farms and stores and selling miners their goods. Ranchers provided beef, and loggers provided timber to the miners and to the growing towns. Roads and railroads were built to these towns. More trade and travel then became possible. With towns, farms, roads, and railroads, other business and industry came to the areas. Without the gold rush, settlement of the southwest and northeast parts of



## Gold Mining in Oregon *(continued)*

the state would have been slower, and the history of the state different. As mining became a company-run business, the miner was more likely to be a man with a family. Mining towns and camps sprang up near the mines, with post offices, schools, cabins, and bunkhouses. Some of these towns, such as Jacksonville in southwestern Oregon, managed to survive even after mining stopped. Other towns were abandoned when the gold ran out, or when the cost of mining was higher than the price of the gold.

Gold mining was important in certain parts of Oregon until World War II in the 1940s. The prosperity of the United States during the 1920s made it a poor time for gold mining. Workers and equipment were expensive, and the price of gold was set by the government. The cost of mining could not be passed on in the sale of gold.

During the Great Depression of the 1930s, this situation completely changed. Many people came to Oregon to eke out a living in the mines. Gold mining was shut down in the 1940s during World War II, in order to focus on mining minerals, such as iron and oil, that are important to fighting a war. Following the war, gold mining started up again to a small extent. In the last 20 years of the 20th century, new inventions for mining and the rise in the price of gold once again brought people into gold mining.

### The People of the Mines

The first miners were mostly men, from many different places around the world. They brought with them their own ways of working and ideas about how to live. Miners came from the United States, Mexico, Europe, China, and Hawaii (the Hawaiians were known as “kanakas”). Most of the miners who came thought they would “strike it rich” and return to their homes and families in their homelands. Yet many who came eventually decided to stay in Oregon.

Of the many different people coming to work in the Oregon mines, the Chinese were especially important. In China, America was known as “Gum San,” the Mountain of Gold. Thousands of Chinese, mostly poor peasants, came to the mines of California, Oregon, Idaho, and Nevada during the Gold Rush days. They hoped to make money to send back to their families in China. They planned to return to China when they had become rich. These “sojourners” worked and lived together, and followed a Chinese way of life, including foods, clothes, and customs, as much as possible. They were strong, hard, and careful workers, often making money on claims that white miners had abandoned.

The Chinese faced many difficulties in the United States. They were not considered equal to the white miner and were not treated equally under the law. They had to pay extra taxes and could not own land or mining claims. They often did the most dangerous and hardest work. In the early 1880s, a law was passed preventing any more Chinese from coming into the United States.

Eventually, many of the Chinese in the United States returned to China. The bones of others who died in the United States were shipped back to their home villages. Since most of the Chinese people who came to Oregon were men without wives or children in the United States, there were only a few Chinese left in Oregon by the 1930s.

“Doc” Hay was one of the few Chinese to make Oregon his lifelong home. Born





## Gold Mining in Oregon *(continued)*

to poor peasant parents in southern China, Hay came to the mines as a very young man. He lived with other Chinese miners in the “Chinatown” of John Day, in northeastern Oregon. There, he teamed up with another Chinese man to run a store for the Chinese miners. He had a special talent for doctoring and studied with a Chinese herbal doctor to learn the art and craft of Chinese medicine. His craft became widely respected by both the Chinese and white people in the area. Long after the “Chinatown” had shrunk to only a small community, Hay still had a busy practice. The building that served as his home and business is now a museum in the town of John Day.

The Gold Rush also had bad effects. The effect on Indian people living in the gold-bearing areas was disastrous. Mining destroyed their main food sources and their homes. Rivers and streams they lived along were “claimed” and taken over by miners. Many Indian people fought back but were driven from their homelands. Many died; others were taken to reservations.

### What’s Left Today? The Archaeology of the Mines

Archaeologists face a special problem when studying mining remains. A good mining place is often mined over and over again, especially as new techniques and inventions allow miners to recover more gold from old deposits. Thus, the remains of the earliest mining places and camps get covered up or destroyed by later miners. Yet there are still many telltale signs of Oregon’s mining history on the land, especially along the rivers and in the mountains in the northeast and southwest. Some of the most obvious are:

**Tailing piles:** These are vast mounds of rock and gravel that have been washed and dumped through hydraulic and dredge mining. They may be seen along many rivers and streams in the gold country.

**Hydraulic faces:** Hydraulic miners washed vast quantities of earth off river terraces and hillsides, leaving abrupt, steep scars in the landscape. Many of these cut-banks are still visible along rivers and streams.

**Ditches, flumes, rock walls:** It was important to direct water where it was needed, and miners built miles of ditches and flumes (wooden ditches over gullies or creeks) and rock walls to bring in water and channel it where it was needed.

**Mining equipment and artifacts:** Many mining sites contain pieces of equipment and tools the miners left behind when they departed. These include picks and shovels, parts of ore-crushing mills, pieces of pipe, and other machinery.

**Miners’ camps:** The remains of cabins and garbage dumps are frequent reminders of the places the miners lived while working at their mines. Sometimes these occur as single dwellings; other times they represent a small, temporary town.

**Tunnels, shafts, and adits:** Lode miners dug into the mountains to remove the gold ore. A tunnel is an excavation that goes through to another tunnel or to the surface; an adit is an excavation that goes straight into a mountainside and ends. A shaft is an excavation straight down into the ground. All three types are common in mining country but can be very dangerous to enter and explore. Poison air, hidden shafts, and unfriendly animals all occur in these reminders of history.



## Appendix—Resources

Acorn Naturalists, 17300 East 17th St, #J236, Tustin, CA 92780, 800-422-8886 <http://www.acornnaturalists.com>

American Geological Institute, <http://www.americangeosciences.org/for-students-and-educators>

Bend Ranger District, U.S. Forest Service, Deschutes National Forest, <http://www.fs.usda.gov/detail/deschutes/maps-pubs/?cid=stelprdb5289442>

Cape Perpetua Visitors Center, Siuslaw National Forest, Yachats, OR <http://www.fs.usda.gov/recarea/siuslaw/recarea/?recid=42279>

Carolina Biological Supply Company, <http://www.carolina.com>

Crater Lake National Park, <https://www.nps.gov/crla/index.htm>

Delta Education, <https://www.deltaeducation.com>

Discover Your Northwest books and DVDs web page (<http://www.discovernw.org/mm5/merchant.mvc?Screen=SFNT>)

Eagle Cap Ranger District, U.S. Forest Service, Enterprise, OR <http://www.fs.usda.gov/recarea/wallowa-whitman/recarea/?recid=51355>

*Exploring Oregon's Past, A Teacher's Activity Guide For Fourth Through Seventh Grades*, Bureau of Land Management, Oregon State Office

Hawaii Pacific Parks, <https://www.hawaiipacificparks.org/>

Hells Canyon National Recreation Area, Enterprise, OR <http://www.fs.usda.gov/detail/wallowa-whitman/recreation/?cid=stelprdb5238987>

John Day Fossil Beds National Monument, Cant Ranch Headquarters, Dayville, OR <https://www.nps.gov/joda/index.htm>

Marys Peak, U.S. Forest Service Alsea Ranger District, Alsea, OR <http://www.fs.usda.gov/siuslaw/>

Mount Ashland, U.S. Forest Service Ashland Ranger District, 645 Washington St., Ashland, OR 97520, 541-482-3333

Newberry National Volcanic Monument, Deschutes National Forest, Bend, OR <http://www.fs.usda.gov/recarea/deschutes/recarea/?recid=66159>

Oregon Caves National Monument, Cave Junction, OR <https://www.nps.gov/orca/index.htm>

Oregon Department of Geology and Mineral Industries, Portland, OR <http://www.oregongeology.org/sub/default.htm>

- Interactive Geologic Map <http://www.oregongeology.org/geologicmap/>
- Oregon: A Geologic History, <http://www.oregongeology.org/sub/publications/IMS/ims-028/index.htm>

Oregon Museum of Science and Industry (OMSI), 1945 SE Water Ave., Portland, OR <http://www.oms.edu/>



Oregon State Parks <http://oregonstateparks.org/>

*Stories in Stone, GEMS Teacher Guide.* The GEMS series includes more than 60 teacher's guides and handbooks for preschool through 10th grade, available from LHS GEMS, Lawrence Hall of Science, University of California, Berkeley, CA 94720-5200, 510-642-7771.

Upper Table Rock, Bureau of Land Management, Medford District, Medford, OR <https://www.blm.gov/or/resources/recreation/tablerock/table-rock-hiking.php>

U.S. Geological Survey <https://www.usgs.gov/products/publications/official-usgs-publications>

Alt, D.D. and D.W. Hyndman. *Roadside Geology of Oregon.* 1998. Missoula, MT. Mountain Press Publishing Co.

Anderson A., G.Diehn, and T. Krautwurst. *Geology Crafts for Kids: 50 Nifty Projects to Explore the Marvels of Planet Earth.* 1998. New York City, NY.

Bates, R. and J.A. Jackson. *Dictionary of Geologic Terms.* 1984. The American Geological Institute, New York City, NY. Anchor Books, Doubleday.

Carlow, J. and C. Richardson. *China Doctor of John Day.* 1979. Richardson, Binforde and Mort. Portland, OR.

Chesterman, W.C. *National Audubon Society Field Guide to North American Rocks and Minerals.* 1979. New York City, NY. Knopf

Lawton, R., D. Lawton, and S. Pantaja. *Discover Nature In The Rocks, Things to Know, Things to Do.* 1997. Mechanicsburg, PA. Stackpole Books.

Morris, E. and J.E. Allen. *Hiking Oregon's Geology.* 1997. Seattle, WA. The Mountaineers.

Orr, E.L. and W. Orr. *Oregon Fossils.* 1999. Dubuque, IA, Kendall/Hunt Publishing Co.

Orr, E.L., W. Orr and E.M. Baldwin. *Oregon Geology.* 1992. Dubuque, IA. Kendall/Hunt Publishing Co.

Parker, S. *(The) Earth and How It Works.* 1990. New York City, NY. Dorling Kindersley Inc.

Pough, F.H. *(A) Field Guide to Rocks and Minerals—Peterson Field Guide.* 1997. New York, NY. Houghton Mifflin Co.

Pough, F.H. *Peterson First Guide to Rocks and Minerals.* 1991. New York City, NY. Houghton Mifflin Company.

Sinkankas, J. *Field Collecting Gemstones and Minerals.* 1995. Prescott, AZ. Geoscience Press.

Thompson, I. *National Audubon Society Field Guide to North American Fossils.* 1992. New York City. Knopf

---

Trade-name products and services are mentioned as illustrations only. This does not mean that the Oregon State University Extension Service either endorses these products and services or intends to discriminate against products and services not mentioned.

---

© 2017 Extension work is a cooperative program of Oregon State University, the U.S. Department of Agriculture, and Oregon counties. Oregon State University Extension Service offers educational programs, activities, and materials without discrimination on the basis of race, color, national origin, religion, sex, gender identity (including gender expression), sexual orientation, disability, age, marital status, familial/parental status, income derived from a public assistance program, political beliefs, genetic information, veteran's status, reprisal or retaliation for prior civil rights activity. (Not all prohibited bases apply to all programs.) Oregon State University Extension Service is an AA/EOE/Veterans/Disabled.

---

Published July 2000. Revised April 2017.