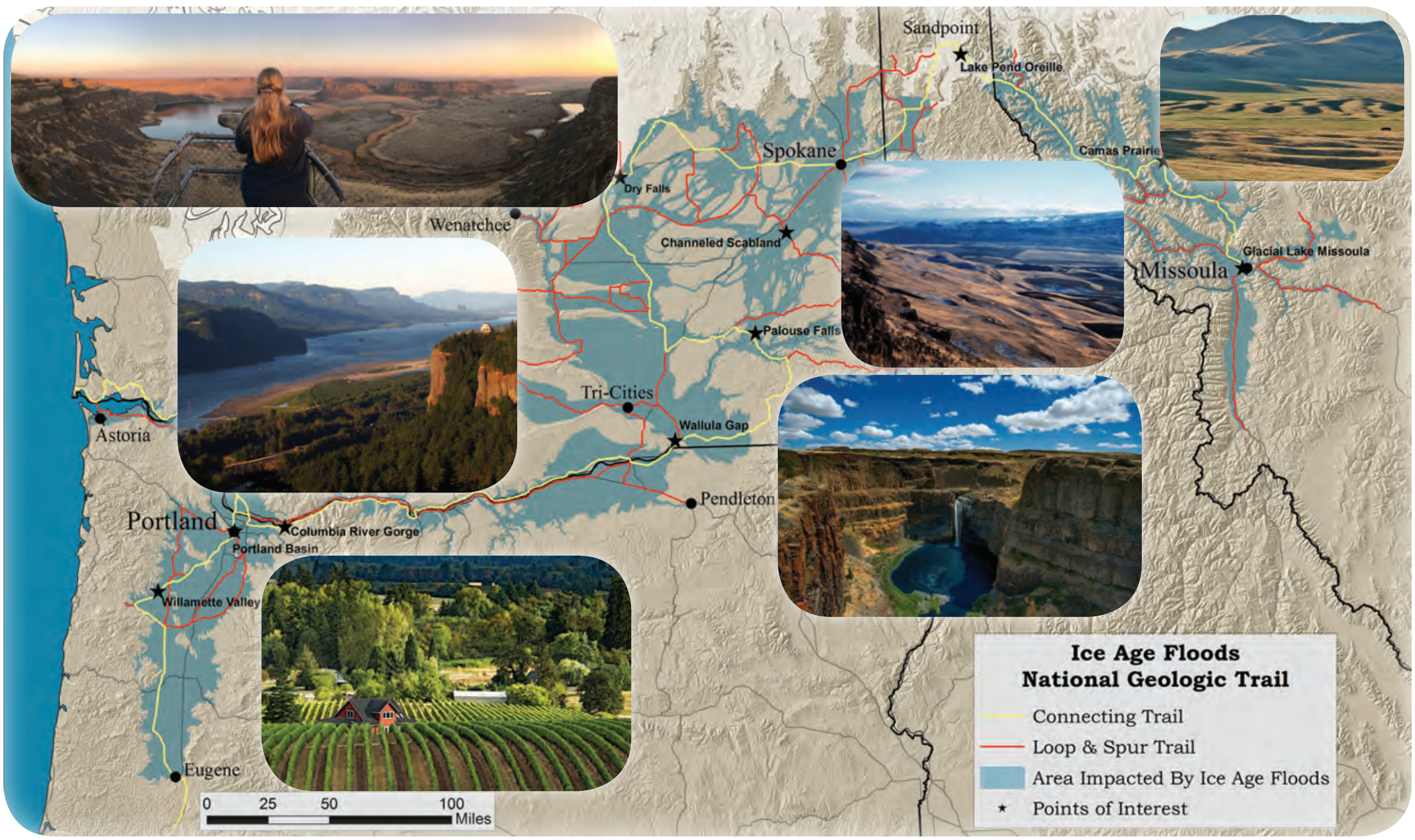
National Park Service
U.S. Department of the Interior

Investigating Ice Age Floods

Inquiry + Discovery of the National Geologic Trail + Beyond



Hands-On Science Lessons
Adaptable for Grades K -12

Aligned to NGSS + CCSS

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Some sections were adapted from an earlier
Ice Age Floods draft curriculum from NPS.

About this Educator's Guide + Program

Welcome! We are so glad you're joining us on this journey of discovery. This educator's guide provides adaptable lesson plans and other resources to help you engage students with the forces that created our dramatic landscapes. This includes the most recent Ice Age Floods some 18,000 to 15,000 years ago, which crossed Montana, Idaho, Washington, and Oregon, as well as the forces that created the rocks they eroded and more. Students experiment with scientific phenomena, ask questions, analyze and interpret data, construct explanations, engage in argument from evidence, and obtain, evaluate and communicate information. In short, they get to be scientists as they explore the awe-inspiring phenomena of our Northwest (NW) landscapes and the processes that created them through hands-on investigations, field studies, and other engaging projects.

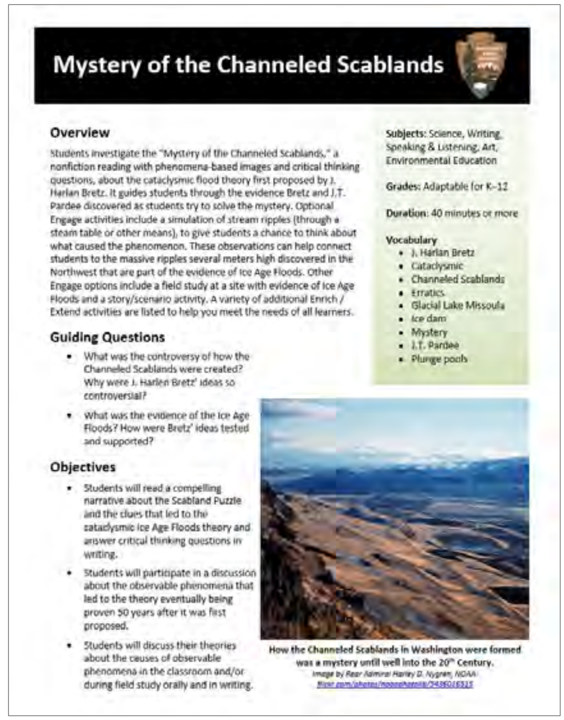
The Columbia River Gorge is one of many NW phenomena that are evidence of Ice Age Floods.
Wikimedia Commons:
commons.wikimedia.org/wiki/File:Columbia_river_gorge_from_crown_point.jpg

One of our goals is to help students develop an appreciation of our unique NW landscapes and the immense area affected by the Floods. This also provides an ideal, place-based springboard to explore the Three Dimensions of NGSS: Disciplinary Core Ideas, Crosscutting Concepts, and Science and Engineering Practices. The cross-curricular lesson plans provide an inquiry-driven, experiential program aligned to the Common Core State Standards and environmental literacy, as well, in a way that inspires students and supports quality science education through memorable projects that infuse the arts and other content areas. When the lesson plans are delivered in sequence, a storyline develops, using the creation of our NW landforms as a compelling framework to help you cover core concepts and improve student skills. The curriculum should not compete with other curricular goals for classroom time.

Structure of the Guide + Lesson Plans

The curriculum is outlined on the Contents page that follows. It is targeted to grades 3–8, but designed to be adaptable to meet the needs of all students, K–12. We suggest the lessons be taught in order over approximately two weeks, although it can be extended longer and go more in-depth if many Enrich / Extend activities found at the end of each lesson are incorporated. Students will explore the scientific processes geologists use to make discoveries—and the fascinating area of science—like most other disciplines—is dynamic and constantly changing.

The lessons are designed to be a first glimpse into the Ice Age Floods. Students explore phenomena and form their own explanations for how the modeling projects and other activities related to observable geologic features. Students are gradually introduced to concepts, processes, and theories that will assist them in forming and revising their own explanations and theories. We provide links and references to numerous other programs and resources which you may find useful throughout the lessons and at the end of each of them in an “Expand Knowledge + Skills” section. Reproducible handouts at the end of lessons can be used to help guide student inquiry, and we can provide editable versions of them and the complete curriculum if you would like to adapt them to the particular needs of your students. Each lesson contains these components:



Mystery of the Channeled Scablands

Overview

Students investigate the "Mystery of the Channeled Scablands," a nonfiction reading with phenomena-based images and critical thinking questions, about the cataclysmic flood theory first proposed by J. Harlan Bretz. It guides students through the evidence Bretz and J.T. Pardee discovered as students try to solve the mystery. Optional Engage activities include a simulation of stream ripples (through a steam table or other means), to give students a chance to think about what caused the phenomenon. These observations can help connect students to the massive ripples several meters high discovered in the Northwest that are part of the evidence of Ice Age Floods. Other Engage options include a field study at a site with evidence of Ice Age Floods and a story/scenario activity. A variety of additional Enrich / Extend activities are listed to help you meet the needs of all learners.

Subjects: Science, Writing, Speaking & Listening, Art, Environmental Education

Grades: Adaptable for K–12

Duration: 40 minutes or more

Vocabulary
- J. Harlan Bretz
- Cataclysmic
- Channeled Scablands
- Erratics
- Glacial Lake Missoula
- Ice dam
- Mystery
- J.T. Pardee
- Plunge pools

Guiding Questions
- What was the controversy of how the Channeled Scablands were created? Why were J. Harlen Bretz' ideas so controversial?
- What was the evidence of the Ice Age Floods? How were Bretz' ideas tested and supported?

Objectives
- Students will read a compelling narrative about the Scabland Puzzle and the clues that led to the cataclysmic Ice Age Floods theory and answer critical thinking questions in writing.
- Students will participate in a discussion about the observable phenomena that led to the theory eventually being proven 50 years after it was first proposed.
- Students will discuss their theories about the causes of observable phenomena in the classroom and/or during field study orally and in writing.

How the Channeled Scablands in Washington were formed was a mystery until well into the 20th Century.

- **Overview**
- **Objectives**
- **Subjects** and **Grades** addressed
- **Time** needed to complete the lesson (approximate)
- **Vocabulary** (defined in the lesson and in the **Glossary** at the end of the curriculum)
- **Standards**: A table lists the associated Next Generation Science Standards. Common Core State Standards that can be met by the lesson are listed, as well.
- A **Teacher Background** section describes the in-depth science content and vocabulary that are helpful to understand and deliver the lesson with clarity and answer questions as they arise.
- The **Materials + Preparation** section is a handy synopsis of what is needed to set up the lesson, including a materials list.
- **Teaching Suggestions** are presented in ways that are fully NGSS 3D compliant within the evidence-based **5E Instructional Model**: **Engage, Explore, Explain, Enrich / Extend**, and **Evaluate.**
- Additional resources are listed at the end of each lesson plan in the **Expand Knowledge + Skills** section, followed by any student handouts, images, and charts needed for each lesson.

These adaptable lessons help train your students to be good scientists and critical thinkers, with a unifying theme of exploration and investigation, in the same way geologists J. Harlan Bretz and J.T. Pardee once explored our landscapes developed their revolutionary theories about the Floods.
We also recommend that you check out Chapters 10 and 11 in the 2017 book “Learning to Read the Earth and Sky: Explorations Supporting the NGSS Grades 6-12” By Russ and Mary Colson, published by NSTA Press. These chapters explore “historical science”: “Rocks are the residue of past geological processes. That residue–the rock–holds the clues to how the rock formed long ago” (p. 197).

With gratitude for your involvement and all you do for the next generation,

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Thanks + Appreciation

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- ★ **Bruce Bjornstad**, geologist / author; retired senior research scientist at Battelle
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- ★ **Nick Zentner**, Geology instructor, Central Washington University

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Contents

About Ice Age Floods National Geologic Trail

Ice Age Floods National Geologic Trail (IAFNGT) is the first national geologic trail in the U.S. It is one of the few National Trails focused on natural, rather than human, history. It highlights the extraordinary geologic features left behind by a series of perhaps 40+ cataclysmic floods that swept across the Pacific NW between 18,000 and 15,000 years ago. IAFNGT offers a remarkable range of opportunities for curriculum-based educational programming, especially in “STEAM” fields of science, technology, engineering, art, and mathematics. College-level geology and other earth sciences departments have long used Trail routes and sites as field study destinations across the region, and this curriculum seeks to help K–12 students and teachers more fully engage with it.

When the ice dams broke, enormous walls of water up to 1,200 feet (366 m) high raced to the Pacific Ocean with a flow rate of at least 10 times the volume of all the world’s rivers combined. This cut new canyons through solid rock and deposited sediments ranging from thick layers of fertile soil to massive erratic boulders that were embedded in icebergs. Gigantic basalt coulees, enormous waterfalls, and flood ripples of immense proportion are just a few examples of the evidence that survives to illustrate the scale and power of the Floods.

Areas of the Ice Age Floods that occurred 18–15,000 years ago (and source of them—Glacial Lake Missoula)
Adapted with permission from a screenshot in “Glacial Lake Missoula”: youtu.be/wJo8m4oKc6k. Check it out!

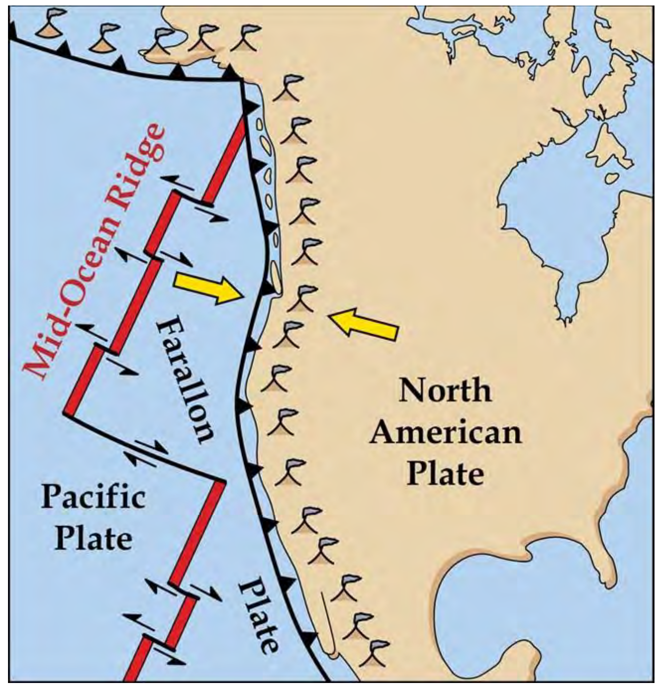
Thousands of square miles/km in the Pacific NW were impacted, far too large an area to be fully covered by a single site. Today, the efforts of many agencies to tell this phenomenal story are linked together by the IAFNGT. The Trail isn’t a traditional trail which you can walk; rather it is a group of driving routes and engaging sites throughout the region. One can visit parks and museums to learn more and explore. Many features can be easily seen while driving by or stopping at an overlook, while others encourage you to get further out to explore.

A Brief History of NW Geology + the Ice Age Floods

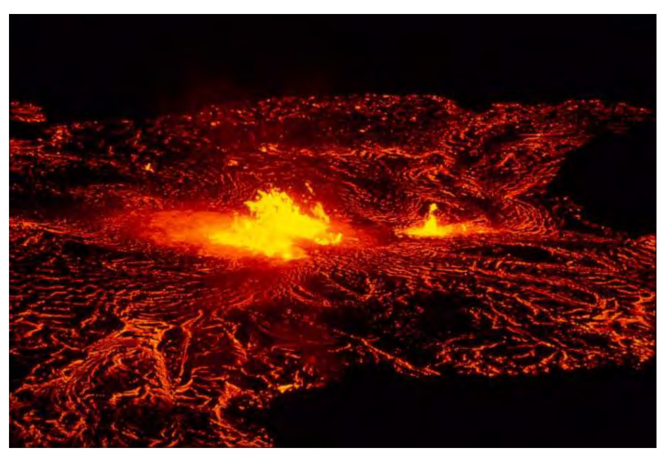
Pre-Flood History

More than 800 million years ago (MA), modern-day Eastern Washington was the west coast of North America. However, tectonic shifts 200MA caused the **Pacific Plate** to subduct under the **North American Plate**. This created a deep oceanic trench, and over the next few million years of convergence, created the mangled form of sedimentary and metamorphic rock known as the **Kootenay Arc**.

As the two plates continued to converge over the next 100 million years, the North American plate also collided with a series of massive islands in the Pacific Ocean known as the **Okanogan subcontinent**. The force of the collision destroyed the trench between the Pacific and North American plates and pushed much of the contents upward, out of the ocean. The North American Plate continued moving west over the Pacific Plate, ramming the Kootenay Arc into the islands themselves. As the Okanogan Islands integrated into the North American Plate they became the modern-day **Okanogan Highlands** in Northeast Washington and Southern British Columbia. Around 50MA, the North American plate continued on its westward path, where it rammed into and fused with the eastern portion of another subcontinent: the **North Cascade subcontinent**. The North Cascade subcontinent was different from the previous two; millions of years of geomorphic stress on it left it riddled with active volcanoes. “Forty million years ago, a large tectonic plate, known as the Farallon Plate, was between the Pacific and North American plates. Subduction of the Farallon Plate beneath the entire West Coast created a line of volcanoes from Alaska to Central America” (NPS: nps.gov/subjects/geology/plate-tectonics-transform-plate-boundaries.htm).



A line of active volcanoes 40 million years ago
NPS: nps.gov/subjects/geology/plate-tectonics-transform-plate-boundaries.htm



Volcanoes created the majority of NW rocks
Pixabay: pixabay.com/photos/volcano-lava-eruption-night-heat-1784656

Volcanic Activity, Basalt Flows, and the Yakima Fold Belt

The North Cascade subcontinent’s volcanoes fell dormant 25MA and ceased eruptions for 10–15 million years. The focus of volcanic activity shifted eastward to the present-day borders of Washington, Oregon, and Idaho. Around 17.5MA, a hot spot, or upwelling of heat from the Earth’s core, reached the surface beneath the eastern border of Washington and Oregon. The hot spot produced intense heat and pressure, causing large volcanic fissures to open at the surface. Molten basalt flowed from the fissures and covered much of the inland Pacific Northwest. New fissures continued to open over the next several million years, producing new basalt flows which covered previous ones, creating a basalt “layer cake” over three miles deep in places like Pasco, Washington. Today these basalt flows are known as the **Columbia River Basalt Group**—the bedrock for most of the Ice Age Floods pathways.

Basalt forms from cooling lava
Wikimedia Commons: commons.wikimedia.org/wiki/File:20011005-0039_DAS_large.jpg

The large basalt flows, now visible from the immense scour of the floods, show characteristic colonnade and entablature formations. As the basalt cooled, the entablature formed first as the top layer of the basalt flow was cooled by air or water. Slowly, the interior of the flow cooled, as well, and cracks in the basalt formed as the rock contracted, creating colonnades or geometrically-fractured columns. The fractured nature of the colonnades made them highly susceptible to erosion, while the entablature is more resistant.

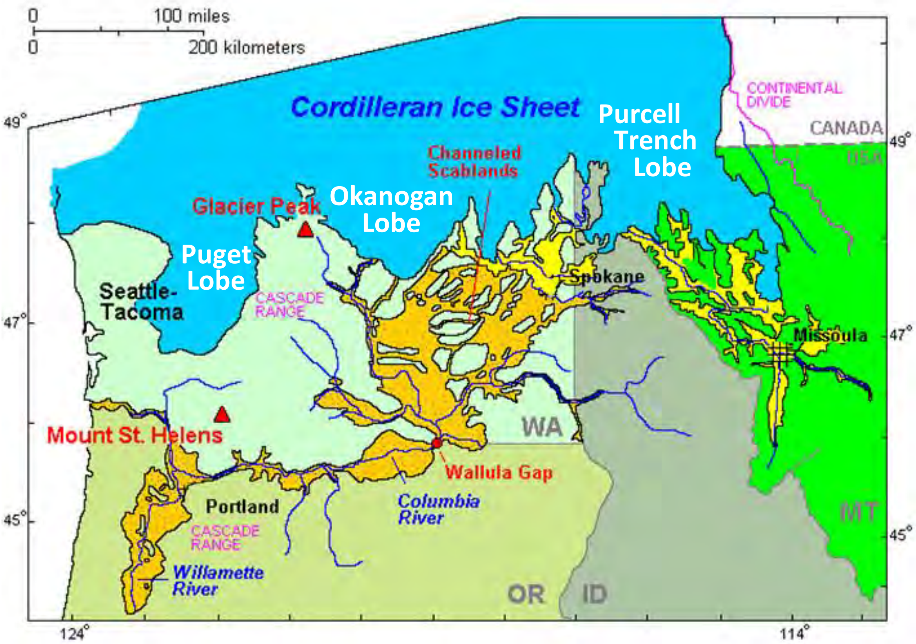
Geologist Nick Zentner examines columnar basalt
Video screenshot used by permission from Nick Zentner: nickzentner.com/#/2-minute-geology

Around 15.3MA, tectonic pressure on the North American plate compressed part of the basalt flows to produce the **Yakima Fold Belt**, a series of east-west trending syncline and anticline pairs filled with sediment and bounded by ridges that decline as they continue east. The belt would be an important break for the future floodwaters.

The Last Ice Age + The Cordilleran Ice Sheet

The climate began to cool around 2.6MA at the start of the last ice age, known as the **Pleistocene Epoch**. It led to the formation of large ice sheets over much of present-day Canada, including the **Cordilleran Ice Sheet** that covered much of western Canada, as well as much of Alaska, northern Washington, and part of northern Idaho and northwest Montana. The ice sheet descended towards the Pacific Northwest of the United States and created ideal conditions for the catastrophic floods which shaped the Eastern Washington landscape.

In Canada, the ice carved the topography—scraping and grinding the original mountains into dust. This dust, known as **loess**, was carried by winds and rain and deposited over much of the inland Pacific Northwest as fine sediment. Many modern-day wheat fields in Washington sit atop these massive loess deposits. During periods of the furthest ice extent, three major lobes of the Cordilleran Ice Sheet extended into the United States. The **Puget Lobe** of the **Cordilleran Ice Sheet**, which extended over Puget Sound and Seattle, covered the area in 3,000 feet (900+ meters) of ice. To the east of the Cascades, the **Okanogan Lobe** in the Okanogan Valley extended as far south as Dry Falls, Washington. In the Idaho panhandle, the **Purcell Trench Lobe**, carved Lake Pend Oreille into the landscape.



Map showing the three lobes of the Cordilleran Ice Sheet.
The areas of the Ice Age Floods are shown in orange and yellow.
Adapted from a Wikimedia Commons image from USGS data: commons.wikimedia.org/wiki/File:Map_missoula_floods. gif

The Glacial Lake Missoula + Glacial Lake Columbia Floods

For millennia, the Columbia and Spokane Rivers had gradually incised their paths, creating deep valleys. However, the Okanogan lobe dammed the flow of the Columbia River near present-day Grand Coulee Dam for a period. The river basins quickly filled with water held back by the ice dam, creating Glacial Lake Columbia. Similarly, the Purcell Trench lobe intermittently blocked the Clark Fork River in Montana. With few natural outlets, water behind the Purcell Trench lobe backed up to form **Glacial Lake Missoula** in the Clark Fork River valley and adjacent valleys. Periodically, the ice dams broke and released catastrophic outbursts of water from Glacial Lake Missoula which flooded into the **Glacial Lake Columbia** basin. These extreme influxes of water overtopped the Glacial Lake Columbia basin and carved a number of pathways southward through the basalt bedrock. Pre-existing topographic lows combined with

Site of the immense Glacial Lake Missoula in Montana, which may have held 500 – 600 cubic MILES (800 – 966 cubic km) of water
Image courtesy Nick Zentner + the late Tom Foster, HUGEfloods.com: hugefloods.com/LakeMissoula.html

changing extents of the Okanogan lobe to influence the erosional and depositional effects of the Ice Age Floods.

The first Missoula floods stripped overlying sediments like loess off of the Columbia River Basalt bedrock. Rushing waters and headward erosion from later floods plucked away the now-exposed fractured basalt colonnades and destabilized entablatures, forming **coulees**—box shaped canyons—in certain places. The vertical alignment of the colonnades allowed for formation of nearly vertical walls of the coulees, opposed to the V-shaped valleys we typically find in those eroded by rivers.

Frenchman Coulee near Vantage, Washington
Creative Commons image by Gabriele Giuseppini:
commons.wikimedia.org/wiki/File:Frenchman_Coulee_-_panoramio.jpg

During certain flood events, water that overflowed Glacial Lake Columbia before reaching the Okanogan Ice Lobe poured down to form two large braided channels: the **Channeled Scablands**. The Cheney-Palouse scabland tract formed south of the Spokane Valley, while the Crab Creek-Telford scabland tract formed near the Spokane and Columbia River confluence. The overflows scoured surface sediment and removed the uppermost basalt flows, but lacked the erosive potential of the main Missoula Flood pathway through **Grand Coulee**. The momentum of the water entering Glacial Lake Columbia forced the majority of the flood down the entire Columbia River basin towards the Okanogan Ice Lobe. With a fully extended ice lobe, floodwaters followed the ice's margin southward and carved a deep gorge, now known as **Upper Grand Coulee**, into the Columbia River Basalts. Concurrently, headward erosion in the Quincy Basin created the **Lower Grand Coulee** along the Coulee Monocline, a slight dip in the surface of the Columbia River Basalt.

Evidence also suggests that early floods did not encounter a fully extended Okanogan Ice Lobe. Moses Coulee, which parallels Grand Coulee to the west with similar deep-cut hanging valleys, potentially formed as an older flood pathway. The terminal moraine of the Okanogan Lobe drapes into Moses Coulee indicating that the coulee formed prior to the extension of the ice lobe. The town of Wenatchee, Washington sits on a gigantic flood bar; evidence that certain floods followed this path of the Columbia River when the Okanogan Ice Lobe retreated or weakened near Grand Coulee.

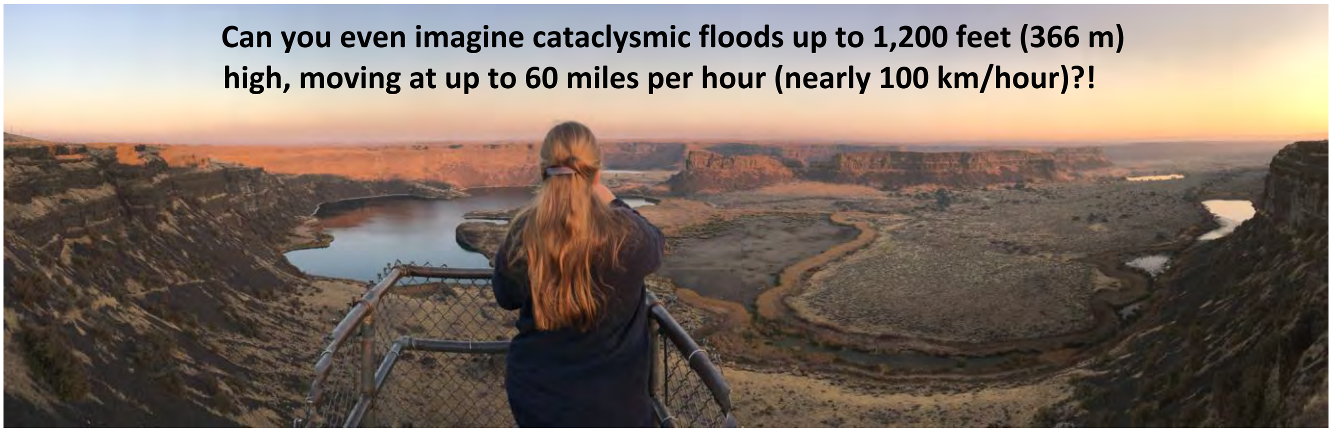


Image by MelanieBMac from Pixabay: pixabay.com/photos/eastern-washington-dry-falls-scenery-4484789

The Quincy Basin + Surrounding Landforms

Floodwaters that utilized the Grand Coulee were channelized from their start at the Okanogan ice lobe to the end of the coulee in the Quincy Basin. As the floodwaters entered the basin, they spread out, reducing their velocity and depositing larger sediments near the mouth of Grand Coulee in what is now known as the **Ephrata Fan**. West of the Ephrata Fan, the Yakima Fold Belt, previously incised by the Columbia River, controlled floodwaters leaving the Quincy Basin. Floodwaters were forced eastward around the folded ridges or flowed west and re-entered the Columbia River Basin. Once back in the basin, the floods formed a number of recessional cataracts including Potholes Coulee and Frenchman Coulee; both are similar to Grand Coulee and Moses Coulee but limited flow prevented them from reaching a large extent.

Wallula Gap + the Columbia River Gorge

In the Pasco Basin to the south, all Missoula floodwaters including those from the Channeled Scablands reconnected to form Lake Lewis. The Columbia River pathway follows the lowest topographic pathway through the Cascades and passes through two natural hydraulic gaps in the topography: **Wallula Gap** and the **Columbia River Gorge**. Floodwaters stagnated as they slowly passed through these two gaps, sending backwater into the Walla Walla River and Yakima River valleys. Fine sediments settled out of the slow-moving floodwater, forming “slack water deposits” in side valleys near the gaps. These slack water deposits are broken up by tephra layers from volcanic eruptions in the Cascades and preserve a record of the number of Missoula floods.

Wallula Gap looking south and the Columbia River
Wikimedia Commons:
commons.wikimedia.org/wiki/File:Wallula-Gap--Looking-South.jpg

From Volcanic Eruptions to Ancient Ecosystems

What Forces Created Our Rocks and Landforms?

Subjects: Science, Writing, Speaking & Listening, Art, Environmental Education, Math

Grades: Adaptable for K–12

Duration: Two 50-minute class periods or one long period; can be shortened or extended to a week or more

Vocabulary

- Basalt
- Crust
- Earthquake
- Erosion
- Granite
- Igneous rock
- Metamorphic rock
- Mineral
- Obsidian
- Ring of Fire
- Rock
- Rock cycle
- Sandstone
- Sedimentary rock
- Weathering

Overview

The rocks that comprise our landforms are an important part of the story of Ice Age Floods. In this lesson, students explore rocks and how they are created through a variety of engaging activities. Options include a "Mystery Rocks" activity, a modeling project in which students explain the rock cycle, an interactive "Rock Story," a "Mini Research Project" (or in-depth project if time allows), a "Comparing Volcanoes" activity, and an "Earth Burps!" activity to model how lava is ejected from a volcano and new rock is created.

The lesson is supported by an interactive PowerPoint presentation which you can adapt to best meet the needs of your students. A variety of additional Enrich / Extend activities are listed to help you meet the needs of all learners.

Guiding Questions

- How are geologists like detectives?
- How are rocks linked to other scientific phenomena, like volcanoes and weather?
- How can we describe different types of rocks?
- How are different types of rocks formed?
- Where can we find different types of rocks?

Objectives

- Students will explain how different types of rocks are created and changed, orally and in writing.
- Students will create models of the rock cycle in a format of their choice.
- Students will be able to explain the connections between rocks and other phenomena, like volcanoes and weather.

What are the links between rocks and other phenomena?

Image by Enrique Lopez Garre, Pixabay:
pixabay.com/photos/volcano-eruption-lava-smoke-rocks-4813837

Next Generation Science Standards + Common Core State Standards		
NEXT GENERATION SCIENCE STANDARDS	**Performance Expectations** We suggest you tailor the lesson to meet the PE(s) for your grade level.	**2-ESS1-1**. Use information from several sources to provide evidence that Earth events can occur quickly or slowly. **4-ESS1-1**. Identify evidence from patterns in rock formations and fossils in rock layers to support an explanation for changes in a landscape over time. **5-ESS2-1**. Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact. **MS-ESS2-1**. Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process. **MS-ESS2-2**. Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales. **MS-ESS3-1**. Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes. **MS-PS1-4**. Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed. **HS-ESS2-1**. Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features. **HS-ESS2-3**: Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.
	Crosscutting Concepts	• Cause and Effect • Energy and Matter • Patterns • Scale, Proportion, and Quantity • Stability and Change • Systems and System Models
	Science & Engineering Practices	• Developing and Using Models • Constructing Explanations and Designing Solutions • Engaging in Argument from Evidence • Obtaining, Evaluating, and Communicating Information

	Disciplinary Core Ideas	**ESS1: Earth's Place in the Universe** **ESS2.A: Earth's Materials and Systems** **ESS2.D: Weather and Climate** **ESS3: Earth and Human Activity** **ESS3.D: Global Climate Change** **PS1: Matter and Its Interactions**
Common Core State Standards English Lang. Arts	**Writing**	4, 10
	Speaking & Listening	1, 2
	Language Standards	1, 2, 3, 6
	Writing Standards Science & Technical Subjects	4, 7, 10
Math CCSS	Math can be incorporated to meet the standards at your grade level and/or to reinforce concepts learned previously. See the Enrich / Extend section for ideas.	

Teacher Background

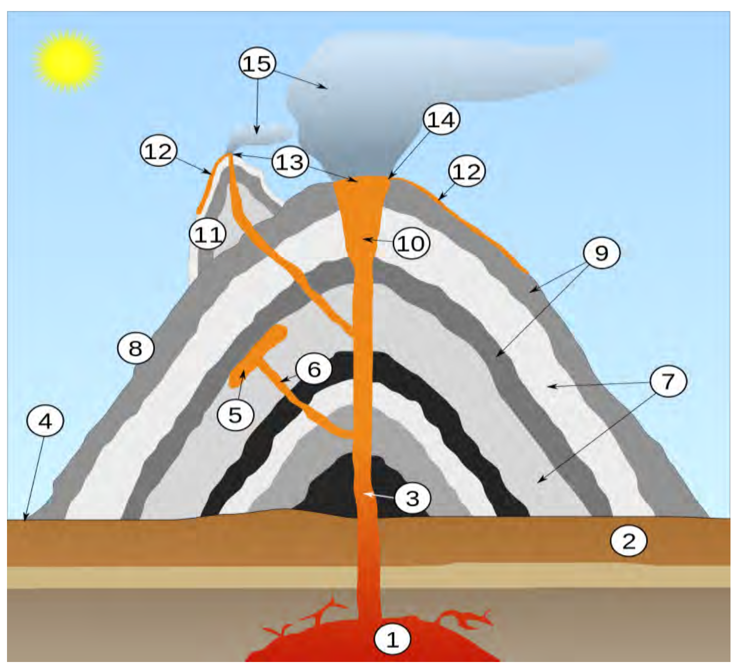
This lesson uses a variety of interesting scientific phenomenon to help you engage students and deepen their understanding of rocks, how they can be created and changed, and how they help explain the interesting landforms we see around us.

Volcanoes are places on Earth's surface where liquid rock (known as **lava** at the surface), gases, and ash can vent into the atmosphere. The Earth's **crust** consists of 17 solid **tectonic plates** that float on liquid rock (known as **magma** underground) in Earth's **mantle**. Magma is less dense than solid rock, so it rises to the surface the way oil does in salad dressing. The process is fueled by **convection**: the astounding heat of Earth's core—about 10,800° Fahrenheit (6,000° Celsius)—melts rock and causes it to flow to cooler areas up toward the surface.

These free sources provide background information on the different types of volcanoes, such as stratovolcanoes (composite volcanoes) and supervolcanoes:

- "Volcanoes." Wikipedia provides accurate information and illustrative images on the topic, such as the one to the right (with labels), as well as links to other sources: en.wikipedia.org/wiki/Volcano.

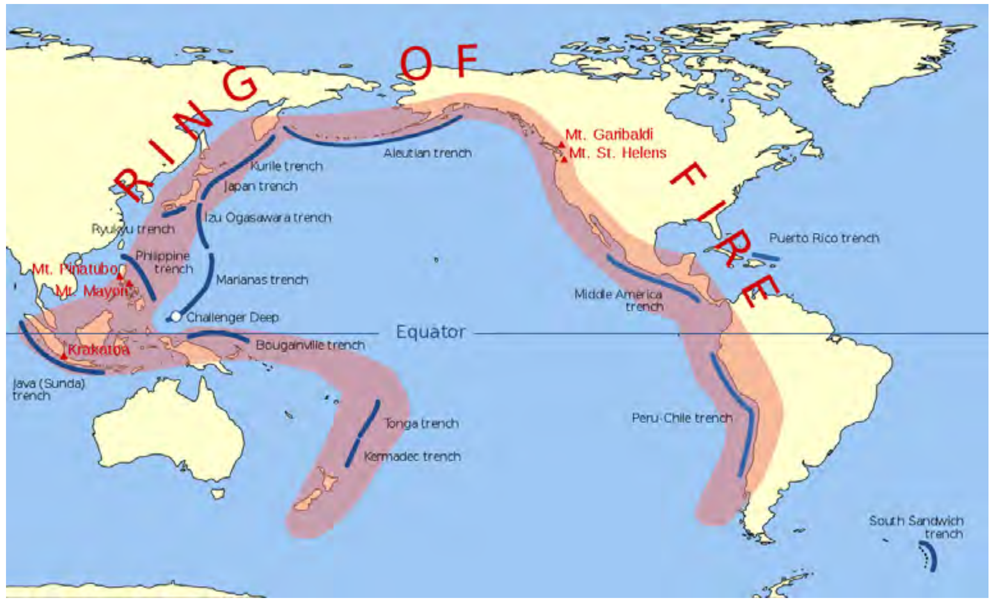
Mount St. Helens is an active stratovolcano in Washington.
Pixabay: pixabay.com/photos/mount-st-helens-volcanic-eruption-164848



Do you know the parts of a stratovolcano?
Wikimedia Commons: commons.wikimedia.org/wiki/File:Volcano_scheme.svg

- “Earthquakes, Volcanoes, and Tsunamis.” NSTA Press: web.archive.org/web/20120913041924/http://www.enviroliteracy.org/nsfmod/NaturesFury.pdf

The Pacific **Ring of Fire** is the area around the Pacific Ocean that contains about 75% of the world’s active volcanoes. The Pacific Northwest is part of the ring, and Eastern Washington was once along the Pacific Coast with more active volcanoes. The volcanoes of the current Northwest created a lot of the rocks we find, and earthquakes and convection helped to bring up other rocks we find here from deep underground.



Wikimedia Commons: commons.wikimedia.org/wiki/File:Pacific_Ring_of_Fire.svg

Lava Flows

Over a period of 11 million years, some of the largest basaltic lava flows ever to appear on the Earth’s surface engulfed about 163,000 square kilometers (63,000 square miles) of the Pacific Northwest. Lava flow after lava flow poured out, eventually accumulating to a thickness of more than 1,800 meters (6,000 feet). As the molten rock came to the surface, the Earth’s crust gradually sank into the space left by the rising lava. The subsidence of the crust produced a large, slightly depressed lava plain now known as the Columbia Basin (Plateau). The ancient Columbia River was forced into its present course by the northwesterly advancing lava. The lava, as it flowed over the area, first filled the stream valleys, forming dams that in turn caused impoundments or lakes. In these ancient lake beds are found fossil leaf impressions, petrified wood, fossil insects, and bones of vertebrate animals.

Flowing lava turns into rock as it cools; this is how the majority of rocks in the Pacific Northwest formed.
Wikimedia Commons: commons.wikimedia.org/wiki/File:Volcano_scheme.svg

The Three Types of Rock

- **Igneous** rocks are formed from cooled lava and magma. These include:
    - **Basalts** that are “dark colored, fine-grained **extrusive** [volcanic] rock. The mineral grains are so fine that they are

Basalt: The most abundant rock in the Northwest.
Shared via Creative Commons license by James St. John on Flickr: flickr.com/photos/jsjgeology/16540710327

impossible to distinguish with the naked eye or even a magnifying glass. They are the most widespread of all the igneous rocks." They are "formed by the rapid cooling and hardening of the lava flows. Some basalts are **intrusive**, having cooled inside the Earth's interior" ("Igneous Rocks." Oregon State Univ.: volcano.oregonstate.edu/igneous-rocks?picture=301).

- **Granite** is formed "from the slow crystallization of magma below Earth's surface. Granite is composed mainly of quartz and feldspar with minor amounts of mica, amphiboles, and other minerals. This mineral composition usually gives granite a red, pink, gray, or white color with dark mineral grains visible throughout the rock" (Geology.com: geology.com/rocks/granite.shtml).

Granite: intrusive igneous rock
James St. John. Shared via Creative Commons license on Flickr: flickr.com/photos/jsjgeology/16540710327

- **Obsidian**, which is a natural glass rich in silica that forms from fast-cooling lava. Crystals do not have time to form, resulting in its exceptionally smooth texture and shiny appearance (ability to reflect light). It has been a favored material for tools since before the dawn of modern humans and is still used for some precision tools like surgeon's blades. Tools such as the arrowheads shown here are formed by chipping off sections to form the very sharp edges.

Obsidian arrowhead
Shared via Creative Commons by Jessie Essex on Flickr: flickr.com/photos/jessieessex/15952938792/in/photostream/lightbox

- **Sedimentary** rocks are formed by sediment (including eroded rocks and the calcium from marine organisms) that is compacted and cemented together by gravity and heat from the Earth. The most common types of sedimentary rocks are:
  - **Sandstone**, formed by sand and other **sediment** compacted by gravity and cemented together with minerals and heat from the Earth.
  - **Limestone**, formed by calcium from algae, animal shells, and coral, compacted and cemented together.
- **Metamorphic** rocks are those changed underground from another type of rock by heat (from hot magma below) and pressure (from rocks pushing down above them from the force of **gravity**). ("Morph"

Nubian sandstone from Petra, Jordan.
Wikimedia Commons: en.wikipedia.org/wiki/Nubian_Sandstone#/media/File:Wall_Patterns.jpg

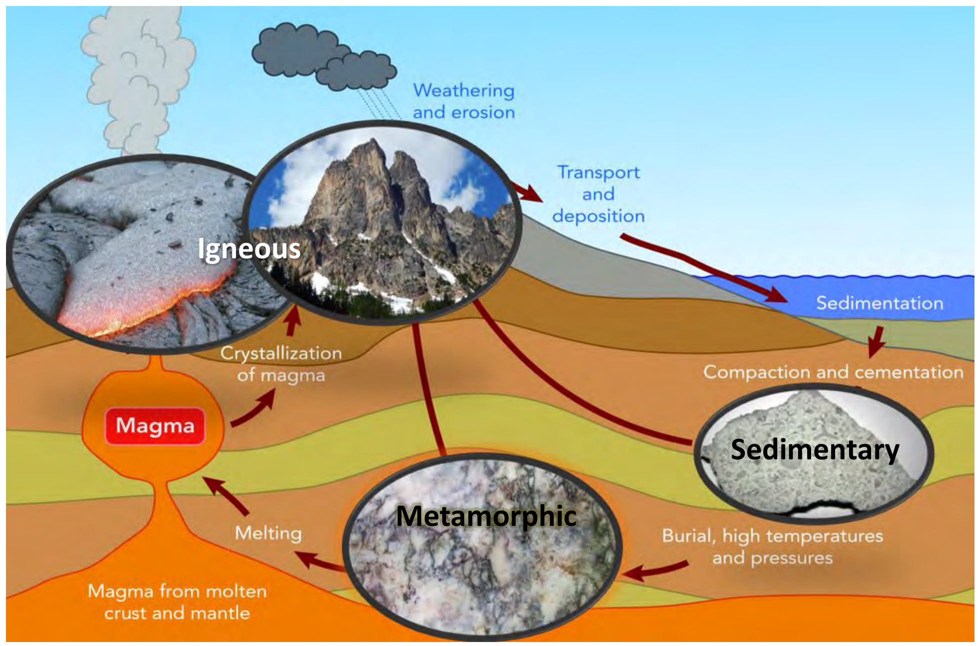
means change.) **Marble** is a common metamorphic rock that is formed from limestone.

Marble: a common metamorphic rock

Creative Commons. Max Pixel: maxpixel.net/Pattern-Texture-Mineral-Marble-Stone-Overlay-1311146

The Rock Cycle describes how the three types of rock are related:

- Igneous rocks form from **molten** (liquid) rock.
- They breakdown from weathering and erosion and can form sedimentary rocks.
- Sedimentary and igneous rocks can be transformed into metamorphic rocks. Metamorphic rocks can move to the surface and be eroded. Their sediment can become part of sedimentary rocks.
- All three types can be melted by the intense heat of the Earth's interior and eventually form igneous rocks.

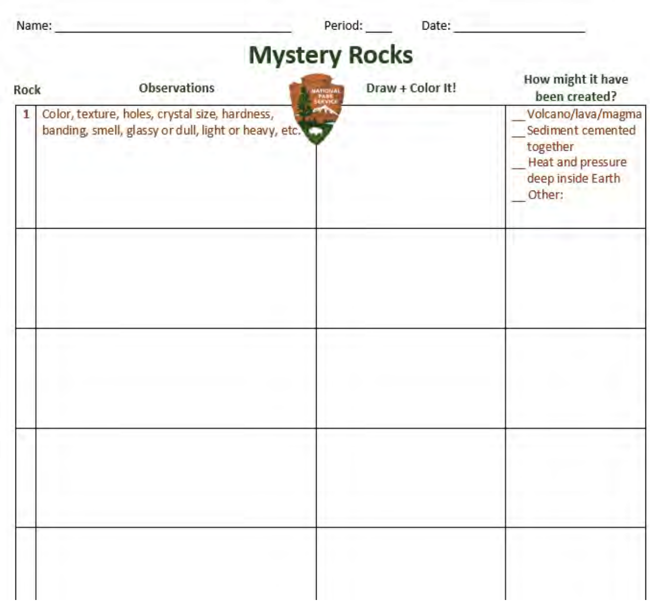


The Rock Cycle

Adapted from model by Siyavula Education. Shared via Creative Commons license on Flickr: flickr.com/photos/121935927@N06/13581730833

Materials + Preparation

- **For the "Mystery Rocks" activity**:
  - o Examples of different types of rocks for groups of 3–5 students to share, including igneous rocks such as basalt, granite, pumice, and obsidian. Wikipedia has a comprehensive list of rocks by type with links to images and more information: en.wikipedia.org/wiki/List_of_rock_types. Geology.com is another excellent resource with clear visuals, and they also sell rock kits: geology.com/rocks.
  - o Copies of the "Mystery Rocks" handout for each student found at the end of the lesson



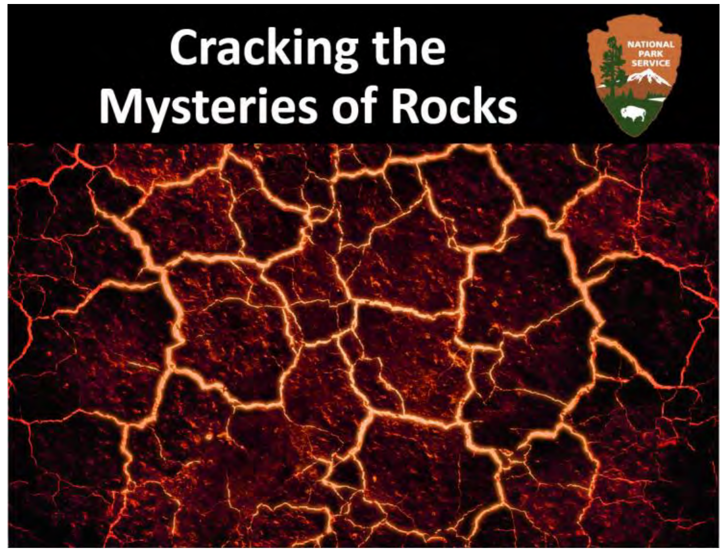
Name: ____________ Period: ____ Date: ____________

Mystery Rocks

Rock	Observations	Draw + Color It!	How might it have been created?
1	Color, texture, holes, crystal size, hardness, banding, smell, glassy or dull, light or heavy, etc.		__Volcano/lava/magma __Sediment cemented together __Heat and pressure deep inside Earth __Other:

- Colored pencils, markers, and/or crayons
- *Optional:* Magnifying devices such as hand lenses and macro lenses for pairs of students to share
- This activity can also be done online with images of rocks, as explained in the first "Enrich / Extend" activity.

- **Prepare to show the "Cracking the Mysteries of Rocks" PowerPoint presentation as an interactive visual aide**; feel free to adapt for your students



- Data projector and computer
- Access to Internet and/or library for research
- **If you plan to create a volcano model** as an Engage activity and/or have student groups create them, you'll need these (or similar) for each volcano model:
    - Baking pan
    - Bottle (32 ounce or 1 liter works well; a similar-sized flask is ideal)
    - 1 cup vinegar
    - 1 tablespoon baking soda
    - *Optional:* Red food coloring
    - *Optional:* Sand
- *Optional:* Document camera (connected to data projector)
- *Optional:* Review the sources and watch the videos listed at the end of the lesson for additional background information. You could also share one or more of the videos with your students and discuss them.

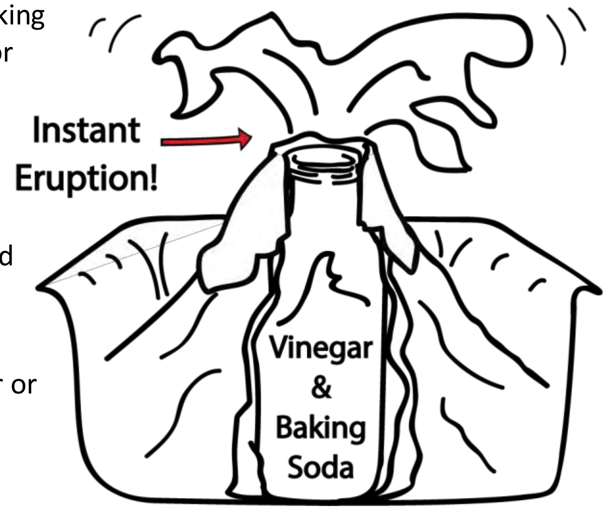
Teaching Suggestions in the 5E Model

Engage

1. **Options to engage students with scientific phenomena, activate prior knowledge, and stimulate critical thinking** (2–20 min.)
    - **Students collect interesting rocks.** A week or more in advance (or perhaps during class/recess), ask students to look for and collect interesting rocks. Tell them that they should bring them to class on the date you will be investigating rocks. They can also take pictures of large rocks/boulders, interesting land forms with exposed rock, etc.

Students can collect interesting rocks.
National Park Service: nps.gov/subjects/geology/rocks.htm

- **Create a model of a volcano** with vinegar and baking soda. Demonstrate for the class to observe and/or have student groups make them. A variety of methods can be found online, but one easy method from *The EverGreen Twins Activity Book* by Rick Reynolds shared by permission is to:



  - Make sure your bottle is empty, clean, and dry.
  - Take the materials and class outside, if possible, or clear your work area so paper or electronics can't get wet.
  - Place the bottle in the middle of the pan.
  - If you decide to use sand, moisten it with water and mound it up to the top of the bottle or flask to form a mountain. Be careful not to get any inside the bottle.
  - Add the baking soda to the bottle.
  - Add a few drops of red food coloring to the vinegar if you have it, and then pour it into the bottle. Stand back and watch the volcano erupt!
  - Ask students to think about how this model of a volcano is similar to and different from a real volcano. The "**Comparing Volcanoes**" activity at the end of the lesson can help students organize and record their ideas in words and pictures. They use a Venn diagram to compare their chemical reaction volcano it to a volcano in nature.
  - Clean up by scooping out the sand with your hands or a spade (if you used it) and let it dry in the sun for the next time. Then pour the liquid contents of the pan and bottle into a sink and rinse. Vinegar and baking soda make great green cleaners, so it will clean and deodorize the sink and drain.

2. **Show a short video clip of an explosive volcanic eruption with the sound turned off** (to encourage students to think about the phenomenon rather than have it explained to them). Options include:

   - "Volcanoes 101" (4:15—choose a short clip). National Geographic: youtu.be/VNGUdObDoLk
   - "Dramatic Volcanic Eruption in Chile" (1:29). BBC.: bbc.com/news/av/world-latin-america-31721795/dramatic-volcanic-eruption-in-chile
   - "Dramatic Volcano Eruptions." George Kourounis (1:40): youtu.be/uxds7VY7yl8

Then ask students to discuss with a partner the ways in which volcanic eruptions connect to rocks, the Earth, and the landforms we observe around us. They can record their ideas in science notebooks. Then they should be encouraged to share their best ideas with the class.

Explore

3. **"Mystery Rocks" activity** (7–20 min.)

   Students explore a variety of interesting specimens, recording observations, colored sketches, and ideas about how the rocks were created. This can be done with rocks the students collect outside of (or during) class time, as well as those provided by the teacher.

National Park Service: nps.gov/kewe/learn/education/classrooms/copper-traces-activity-stations.htm

   - Pass out numbered rock specimens, including types of igneous rocks (basalt, granite, pumice, obsidian, etc.) to groups of 3–5 students. We suggest about the same number of rocks as the number of students in a group for younger children and 7 or more for older groups.
   - Ask questions (and/or write them on the board) for students to think about and discuss, such as:

     - What do you observe about the rocks?
     - How would you describe their color, texture, crystal size, hardness, etc.? Are there holes? Is there banding, a smell, is it glassy or dull, light or heavy, etc.?
     - How might the rocks have been created?
     - After students have had a minute to explore and discuss the rocks, pass out the "Mystery Rocks" activity sheet or ask them to open their science notebooks to a new page. Explain that they should record their observations and draw a simple colored sketch of each rock. They should also record any ideas about how the rocks were created.
     - Circulate to answer any questions. After 5–10 minutes, tell the groups that they should be ready to describe their favorite rock(s) to the class. Give them a few more minutes to work. If student finish recording their observations, they can try to identify the rocks with the support of resources such as books and websites, including:
       - "Rocks: Igneous, Metamorphic and Sedimentary." Geology.com: geology.com/rocks
       - Wikipedia: en.wikipedia.org/wiki/List_of_rock_types

Explain

4. **Ask groups to volunteer to show and describe their rocks to the rest of the class.** (5 min.)
   They could use a document camera if one is available to show their rocks and/or observations/drawings. They should also share any ideas about how the rocks were created.

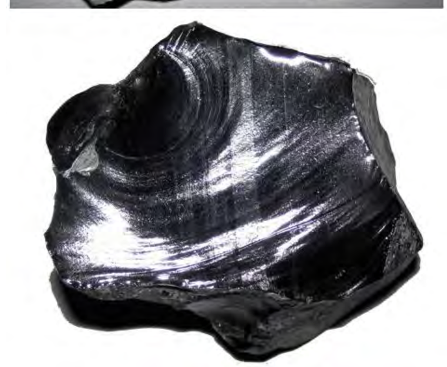
5. **Discuss different types of rocks.** (5–10 min.)

   - Use the "**Cracking the Mysteries of Rocks**" PowerPoint presentation as an interactive visual aide to help facilitate discussion and convey key concepts. Wait to use the terms igneous, sedimentary, and metamorphic until they are presented on screen toward the end of the presentation, so students can first focus on the interesting phenomena that create the rocks, rather than the terms. See the Slide Notes for details about the rocks and rock types that you could share.

Discuss the different rock types in collaboration with students.
Wikimedia Commons:
commons.wikimedia.org/wiki/File:Cub_Scouts_Earn_Geology_Badge_(8201286736).jpg

   - Explain the concept of the **rock cycle** with the support of the visual model. **The Rock Cycle** describes how the three types of rock are related:

     - Igneous rocks form from **molten** (liquid) rock. These are called **extrusive** if they are created at the surface (like most **basalt**), or intrusive if they are created deep underground (like **granite**.)
     - Rocks are broken down by **weathering** and **erosion**. Fine rock particles, such as sand, can form sedimentary rocks.
     - **Sedimentary** and **igneous** rocks can be transformed into **metamorphic** rocks by the Earth's heat and pressure. Metamorphic rocks can move to the surface and be eroded. Their **sediment** can become part of sedimentary rocks.
     - All three types can be melted by the intense heat of the Earth's interior and eventually form igneous rocks.



- On the **Pacific** “**Ring of Fire**” slide, ask students to think about what the map is showing. Discuss how it describes the area around the Pacific Ocean that contains about 75% of the world’s active volcanoes, and that the Pacific Northwest is part of the ring. Ask, “How might the landforms and rocks of Pacific Northwest and the rest of the Ring of Fire be especially impacted by volcanoes and earthquakes? What evidence of volcanoes and shifting land can we observe in the Northwest?” Discuss how all the volcanoes here created a lot of the rocks we find, and earthquakes helped to bring up rocks from deep underground like igneous granite and metamorphic rocks to the surface.
- Discuss how scientists that study the Earth—including rocks—are called **geologists**. How are they like detectives, similar to the way students investigated the rocks today?
- The PowerPoint can also be used as a review game at the end of the lesson or at a future date. Ask students to get into pairs or small groups and record answers to the questions on screen before you show the answers. You can add additional questions by duplicating the slides in the Slide Sorter. Questions can be about specific types of rocks you observed and discussed in your class.

6. **Students create models of the rock cycle in a medium of their choice.** (15–25 min.)
   - Explain that students will be creating their own models which explain the rock cycle. They can use colored pencils, crayons, and/or markers to color the illustrations—or computers with illustration software, if available. You can also suggest they create short videos, dioramas, or use another method to convey the concepts in compelling ways.
   - Explain that they should add labels and annotations (additional information) to explain the rock cycle through their diagrams and/or other mediums.
   - Tell students that it can look similar to the model shown in the PowerPoint presentation or take an entirely different form. Numerous other examples can be found in online searches.
   - Give students a warning five minutes before they will have to stop working. At that time, direct them to finish cleaning up, answering the questions, and completing their diagrams.

A diagram is one option for a rock cycle model.
Wikimedia Commons:
upload.wikimedia.org/wikipedia/commons/1/16/Rockcycle.jpg

7. Close the lesson by having students share their diagrams with each other and/or the class and discuss them. Why is the rock cycle important, and how has it helped to shape our world?

Extend / Enrich

- **Do the "Mystery Rocks" activity online.**

  Use a collaboration app such as Google Jamboard. Add one or more images of a type of rock to each slide. Have students work in groups to complete the same graphic organizer found at the end of the lesson, or they can add their observations/ideas directly on the slides. A similar example with "Mystery Skulls" created by Rick Reynolds that you can feel free to adapt is found at tinyurl.com/y6opywyn. It is based on an activity from the University of Arizona Extension: extension.arizona.edu/sites/extension.arizona.edu/files/pubs/az1145.pdf.

- **Take the students on a field study to observe interesting rocks and landforms first-hand.**

  Good locations to take your class can be found on an interactive map from the Ice Age Floods Institute: iafi.org/floodscapes. Options include:

  - Lake Roosevelt National Recreation Area: nps.gov/laro
  - Dry Falls—once the world's largest waterfall. Interesting article with video from the *Statesman Journal*: statesmanjournal.com/story/travel/outdoors/2018/07/20/sun-lakes-dry-falls-state-park-washington-best-things-do/797006002
  - Palouse Falls, WA
  - The Columbia River Gorge

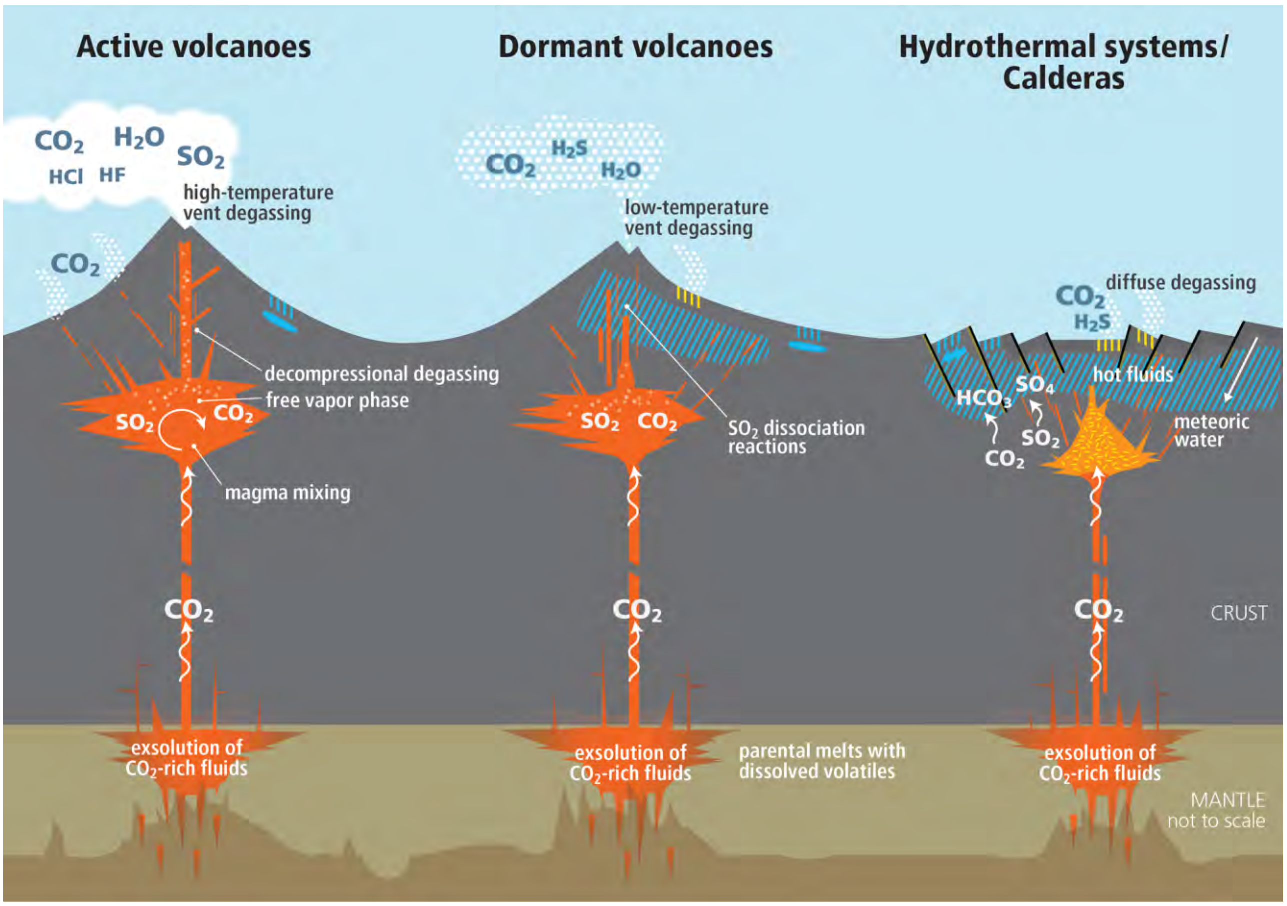
- **Lead an interactive "Rock Story."** Younger students can role-play rocks being created and traveling through the rock cycle via interesting natural processes. A short lesson plan and story from NPS is at nps.gov/teachers/classrooms/rock-stories.htm.

- **Repeat the chemical reaction volcano experiment and collect the carbon dioxide (CO_2) released to use in experiments. Then discuss the role of CO_2 in the atmosphere.**

  - Add the baking soda to a balloon with a funnel. (Set aside the funnel; it is only used to add the soda to the balloon.) Then attach the balloon to the bottle containing vinegar and empty the baking soda into the bottle to create the reaction and inflate the balloon. Tie off the end of the inflated balloon.
  - Students can do experiments with the inflated balloons and compare them to balloons blown up with air from our lungs. Even though the latter contain some CO_2, they have less mass than the balloons with the additional CO_2 from the reaction, so the balloons with additional CO_2 fall to the ground much more quickly—and dramatically.

Air Force Medical Service: airforcemedicine.af.mil/News/Photos/igphoto/2000268192

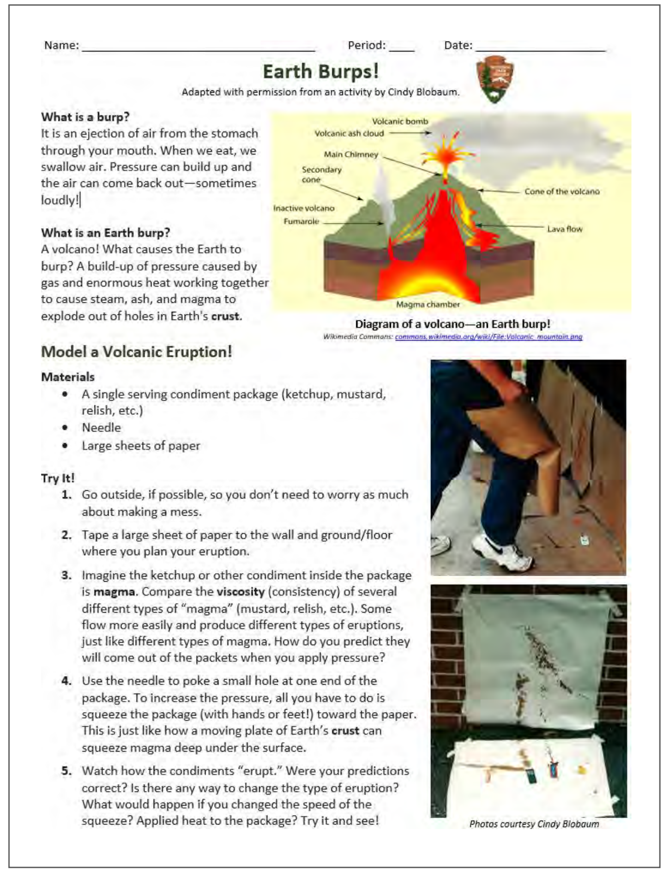
- Discuss how volcanoes can spew huge amounts of CO_2 and other greenhouse gases into the atmosphere, and how humans do, too, from the burning of fossil fuels. Relate the discussion to the implications for our climate, and ask students to discuss the connections between volcanoes, carbon dioxide, extreme weather, and our warming planet. You might ask the students to read and discuss an article about the topic, such as "Are Volcanoes or Humans Harder on the Atmosphere?" from *Scientific American*: scientificamerican.com/article/earthtalks-volcanoes-or-humans. Then ask students to brainstorm and commit to actions they can take to reduce our greenhouse gas emissions personally, as a school, and in the larger community.



Models showing "typical CO_2 emission patterns from volcanic and magmatic systems."
Wikimedia Commons: commons.wikimedia.org/wiki/File:Sketch_showing_typical_CO2_emission_patterns_from_volcanic_and_magmatic_systems.png

- **Ask students to do a "Mini Research Project" (or in-depth project if time allows)** in which students choose a type of rock or mineral to research and present to the rest of the class about how it was created and why it is interesting and/or important.
- **Create collages explaining different types of rocks and how they're formed.** The process is explained in "The Rock Cycle" lesson plan on BetterLesson: betterlesson.com/lesson/632918/the-rock-cycle

- **Do the "Earth Burps" activity** explained at the end of the lesson to model how lava is ejected from a volcano and new rock is created.



Name: ____________ Period: ____ Date: ____________

Earth Burps!

Adapted with permission from an activity by Cindy Blobaum.

What is a burp?
It is an ejection of air from the stomach through your mouth. When we eat, we swallow air. Pressure can build up and the air can come back out—sometimes loudly!

What is an Earth burp?
A volcano! What causes the Earth to burp? A build-up of pressure caused by gas and enormous heat working together to cause steam, ash, and magma to explode out of holes in Earth's **crust**.

Diagram of a volcano—an Earth burp!

Wikimedia Commons: commons.wikimedia.org/wiki/File:Volcanic_mountain.png

Model a Volcanic Eruption!

Materials

- A single serving condiment package (ketchup, mustard, relish, etc.)
- Needle
- Large sheets of paper

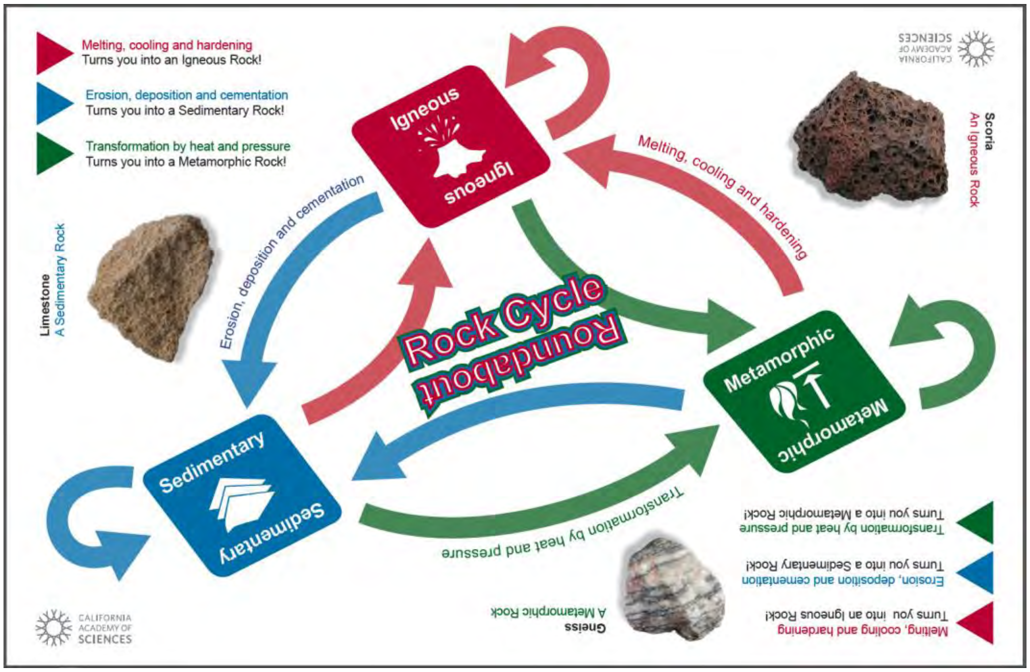
Try It!

1. Go outside, if possible, so you don't need to worry as much about making a mess.
2. Tape a large sheet of paper to the wall and ground/floor where you plan your eruption.
3. Imagine the ketchup or other condiment inside the package is **magma**. Compare the **viscosity** (consistency) of several different types of "magma" (mustard, relish, etc.). Some flow more easily and produce different types of eruptions, just like different types of magma. How do you predict they will come out of the packets when you apply pressure?
4. Use the needle to poke a small hole at one end of the package. To increase the pressure, all you have to do is squeeze the package (with hands or feet!) toward the paper. This is just like how a moving plate of Earth's **crust** can squeeze magma deep under the surface.
5. Watch how the condiments "erupt." Were your predictions correct? Is there any way to change the type of eruption? What would happen if you changed the speed of the squeeze? Applied heat to the package? Try it and see!

Photos courtesy Cindy Blobaum

- **Integrate math and/or data analysis.** For example:
  - After students have identified which of the rocks are igneous, sedimentary, and metamorphic, ask them to calculate the percentages of each type as a group. Then they also create graphs such as histograms and pie charts with the data. You can work with the class as a whole to analyze the data for all the rocks with the support of a data table, then ask students to create graphs with the combined data.
  - Ask students to measure the size and density of crystals in the rock samples. They can use magnifying devices to measure and count density per square cm for samples with really small crystals. How can that help them to determine what types of rocks they are—and how they were made? (**Extrusive** igneous rocks formed from volcanoes, like basalt, that cool quickly and have very small or microscopic crystals—or even lack them altogether in the case of basalt. **Intrusive** igneous rocks like granite have larger crystals. Sedimentary rocks lack crystals, and metamorphic rocks have both crystals and layers.)
- **Invite a geologist or amateur rock hound to speak to your class about their work or show a video of a geologist explaining interesting nearby phenomena.**
  - If possible, take your class on a field study with the support of a geologist or passionate amateur who can explain their work and the rocks/natural history of the area.
  - Several interesting Oregon Field Guide videos are listed on the "Take A Virtual Roadtrip Through Oregon's Fascinating Geology" page from Oregon Public Broadcasting (OPB): opb.org/news/article/geology-oregon-thunder-eggs-caves-canyons-waves. "Columbia Gorge Geology Tour" is one of the videos that includes animations of basalt lava flows: opb.org/television/video/orf-2810-02-digi.
  - Experts may be available from the Ice Age Floods Institute, National Park Service, a local tribe, Univ. of Idaho Ext., WA Dept. of Geology, Oregon State Univ. Ext. Service, the Bureau of Land Management (BLM), etc.

- **Play the "Rock Cycle Roundabout" game from the California Academy of Sciences.** (60 min.) Lesson plan and supporting materials: calacademy.org/educators/lesson-plans/rock-cycle-roundabout



- **Students can create new games that help other students explore the different types of rocks and how they are created.** (60 min.)
  - Encourage them to create engaging game boards, cards, and/or other resources to make the games more fun and educational.
  - This can be an especially good activity to enrich students who complete their other projects quickly, as well as benefit the rest of the class that can play the completed games.
  - Younger students, families, and/or school administrators can be invited into your class to play the games and to hear presentations from your class as part of a celebratory culminating activity for the unit.
- **View a video and/or read an article about the Yellowstone Supervolcano and discuss.** (5–10 min.)
  - Show a short video and discuss the potential impacts on the U.S. if it were to erupt again, being careful to assure students that it is not likely to happy in our lifetimes, but that it is quite possible it will happen again in the future. "Why the Yellowstone Supervolcano Could Be Huge" from the Smithsonian Channel (3:30) is a great summary with compelling visuals: thewonderofscience.com/phenomenon/2018/7/5/yellowstone-supervolcano
  - Students can read and discuss an article about it, such as "Yellowstone volcano hit by almost 300 earthquakes in past month – Will it erupt?":

express.co.uk/news/science/1291762/yellowstone-volcano-eruption-earthquakes-today-usgs-will-yellowstone-erupt

- **Ask students to brainstorm and research ways humans use rocks and potential new uses for them.**
- **Students can design a scientific investigation into rocks.**

  Experiments could include which are the most difficult to scratch, which are the hardest to break with a controlled amount of force, and which types are the most common in your area.
- **Show video clips about different types of rocks, such as those in "Rock Odyssey: A Rocks & Minerals Revue."** It's older and silly, but effective. The students should laugh while they learn, and the songs will get stuck in their heads:
  - On YouTube: youtu.be/s8BUc4zEUyw
  - In libraries on DVD, listed on WorldCat: worldcat.org/title/rock-odyssey-a-rocks-minerals-revue/oclc/191701265

Evaluate

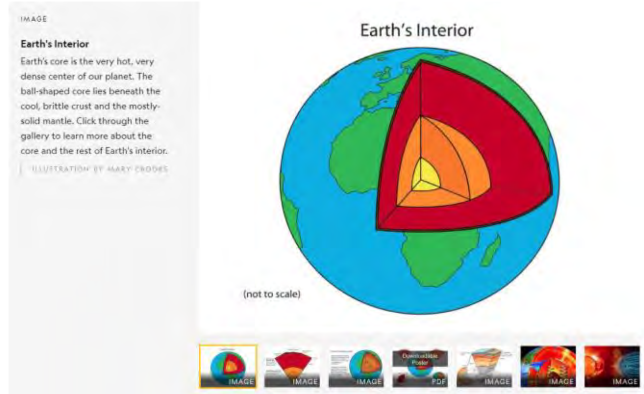
8. **Students can present their rock models and/or other research projects to the class.**
   - Provide a rubric such as the one at the end of the lesson so students know how they will be assessed.
   - Completed projects can also be displayed in the classroom and/or on school walls.
9. **Lead a closing class discussion about the guiding questions of the lesson, upon which students could also reflect in writing.**
   - How are rocks linked to other scientific phenomena, like volcanoes and weather?
   - How can we describe different types of rocks?
   - How are different types of rocks formed?
   - Where can we find different types of rocks?
   - How are geologists like detectives?

   Record student participation in discussion and thank students for thoughtful contributions.
10. **Instead of, or in addition to an all-class discussion, have students think about and discuss some or all of the questions above as a "Think, Pair, Share" activity.**

    Students can record their ideas in science notebooks.
11. **Review student notebooks, completed handouts, diagrams, and any other projects** to celebrate the student work and teach others about rocks and the forces that created our landforms.

Expand Knowledge + Skills

Background on Geology, Rocks, and Rock Types



Screenshot from "Core"—National Geographic: *nationalgeographic.org/encyclopedia/core*

- "Core." (Encyclopedic Entry) National Geographic: nationalgeographic.org/encyclopedia/core
- "Crazy Way to Melt Rocks into Lava." The King of Random: www.youtube.com/watch?v=oMnjbai2-MM&feature=youtu.be
- "Earthquakes, Volcanoes, and Tsunamis." NSTA Press: web.archive.org/web/20120913041924/http://www.enviroliteracy.org/nsfmod/NaturesFury.pdf
- "Igneous Rocks." NPS: nps.gov/subjects/geology/igneous.htm
- "Lake Roosevelt Geology." NPS: nps.gov/laro/learn/nature/geology.htm
- "Sedimentary Rocks Lesson #13." Oregon State University: volcano.oregonstate.edu/sedimentary-rocks-lesson-13
- "Volcano." National Geographic Kids: kids.nationalgeographic.com/explore/science/volcano/
- "Volcanoes." Wikipedia: en.wikipedia.org/wiki/Volcano
- "Yellowstone Supervolcano." The Wonder of Science: thewonderofscience.com/phenomenon/2018/7/5/yellowstone-supervolcano

Lessons / Units

- "Mystery Rocks." Utah Education Network: uen.org/lessonplan/view/21494
- "Rock Stories." NPS: nps.gov/teachers/classrooms/rock-stories.htm
- "Think, Pair, Share Cooperative Learning Strategy." TeacherVision: teachervision.com/group-work/think-pair-share-cooperative-learning-strategy

Standards

- More information about the Next Generation Science Standards, including a link to the *Framework for K-12 Science Education* to which this lesson was aligned: nextgenscience.org/framework-k%E2%80%9312-science-education.
- More information about the Common Core State Standards and links to the complete documents: corestandards.org
- More examples of what NGSS looks like for high school students can be found in Chapter 7 of the *2016 Science Framework for California Public Schools:* cde.ca.gov/ci/sc/cf/documents/scifwchapter7.pdf

Name: ___________________________________ Period: ____ Date: ____________________

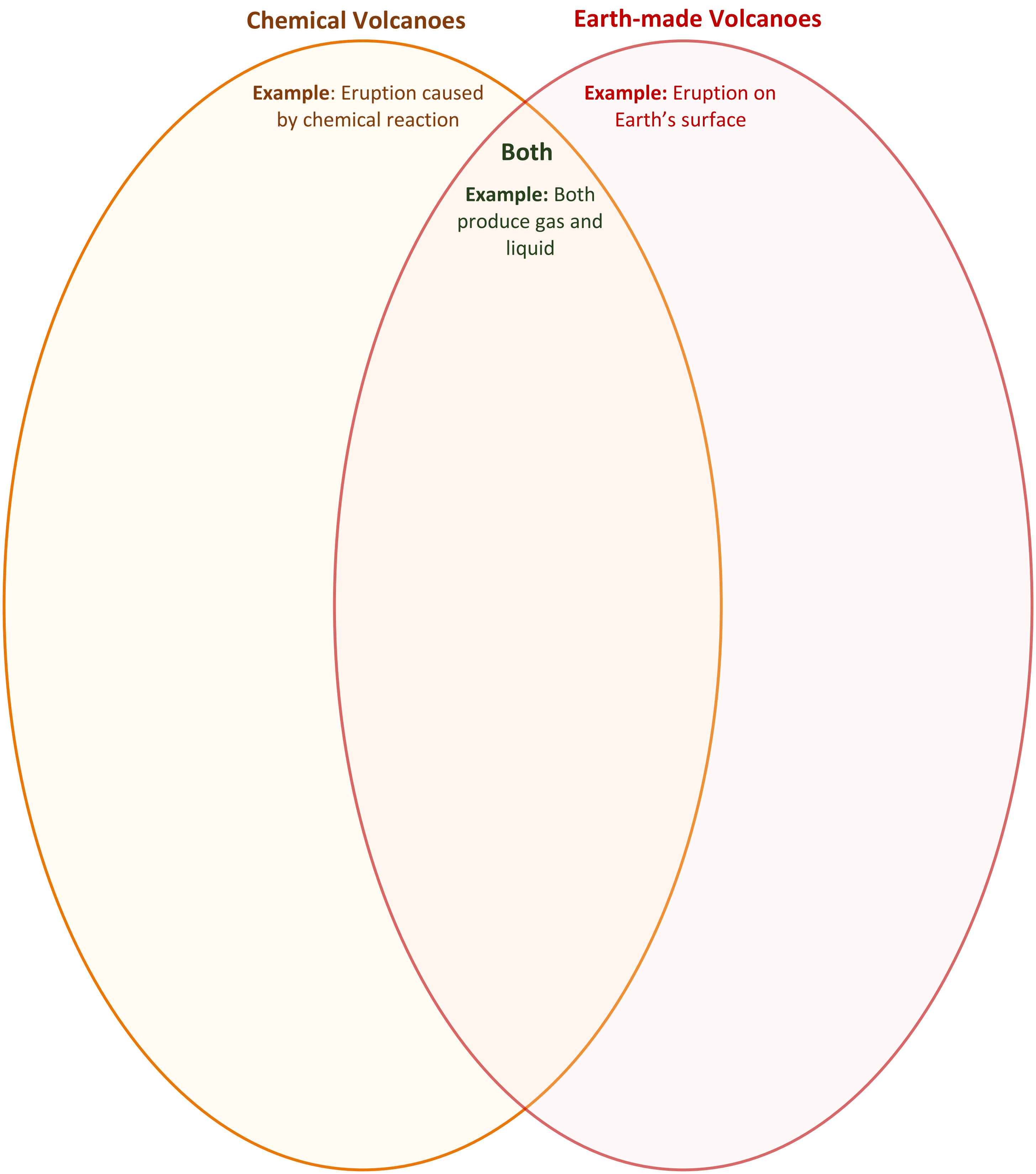
Mystery Rocks

Rock	Observations	Draw + Color It!	How might it have been created?
1	Color, texture, holes, crystal size, hardness, banding, smell, glassy or dull, light or heavy, etc.		__ Volcano/lava/magma __ Sediment cemented together __ Heat and pressure deep inside Earth __ Other:

Name: ______________________________________ Period: ____ Date: _____________________

Comparing Volcanoes

Use words and pictures in the Venn diagram below to compare chemical volcano models to real volcanoes.



Name: ______________________________________ Period: ____ Date: _____________________

Earth Burps!

Adapted with permission from an activity by Cindy Blobaum.

What is a burp?
It is an ejection of air from the stomach through your mouth. When we eat, we swallow air. Pressure can build up and the air can come back out—sometimes loudly!

What is an Earth burp?
A volcano! What causes the Earth to burp? A build-up of pressure caused by gas and enormous heat working together to cause steam, ash, and magma to explode out of holes in Earth's **crust**.

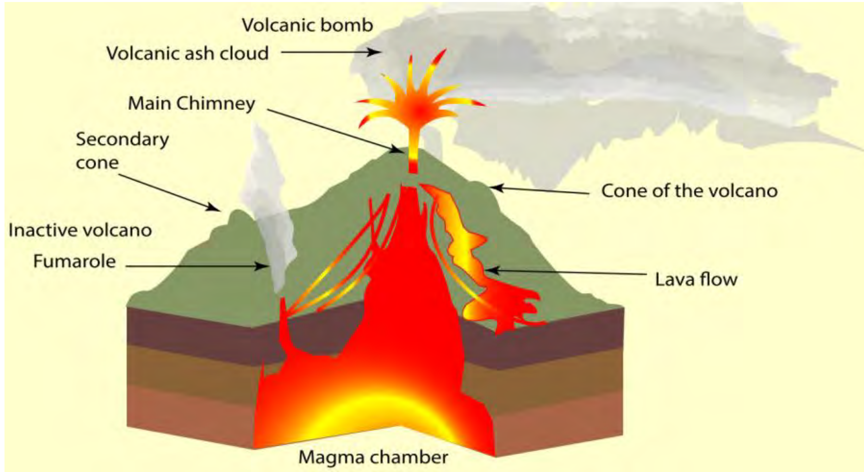


Diagram of a volcano—an Earth burp!
Wikimedia Commons: commons.wikimedia.org/wiki/File:Volcanic_mountain.png

Model a Volcanic Eruption!

Materials

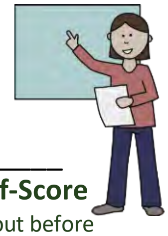
- A single serving condiment package (ketchup, mustard, relish, etc.)
- Needle
- Large sheets of paper

Try It!

1. Go outside, if possible, so you don't need to worry as much about making a mess.
2. Tape a large sheet of paper to the wall and ground/floor where you plan your eruption.
3. Imagine the ketchup or other condiment inside the package is **magma**. Compare the **viscosity** (consistency) of several different types of "magma" (mustard, relish, etc.). Some flow more easily and produce different types of eruptions, just like different types of magma. How do you predict they will come out of the packets when you apply pressure?
4. Use the needle to poke a small hole at one end of the package. To increase the pressure, all you have to do is squeeze the package (with hands or feet!) toward the paper. This is just like how a moving plate of Earth's **crust** can squeeze magma deep under the surface.
5. Watch how the condiments "erupt." Were your predictions correct? Is there any way to change the type of eruption? What would happen if you changed the speed of the squeeze? Applied heat to the package? Try it and see!

Photos courtesy Cindy Blobaum

Name(s): ____ Date: ______________________



Presentation Rubric

Title: ____

Part 1: Content	Maximum Points	Self-Score (fill out before presentation)	Teacher Score
Subject and purpose of presentation clearly introduced	10		
Key concepts identified and clearly explained in well-organized way	10		
Ideas supported by examples, data, graphs, etc.; All information accurate and obtained from reliable sources	10		
Conclusion summarizes key points; Questions answered thoroughly and accurately	10		
Part 2: Delivery / Audience Engagement			
Speech delivered clearly at appropriate volume and speed (not too fast, slow, loud, or soft)	10		
Speed, volume, and voice inflection are varied to engage audience and emphasize key points	10		
Speaker connects with audience through eye contact and does not spend too much time looking at notes or screen	10		
Speaker demonstrates enthusiasm for topic throughout presentation; audience is persuaded by speaker	10		
Part 3: Visuals			
Visuals help to clearly explain concepts	10		
Part 4: Writing Conventions			
Grammatical and spelling conventions followed	10		
TOTALS:	**100**		

Comments:

Shape-Shifting Erosion

Creating Canyons, Soil, and Other Phenomena

Overview

The phenomenon of erosion during the Ice Age Floods on an almost unimaginable scale created the dramatic Northwest landforms we marvel at today. In this lesson, students explore the concepts of erosion through the creation of watershed/erosion models, letting them experience the power of flowing fluids. It will also give them the scientific background to help them solve the “Mystery of the Scabland Puzzle” in a later lesson and understand how catastrophic floods carved many of our most awe-inspiring landscapes out of solid rock. The lesson is supported by an interactive PowerPoint presentation which you can adapt to best meet the needs of your students. A variety of additional Enrich / Extend activities are listed to help you meet the needs of all learners.

Subjects: Science, Writing, Speaking & Listening, Art, Environmental Education

Grades: Adaptable for K–12

Duration: 50 minutes or more

Vocabulary

- Erosion
- Confluence
- Depression (in ground)
- Elevation
- Geomorphology
- Gorge
- Headwaters
- Model
- Ridgeline
- Runoff
- Sediment
- Transport
- Turbidity
- Valley
- Watershed
- Weathering

Guiding Questions

- How do the processes of erosion and weathering transform our landscapes?
- How does erosion of sediment impact our watersheds?
- How are different types of rocks and landforms impacted by erosion?
- What roles do slope and ground cover play in erosion?
- How can humans impact the amount of erosion and its effects on landscapes and water quality?

Objectives

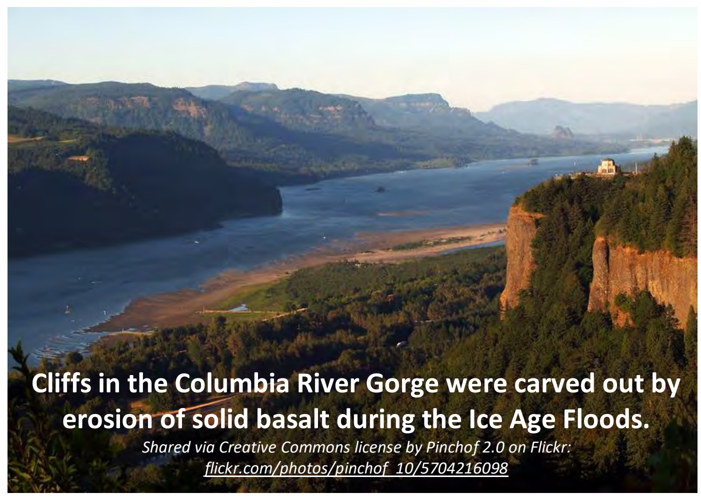
- Students will create models of watersheds/erosion using sand or dry dirt and water.
- Students will draw and label diagrams of their models and compare them to actual watersheds in writing.
- Students will demonstrate understanding of how water flows through a watershed and impacts the landscape, both orally and in writing.
- Students will be able to explain the connections between rocks and other phenomena, like volcanoes and weather.

Video demonstration in “Setting up the Stream Table” by Smithsonian Science Ed Center: vimeo.com/73380956

Next Generation Science Standards + Common Core State Standards		
	Performance Expectations We suggest you tailor the lesson to meet the PE(s) for your grade level.	**2-ESS2-2.** Develop a model to represent the shapes and kinds of land and bodies of water in an area. **2-ESS2-1.** Compare multiple solutions designed to slow or prevent wind or water from changing the shape of the land. **2-ESS1-1**. Use information from several sources to provide evidence that Earth events can occur quickly or slowly. **4-ESS1-1**. Identify evidence from patterns in rock formations and fossils in rock layers to support an explanation for changes in a landscape over time. **5-ESS2-1**. Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact. **MS-ESS2-1**.Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process. **MS-ESS2-2**. Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales. **MS-ESS3-1**. Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes. **HS-ESS2-1**. Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.
	Crosscutting Concepts	• Cause and Effect • Energy and Matter • Patterns • Scale, Proportion, and Quantity • Stability and Change • Systems and System Models
	Science & Engineering Practices	• Developing and Using Models • Constructing Explanations and Designing Solutions • Engaging in Argument from Evidence • Obtaining, Evaluating, and Communicating Information

	Disciplinary Core Ideas	ESS1: Earth's Place in the Universe ESS2.A: Earth's Materials and Systems ESS2.D: Weather and Climate ESS3: Earth and Human Activity ESS3.D: Global Climate Change PS1: Matter and Its Interactions
Common Core State Standards English Lang. Arts	Writing	4, 10
	Speaking & Listening	1, 2
	Language Standards	1, 2, 3, 6
	Writing Standards Science & Technical Subjects	4, 7, 10
Math CCSS	Math can be incorporated to meet the standards at your grade level and/or to reinforce concepts learned previously. See the Enrich / Extend section for ideas.	

Teacher Background



Cliffs in the Columbia River Gorge were carved out by erosion of solid basalt during the Ice Age Floods.
Shared via Creative Commons license by Pinchof 2.0 on Flickr: flickr.com/photos/pinchof_10/5704216098

This lesson helps students understand how **erosion** (wearing away and transport of material) and **weathering** (a term used to describe all of the ways rock is worn away physically or decomposed chemically, but not moved to a new place) can gradually—and sometimes dramatically—change the land. Through a visit to an area showing signs of erosion and/or the process of creating models with sand or dry dirt, students can see how rain, wind, and other natural processes can transform our landscapes.

Weathering occurs in two main ways:

- **Mechanical weathering** is the breaking down of large rocks into smaller pieces. An example is ice freezing in cracks, which expands and can break off rock. Tree roots growing in cracks can break up rock in the same way, as can the heating and cooling of rocks in day/night cycles, which causes them to expand and contract.

- **Chemical weathering** is breaking down rocks via chemical reactions involving water and atmospheric gases like carbon dioxide, oxygen, and water vapor. Examples of these processes include

Roots eroding sandstone via mechanical weathering
Image by LoggaWiggler, Pixabay: pixabay.com/photos/tree-root-tree-root-pine-stone-4585/

rusting, **oxidation**, and **hydrolysis** (such as when water reacts with feldspar crystals in granite and weakens them into clay minerals).

Geomorphology is the study of how landforms change and why they look the way they do. Geomorphologists investigate how weathering, **gravity** and the four **fluid agents** below can transform the land through erosion, transport, and depositing of matter.

- **Gravity** – Broken pieces of rock fall to the ground and roll or slide down slopes.
- **Flowing water** across land (especially sloped land), and through rivers and streams, can transport all sizes of particles.
- **Waves** – Wave action of water at the coast (plus sand and other suspended particles) can erode the beach and even rocks there over time.
- **Wind** – Small grains of sand can be picked up and moved by the wind in dust storms. The grains can also cause **wind abrasion** that is strong enough to erode rock.
- **Glacial ice** – Glaciers of ice containing rocks move slowly downhill, grinding the land surface. This phenomenon will be explored in the next lesson.

Fluvial landforms are those created by flowing water. These are the dominant types of landscapes around the world. The two types of these landforms are:

- **Erosional landforms** (such as valleys and the surrounding mountains and hills that were not eroded away)
- **Depositional landforms** (such as beaches and floodplains created by eroded material)

Hydrolysis weakened the feldspar crystals in this granite. The chemical weathering helped mechanical wave action erode the solid coastal rock.

Creative Commons image from PxHere: pxhere.com/en/photo/733150

The Ice Age Floods deposited enormous quantities of eroded material in the Willamette Valley, Oregon, greatly adding to soil fertility.

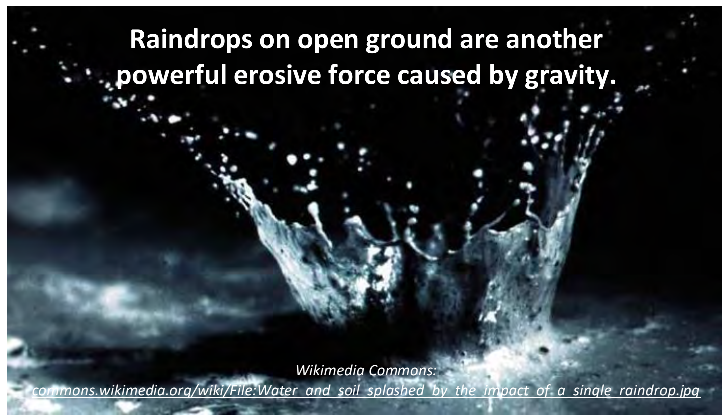
Creative Commons image by Sheila Sund: flickr.com/photos/sheila_sund/25134584933

Types of fluvial erosion:

- **Slope erosion** describes how water flowing downhill from the force of gravity can transport **sediment**, including soil, sand, and rocks, by the dragging force of the water. The sediment itself can also add to the force of erosion. This is normally a gradual process that is slow enough to allow plant communities to grow (and thereby slow the rate of erosion by protecting and holding the soil). But human activities such as clearing forests, development, and overgrazing, as well as unusual natural events, can dramatically speed up the rate of erosion (Strahler and Strahler 1989).

Human activities like land clearing and development can increase erosion and degrade water quality from increased runoff and sediment/pollution in water bodies.
Needpix: needpix.com/photo/293382/highways-freeways-streets-roads-crossing-areal-view-bridges-construction-river

- **Splash erosion** is the term for the direct force of raindrops falling on bare ground. Soil particles are spread in a geyser-like action. If this occurs on a slope, the loose particles can then be more easily spread downhill. An even more important effect of splash erosion is that the soil surface becomes less able to absorb water, resulting in more overland flow of it.



Raindrops on open ground are another powerful erosive force caused by gravity.
Wikimedia Commons: commons.wikimedia.org/wiki/File:Water_and_soil_splashed_by_the_impact_of_a_single_raindrop.jpg

- **Stream erosion** is the "progressive removal of mineral material from the floor and sides of the channel" (Strahler and Strahler 1989). **Stream transportation** is the movement of the eroded particles by dragging them along the stream bed. **Stream deposition** is the accumulation of particles in areas of the stream bed, floodplain, or body of water in which the stream empties.

Stream erosion has been carving the Grand Canyon for millions of years.
Image by KeYang, Pixabay: pixabay.com/photos/horseshoe-bend-grand-canyon-1908283

Wind erosion can remove loose particles. This is most common in deserts and semi-arid environments that do not have sufficient plant cover. If wind drives sand

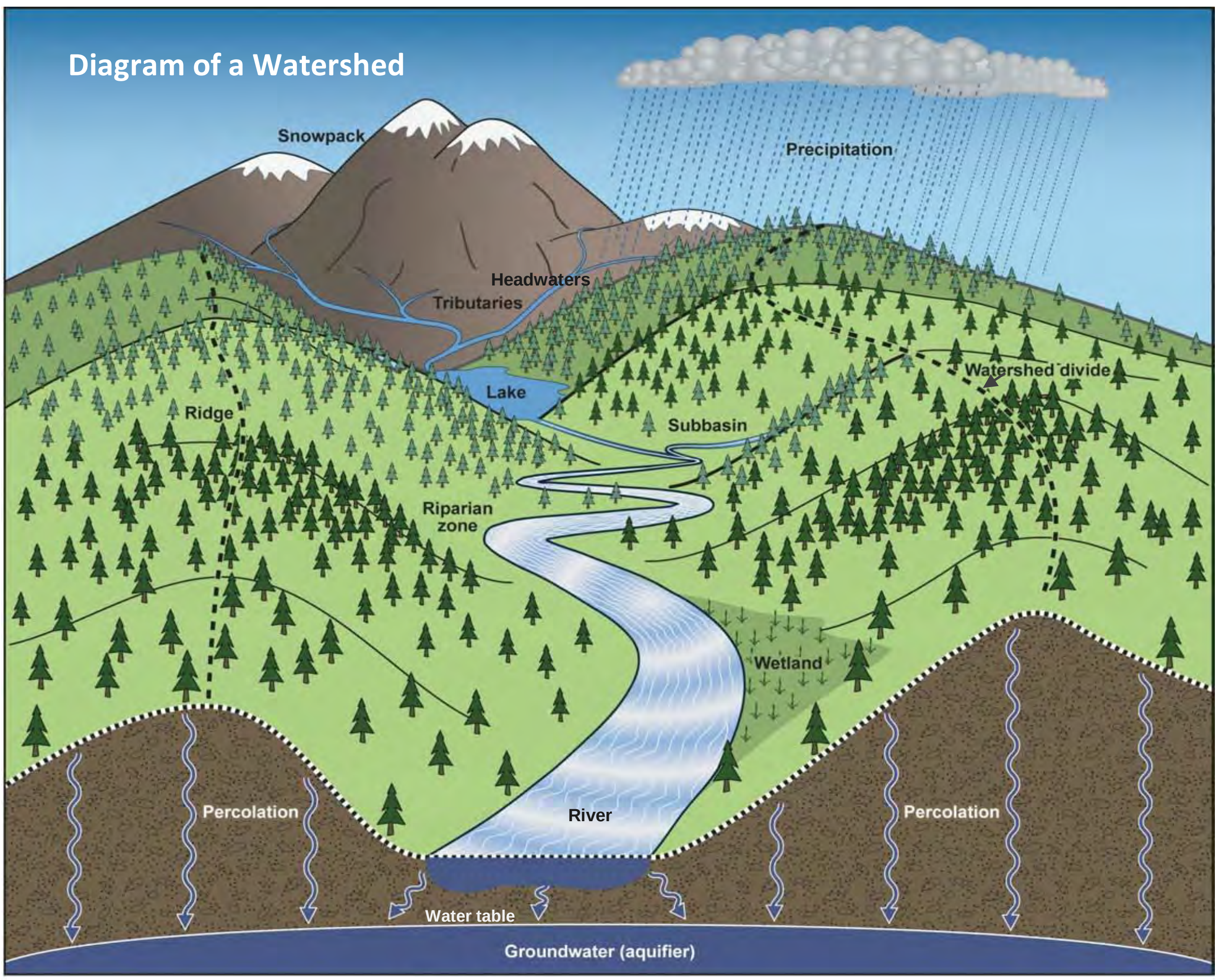
and dust particles against exposed rocks or soil, significant additional erosion can occur through the process known as **wind abrasion**.

Wave erosion is the dominant form along our coasts, caused by the repeated action of waves, as well as the sand and other suspended particles they contain. We will explore **glacial erosion** in the next lesson.

Wind abrasion has been helping to carve Delicate Arch, Arches National Park, Utah.
nps.gov/media/photo/gallery.htm?id=221F3BB7-155D-451F-6738DBB434CFBF5E

Watersheds

An area of land that drains through a particular body of water, such as a river or stream, is known as a **watershed**. Regardless of whether one lives in a coastal city or on rural mountain terrain, we all live in a watershed. Additional concepts that you can choose to incorporate into the lesson are discussed in the Explain section of the lesson.

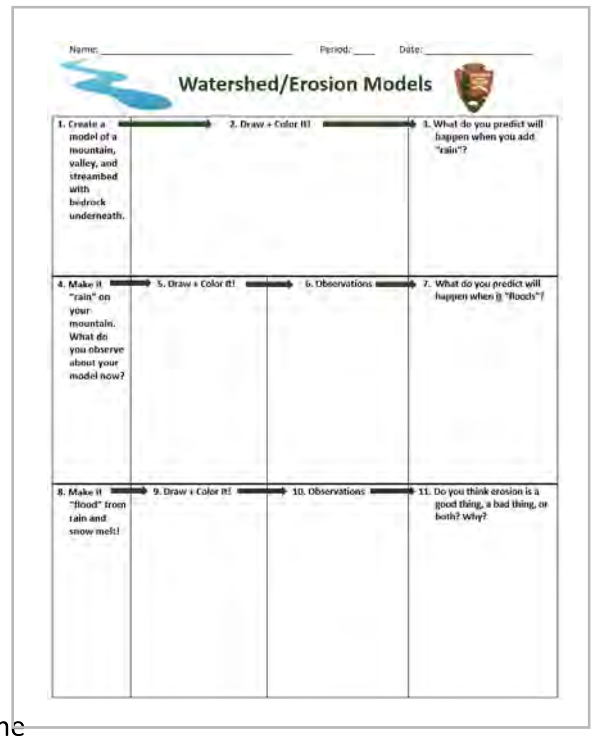


The force of gravity moves water downhill through the watershed, as both surface runoff and groundwater.
Adapted from a public domain image by the EPA and Government Accountability Office (GAO): flickr.com/photos/usgao/7590258768

Materials + Preparation

- **For the "Watershed/Erosion Models" activity** you'll need these (or similar) for each model:
    - o Baking pan or plastic tub with dry sand or dirt; can also be done in area with sand or dry dirt without pans
    - o Rocks (ideally of different types in a container) that students can integrate into their models
    - o Stick to represent a logjam in the river
    - o Spray bottle or container of water (16–32 ounce or ½ liter works well)
    - o Copies of the "Watershed/Erosion Models" handout for each student found at the end of the lesson and/or science notebooks for students to record predictions and observations
    - o Colored pencils, markers, and/or crayons

Smithsonian Science Ed Center: vimeo.com/73380956



Name: ______ Period: ____ Date: ______

Watershed/Erosion Models

1. Create a model of a mountain, valley, and streambed with bedrock underneath.	2. Draw + Color It!		3. What do you predict will happen when you add "rain"?
4. Make it "rain" on your mountain. What do you observe about your model now?	5. Draw + Color it!	6. Observations	7. What do you predict will happen when it "floods"?
8. Make it "flood" from rain and snow melt!	9. Draw + Color it!	10. Observations	11. Do you think erosion is a good thing, a bad thing, or both? Why?

- *Optional:* A slightly more complex model that involves adding a hole to the pan or tub to let water exit to a bucket or sink is explained in "Setting up the Stream Table" by Smithsonian Science Ed Center: vimeo.com/73380956.
- **Prepare to show the "Shape-Shifting Erosion" PowerPoint presentation as an interactive, phenomenon-based visual aide**; feel free to adapt for your students
- Data projector and computer
- Access to Internet and/or library for research
- Watch the "Erosion Demonstration: Hands-on Activity" video from NPS for a demonstration of one way to lead the activity: nps.gov/media/video/view.htm?id=6F9AF2B7-9C26-8C56-47037723897C378E

- *Optional:* Document camera (connected to data projector)

- *Optional:* Review the sources and watch the videos listed at the end of the lesson for additional background information. You could also share one or more of the videos with your students and discuss them.

Teaching Suggestions in the 5E Model

Engage

1. **Options to engage students with scientific phenomena, activate prior knowledge, and stimulate critical thinking** (2–20 min.)

    - **Visit an area with signs of erosion.**

      This can be an area with dramatic signs of water and/or wind erosion, or simply evidence of it in the schoolyard or another nearby area. Ask the students:

        - What (phenomenon) caused this? (Reinforce the word "phenomenon" if they are familiar with it.) A student should say **erosion**, or keep asking questions until they do. With young students, you can wait until the Explain part of the lesson to introduce the term.
        - What kinds of events cause the most erosion? (heavy rainstorms, floods, hail, windstorms, other weather, human activities, and ice freezing in cracks, which expands and can break off rock, also cause erosion)

Wikimedia Commons: commons.wikimedia.org/wiki/File:Erosion.jpg

    - **Students create watershed/erosion models.**

        - Do this at a beach, sandbox, an area with dry dirt, or pass out open containers with dry sand/dirt to groups of 3–5 students (ideally outside to make cleanup easier). Ask them to create a realistic model of land with a mountain, hills, and a valley with a riverbed.
        - While the students work, pass out rocks (ideally of different types in a container) that they can integrate into their models. Tell them that the surface of the ground may be loose soil, which the sand represents. But there's also hard rock under the soil, called bedrock, so take a handful of stones and place them underneath the sand to represent bedrock. They can leave some showing a bit to represent areas of exposed rock, boulders, etc. The sand should be patted down to make it more like solid ground than loose sand at the beach.

Simple watershed model
Image courtesy Rick Reynolds

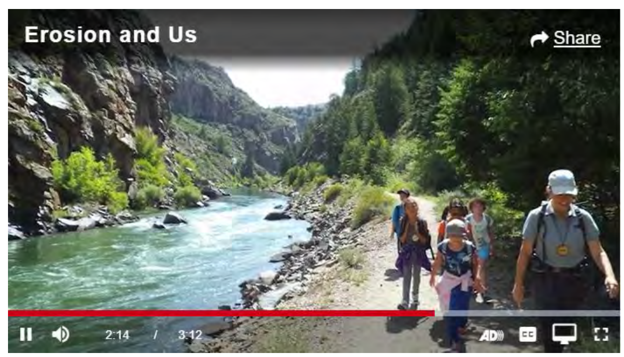
- Pass out a stick to each group to represent a logjam in the “river.”
- Once they have their models set up, check to make sure that there is a “mountain” with “bedrock” underneath, a valley with a stream bed, and that they patted the sand to firm it up.
- Give students a warning a minute or two before they will have to stop working on their models.

2. **Show a short video clip of dramatic erosion in action and have students do a think-pair-share to discuss their ideas about the phenomenon.** (2 – 5 min.)
Consider turning the sound off to encourage students to think about the phenomenon rather than have it explained to them. Options include:
    - “September 9th, 2013. Flash Flood Footage / Erosion Shots Utah Monsoon” (2:57). Rankinstudio: youtu.be/mXlr_Bgb-s0

Dramatic flash flood footage
Rankinstudio: youtu.be/mXlr_Bgb-s0

    - “Erosion and Us” (3:12—choose a short clip). NPS: nps.gov/media/video/view.htm?id=6F398C17-F9E8-2131-9ECD15071AB2FFB1
    - “Bill Nye the Science Guy – Erosion” (23:05—choose a short clip): schooltube.com/media/Bill+Nye+Erosion/1_3weyaoip
    - “Erosion Causing Island in Canada's North to Disappear.” CBC News: youtu.be/iXkrS1u5fl8

Then ask students to discuss with a partner what effects the flooding, etc. will have on the landforms, rocks, and other natural and human-made features they observed in the video. They can record their ideas in science notebooks. You also might discuss strategies for minimizing erosion, such as staying on trails in natural areas.



“Erosion and Us” from NPS also discusses ways to minimize erosion, such as staying on the trail.
NPS: nps.gov/media/video/view.htm?id=6F398C17-F9E8-2131-9ECD15071AB2FFB1

Explore

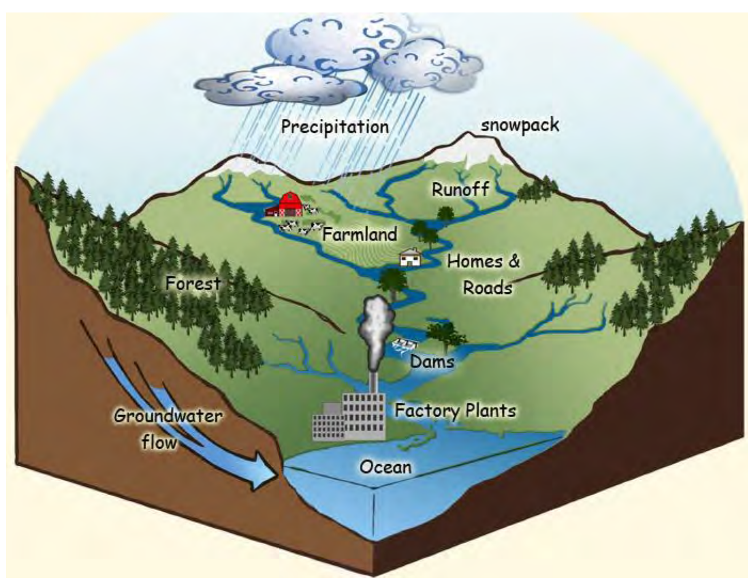
2. **Simulate rain, flooding, and erosion.** (5–7 min.)
    - Ask students to create watershed models as described above if they have not yet done so.
    - Pass out copies of the “Watershed/Erosion Models” activity sheet found at the end of the lesson, or students can take out their science notebooks to record predictions and observations. You can also pass out colored pencils, markers, and/or crayons. Explain that they should draw a simple colored sketch of their model.

- Pass out a spray bottle, watering can (to match the size of the model), or other container of water to each group. Ask students to predict what will happen if "rain" is added to the model. They should record their ideas on the activity sheet or in science notebooks, then they can spray or sprinkle water with their hand onto the "mountain" in their model. They should record the results of their experiment. They can add more water (up to a third or half of the container) to observe the effects of the water, recording observations on the activity sheet or in their notebooks.
- Circulate to answer any questions. When the groups are mostly finished recording their observations, tell them that there has been intense rain and a sudden snow melt that will result in a flash flood. Ask them to predict and record their ideas about what will happen if the rest of the water is poured over the model all at once.

Explain

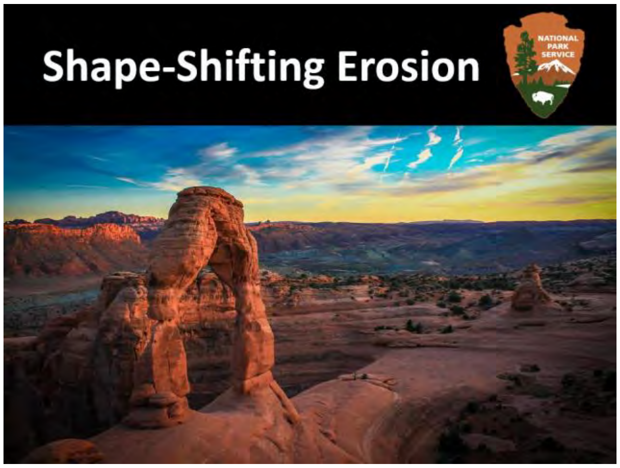
3. **Discuss the concept of a watershed and how it works.** (5 – 10 min.)

- Discuss the activity with questions such as those below. Adjust the amount of terminology you use/introduce based on the level and prior knowledge of your students.
  - Is what happened what you predicted?
  - Where did the water run to and why? (It flowed "downhill" because of **gravity**.)
  - Where did the water collect? (in low-lying areas called **depressions**)
  - What happened to the height of the mountains?
  - What happened when the "soil" absorbed all the water it could hold?
  - What happened when the sediment hit the "logjam"?
  - How does your model compare to the actual watershed? (They should note how very small streams in their models exhibit many of the same features as a larger river.)
- Write (or point to) the word "**watershed**" and explain that it is what the student models represent: an area of land which drains the **precipitation** that falls on it, such as rain and snow. Explain that everyone lives in a watershed, which is usually named after the rivers and streams into which the water flows, such as the massive Columbia River watershed. Ask the students if anyone knows the name of your watershed and consider showing them a topographical map of it that you find online using a data projector.



- Discuss how all **freshwater** eventually flows back to the ocean, though it can sometimes take a long time, such as when it flows into **aquifers**, permeable rock below the surface that store water underground like a "shed" or transmits **groundwater**.
- Draw a quick model on the board which helps explain visually how some water also **evaporates** into the air as a gas called **water vapor**, but that it will eventually get back to the ocean when it **condenses** into clouds and returns to the planet's surface as precipitation. Explain that this is all part of the **water cycle** which works to constantly move and purify water around the world.
- Ask students what part of their models might be called a **ridgeline**. Discuss how it runs along the top of mountains and hills; it is the highest **elevation** area which forms the boundary between two watersheds. Rain that lands in the **headwaters** will flow downhill, following the path of least resistance. These **depressions** and lower elevations are where water begins to collect; puddles and springs may turn into a small stream. Small creeks flowing to a common lower elevation may form a **confluence**, joining together to form a larger stream, which may join others into a larger stream or other water body, such as a pond or river, that might eventually empty into the ocean.

4. **Discuss the concept of erosion.** (5 – 10 min.)



This can first be done as a think-pair-share activity before discussing it as a group with the support of the "Shape-Shifting Erosion" PowerPoint presentation as an interactive visual aide. You also might use a short video with the sound turned off as a visual aide, such as "The Power of Water for Kids: How Erosion by Water Shapes Landforms for Children – FreeSchool": youtu.be/qqsTS67BKmA.

- Explain that there are 5 ways erosion occurs naturally:
  - **Gravity** – Broken pieces of rock fall to the ground and roll or slide down slopes.
  - **Flowing water** across land (especially sloped land), and through rivers and streams, can transport all sizes of particles.
  - **Waves** – Wave action of water at the coast (plus sand and other suspended particles) can erode the beach and even rocks there over time.
  - **Wind** – Small grains of sand can be picked up and moved by the wind in dust storms. The grains can also cause **wind abrasion** that is strong enough to erode rock.
  - **Glacial ice** – They will explore it in the next lesson.
- Relate the crosscutting concept of cause and effect into your discussion, and how water travels via the path of least resistance and settles in areas of lower elevations relative to the system in which it

moves. Students can discuss and/or experiment with ways in which the force of gravity can act on water to **erode** and **transport** materials from areas of high potential energy (those that are steep) and low energy (those that are flat).

  - Discuss the movement of **sediment** as it relates to their models and actual watersheds, caused by **weathering** and the **erosion** of rocks and soil.
  - Ask students to point out these features on their models as you discuss them, and they can draw and label them in their science notebooks and/or on their activity sheets.

- Tell students that erosion can occur because of human activities as well. Ask, "What human activities can cause erosion?" Discuss some of the ways, such as construction sites that disturb the ground, clearcutting of forests, and overgrazing by livestock (such as cows and sheep).
- *Optional if time allows:* Ask, "What happens to pollution or trash on the ground when it rains?" Students can discuss how everything that goes down their drains, in the roads, on their lawns, etc. will eventually go to their streams, rivers, and the ocean.
- *Optional if time allows:* Ask, "Would sediment in a river be good or bad, and why?" (bad, because it hurts water quality for fish and other wildlife)
- The PowerPoint can also be used as a review game at the end of the lesson or at a future date. Ask students to get into pairs or small groups and record answers to the questions on screen before you show the answers. You can add additional questions by duplicating the slides in the Slide Sorter.

5. Have students reflect on how erosion has transformed our landforms over time. This can be done orally with a partner and/or the whole class, as well as in writing in science notebooks and/or on their activity sheets. You may also ask students to reflect on how eroded materials become part of soil, how they can help plants, and/or how they can impact water quality for wildlife and humans in rivers and streams.

  - This should include a discussion of the negative aspects of erosion, as well as the positive, so you might ask students to use a graphic organizer to help them analyze the which aspects are positive, which are negative, and which impacts can be both positive and negative.
  - A Venn diagram is one good tool for this purpose. You might show a video to help students better understand the negative impacts of erosion, such as "Soil Erosion Round the World – Causes and Solutions" from DW News: youtu.be/s0F2c1ECuo4.

Building terraces to slow down erosion and keep sediment out of the river that is killing fish
Screenshot from "Soil Erosion Round the World – Causes and Solutions" from DW News: youtu.be/s0F2c1ECuo4

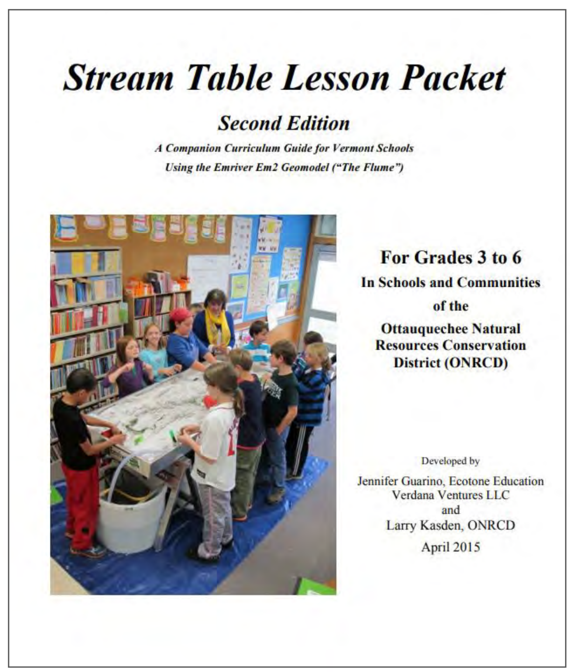
Extend / Enrich

- **Pass out syringes and/or pipettes that can be used to test the effect of wind erosion on the models.** This should be done before water is added to them. Turkey basters also work well. The process is elaborated on in this erosion investigation from the Utah Education Network: uen.org/lessonplan/view/9862.
- **Pass out additional items to make the models more realistic.**

  Students can add sticks to represent trees, houses, a little piece of road or bridge over a river, and a couple cars. Toys such as cars and items from games can also be used, such as monopoly houses. (These items can help students see human connections to the watershed, but they can be distracting from the lesson if you have a high-energy group).

Small wooden houses available online
Etsy: etsy.com/listing/243574927/wooden-monopoly-houses

- **Integrate math and/or data analysis.** For example:
  - Students can measure the volume of the water added to the models in each step using milliliters, liters, cups, pints, and quarts.
  - Then ask, "How do the effects of erosion change with the varying amounts? Is the amount of erosion proportional to the amount of water added to the models? Or is the amount of erosion even greater than the amount of water added at a given time?" (the amount of erosion can be even more dramatic in a flash flood event)
- **Build or purchase one or more stream tables that can be used to create more realistic watershed/erosion models and conduct additional experiments.**
  - MrHollister.com is one of a number of sites that lists instructions for how to create stream tables inexpensively (under $50): mrhollisterphoto.com/stream-table.html.
  - Good curricular resources with additional lesson plans are also found online, including this *Stream Table Lesson Packet*: emriver.com/documents/2017/03/stream-table-lesson-packet-vt.pdf.



Stream Table Lesson Packet **provides additional free lesson plans***:*
emriver.com/documents/2017/03/stream-table-lesson-packet-vt.pdf

- **Discuss/explore ways to lessen the impacts of erosion.**
  - "What are some ways we can lessen the amount of soil particles that enter a stream? Discuss ideas with a partner and list your ideas in your science notebook."
  - Ask each group/pair to share their ideas and list them on the board. Examples for discussion:
    - Put straw bales and buffers around areas of construction to contain sediment run-off.

- Logs and logjams benefit by interrupting the fast flow of water. Sediment gets trapped in the pool areas upstream of logjams in the slower moving water and settles to the bottom, making the water clearer for fish trying to breathe, but could smother fish eggs. Humans have made projects out of installing large logs in streams to slow the fast flow of storm run-off. What are benefits and drawbacks of this strategy? Beavers can also play important roles because of the way they make dams. Good videos and/or articles you might incorporate into the discussion include:
    - "Beaver Dams without Beavers?" Video and article from *Science* magazine, American Association for the Advancement of Science (AAAS): sciencemag.org/news/2018/06/beaver-dams-without-beavers-artificial-logjams-are-popular-controversial-restoration
    - "The Pros & Cons of Logjams." *Harbor Country News:* harborcountry-news.com/features/the-pros-cons-of-logjams/article_04bd5dd7-f3b7-5089-8744-7e80fba1361b.html
- Stabilize stream banks by planting plants and trees.
- Keep off the dirt areas of stream banks and only walk on gravel or stone areas.
- Supply cows and horses and other livestock with water troughs instead of them having to get water from a stream, which erodes its banks.

- **Play the "Walter's Travels - Weathering and Erosion" game from National Geographic**: nationalgeographic.org/interactive/walters-travels-weathering-and-erosion
- **Students can create new games that help other students understand the concepts of erosion and a watershed.**
    - Encourage them to create engaging game boards, cards, and/or other resources to make the games more fun and educational. They can also create the computer games using a tool like Scratch from MIT: scratch.mit.edu. It is an easy-to-learn, visual builder for stories and animations, as well as games. The Unity game engine the most popular game development tool in the world for both 3D and 2D games; is also free for personal use and students, including enjoyable short tutorials: store.unity.com/download-nuo.
    - This can be an especially good activity to enrich students who complete their other projects

A challenge in "Walter's Travels - Weathering and Erosion"—students can test their knowledge and be inspired to create their own games!

quickly, as well as benefit the rest of the class that can play the completed games.

- Invite younger students, families, and/or school administrators into your class to play the games and to hear presentations from your class as part of a celebratory culminating activity for the unit.

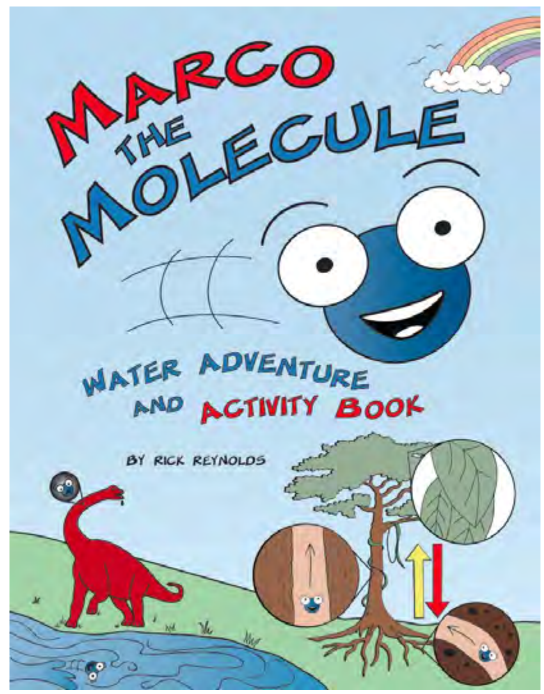
- **View all or part of a longer video about erosion.**

  "Bill Nye the Science Guy – Erosion" (23:05) is an entertaining, educational option: schooltube.com/media/Bill+Nye+Erosion/1_3weyaoip

- **Students can design a scientific investigation into erosion.**

  Experiments could include the amount of substances that erode by varying amounts of force from "rain," flowing water, "waves," and "wind."

- **Read fictional and/or non-fiction books that help teach the concepts of erosion.** Options include:
  - *Cracking Up: A Story About Erosion* by Jacqui Bailey: books.google.com/books?id=SeBxcVk9fIwC
  - *Erosion: Changing Earth's Surface* by Robin Michal Koontz: books.google.com/?id=q7FguGwXXzEC
  - *Marco the Molecule: Water Adventure and Activity Book* by Rick Reynolds: engagingeverystudent.com/marco-the-molecule-water-adventure-and-activity-book



- **Ask students to brainstorm and research ways fish such as salmon can be impacted by erosion—and actions they can take to help.**

- **Take the students on a more involved field study to observe the effects of erosion first-hand.**

  Good locations to take your class include:
  - Lake Roosevelt National Recreation Area: nps.gov/laro
  - Dry Falls—once the world's largest waterfall. Interesting article with video from the *Statesman Journal*: statesmanjournal.com/story/travel/outdoors/2018/07/20/sun-lakes-dry-falls-state-park-washington-best-things-do/797006002
  - Many more great locations can be found on an interactive map from the Ice Age Floods Institute: iafi.org/floodscapes.

- **Invite a geologist or amateur rock hound to speak to your class about their work or show a video of a geologist explaining interesting nearby phenomena.**

- o If possible, take your class on a field study with the support of a geologist or passionate amateur who can explain their work and the rocks/natural history of the area.
- o Several interesting Oregon Field Guide videos are listed on the "Take A Virtual Roadtrip Through Oregon's Fascinating Geology" page from Oregon Public Broadcasting (OPB): opb.org/news/article/geology-oregon-thunder-eggs-caves-canyons-waves. "Columbia Gorge Geology Tour" is one of the videos that includes animations of basalt lava flows: opb.org/television/video/orf-2810-02-digi.
- o Experts may be available from the Ice Age Floods Institute, the National Park Service, a local tribe, Univ. of Idaho Ext., WA Dept. of Geology, Oregon State Univ. Ext. Service, the Bureau of Land Management (BLM), etc.

Evaluate

6. **Ask students to draw a large, detailed watershed/erosion model and compare it to an actual watershed. (10 min.)**

   Students should be encouraged to add labels and **annotations** (more detailed explanations of the features of the diagrams).

7. **Ask students to compare their model(s) to your actual watershed in writing. (5 – 10 min.)**

   Ask students to write in science notebooks about how their model(s) were and were not good representations of actual watersheds, such as your own watershed. Encourage students to use the new terminology you introduced.

8. **Lead a closing class discussion about the guiding questions of the lesson, upon which students could also reflect in writing.**

   - How do the processes of erosion and weathering transform our landscapes?
   - How does erosion of sediment impact our watersheds?
   - How are different types of rocks and landforms impacted by erosion?
   - What roles do slope and ground cover play in erosion?
   - How can humans impact the amount of erosion and its effects on landscapes and water quality?

   Record student participation in discussion and thank students for thoughtful contributions.

9. **Instead of, or in addition to an all-class discussion, have students think about and discuss some or all of the questions above as a "Think, Pair, Share" activity.**

   Students can record their ideas in science notebooks.

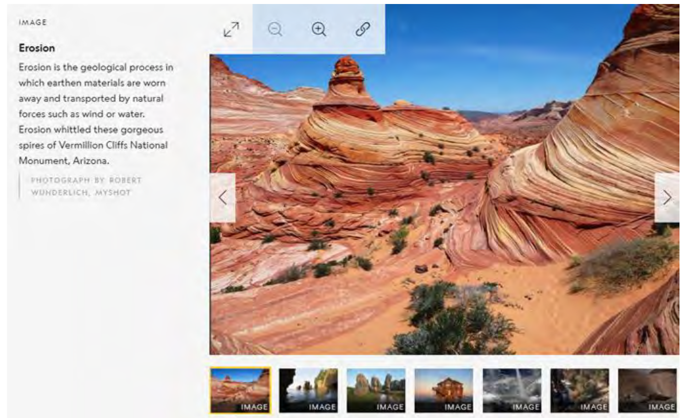
10. **Review student notebooks, completed handouts, and any other projects**.

    Display completed student projects to celebrate their work and teach others about erosion and the other forces that created our landforms.

Expand Knowledge + Skills

Background on Erosion, Weathering, and Watersheds

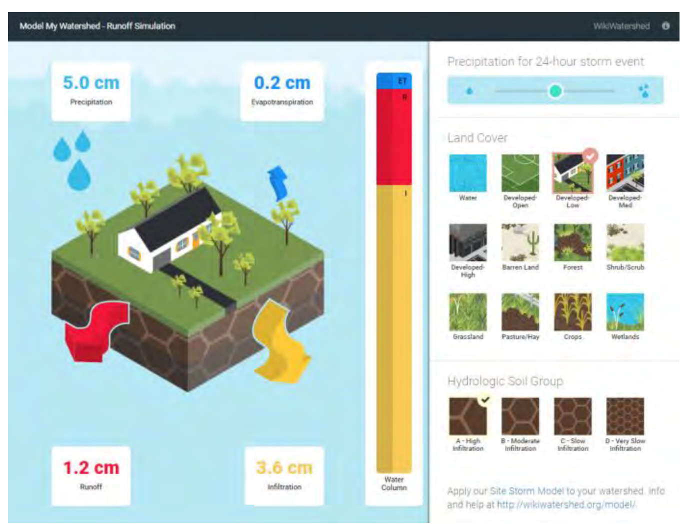
- "Erosion." National Geographic: nationalgeographic.org/encyclopedia/erosion
- "Lesson 1: Watershed Basics." National Environmental Education Foundation (NEEF): neefusa.org/nature/water/lesson-1-watershed-basics
- Lutgens, F., Tarbuck, E., and Tasa, D. (2012). *Essentials of Geology.* Prentice Hall
- Strahler, A.N. & Strahler, A.H. (1989). *Elements of Physical Geography (4th Ed.)*. John Wiley & Sons
- "Watersheds and Drainage Basins" USGS: water.usgs.gov/edu/watershed.html
- "Weathering." National Geographic: nationalgeographic.org/encyclopedia/weathering



"Erosion" from National Geographic is an annotated slideshow. Click the double-headed arrow that appears when you hover over the images to make the slideshow full-screen.

Lessons / Units

- "Earth Camp, Austin, Texas Curriculum." City of Austin Watershed Protection Department: austintexas.gov/sites/default/files/files/Watershed/youth_education/earth-camp/EC-Curriculum-2015.pdf
- "Floods! Erosion by Water." Illinois Mathematics and Science Academy: digitalcommons.imsa.edu/cgi/viewcontent.cgi?article=1001&context=model_ngss_lessons_4_5
- "Investigation 4 – Erosion." Utah Education Network: uen.org/lessonplan/view/9862
- "Model My Watershed – Runoff Simulation." Stroud Water Research Center: runoff.modelmywatershed.org/
- "Think, Pair, Share Cooperative Learning Strategy." TeacherVision: teachervision.com/group-work/think-pair-share-cooperative-learning-strategy
- "Unit 1: Hydrologic Cycle." Julie Monet: serc.carleton.edu/integrate/teaching_materials/energy_and_processes/activity_1.html
- "Unit 2: Fluvial Processes that Shape the Natural Landscape." Julie Monet: serc.carleton.edu/integrate/teaching_materials/energy_and_processes/activity_2.html



Screenshot from "Model My Watershed – Runoff Simulation"

- "Unit 4: Hazards from Flooding." Kyle Gray: serc.carleton.edu/integrate/teaching_materials/energy_and_processes/activity_4.html
- "Watershed Modeling STEM Mini-Unit Teacher Guide." Stroud Water Research Center: 3zlpu231e6hebptt888geo1b-wpengine.netdna-ssl.com/wp-content/uploads/watershed-modeling-mini-unit-teacher-guide.pdf
- "Watersheds and Public Water Systems." Strategic Energy Innovations: energizeschools.org/uploads/1/1/2/6/11264215/sei_watersheds_and_public_water_systems_preview.pdf

Videos

- "Bill Nye the Science Guy – Erosion" (23:05—choose a short clip): schooltube.com/media/Bill+Nye+Erosion/1_3weyaoip
- "Erosion and Preservation of the Water Table." Video and student activity from NPS: nps.gov/media/video/view.htm?id=9FE7B3FF-155D-451F-6752E6F198C11CBD
- "Erosion and Us" (3:12—choose a short clip). NPS: nps.gov/media/video/view.htm?id=6F398C17-F9E8-2131-9ECD15071AB2FFB1
- "Erosion Causing Island in Canada's North to Disappear." CBC News: youtu.be/iXkrS1u5fl8
- "Weathering & Erosion." Generation Genius (produced with NSTA): generationgenius.com/videolessons/weathering-and-erosion-video-for-kids
- "Weathering and Erosion: Crash Course Kids #10.2." youtu.be/R-Iak3Wvh9c
- "Weathering, Erosion, and Deposition." parkcityprep.org/apps/video/watch.jsp?v=172918

Screenshot from the classic "Bill Nye the Science Guy – Erosion"

Standards

- More information about the Next Generation Science Standards, including a link to the *Framework for K-12 Science Education* to which this lesson was aligned: nextgenscience.org/framework-k%E2%80%9312-science-education.
- More information about the Common Core State Standards and links to the complete documents: corestandards.org

Name: ______________________________ Period: ____ Date: ____________________

Watershed/Erosion Models

1. Create a model of a mountain, valley, and streambed with bedrock underneath. →	**2. Draw + Color It!** →		**3. What do you predict will happen when you add "rain"?**
4. Make it "rain" on your mountain. What do you observe about your model now? →	**5. Draw + Color It!** →	**6. Observations** →	**7. What do you predict will happen when it "floods"?**
8. Make it "flood" from rain and snow melt! →	**9. Draw + Color It!** →	**10. Observations** →	**11. Do you think erosion is a good thing, a bad thing, or both? Why?**

Glaciers
Bulldozing Rivers of Ice

Overview

Students explore glaciers, one of the most powerful forces that have shaped our landscapes—and the source of the massive quantities of water and eroded rock that scoured our landscapes during the Ice Age Floods. Options include the creation of hands-on models and stories to help them imagine their massive scale and erosive potential. The lesson is supported by an interactive PowerPoint presentation which you can adapt to best meet the needs of your students. A variety of additional Enrich / Extend activities are listed to help you meet the needs of all learners.

Guiding Questions

- What are glaciers?
- Why and how do glaciers move?
- How do glaciers change our landforms?
- What is the evidence of the Ice Ages? How did they transform the Northwest?
- How do humans impact glaciers?

Like almost all glaciers around the world, those on Mt. Hood are shrinking due to climate change, but still carving the landscape.

Shared via Creative Commons license Sheila Sund on Flickr: flickr.com/photos/23155134@N06/16816011069

Objectives

- Students will create models of glaciers and glacial erosion using ice cubes with embedded rocks and clay or Play-Doh.
- Students will draw and label diagrams of their models and compare them to actual glaciers in writing.
- Students will demonstrate understanding of how glaciers form, flow, and transform the landscape orally and in writing.
- Students will be able to explain the connections between glaciers and other scientific phenomena, like weather and dramatically eroded mountains and other landscapes.

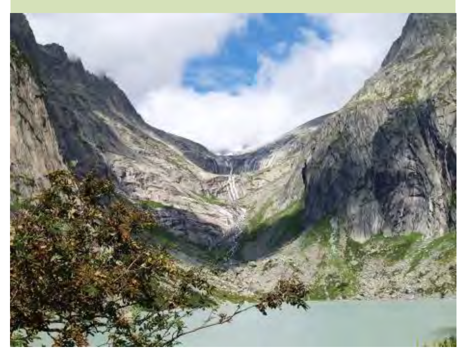
Subjects: Science, Writing, Speaking & Listening, Art, Environmental Education

Grades: Adaptable for K–12

Duration: 50 minutes or more

Vocabulary

- Ablation
- Accumulation
- Boulder
- Climate change
- Elevation
- Erosion
- Flow
- Gas / water vapor
- Glacial erratic
- Glacier
- Gorge
- Gravity
- Ice Age
- Liquid
- Melting
- Model
- Precipitation
- Solid
- Sublimation
- Transport
- Valley



U-shaped valley eroded by glaciers

Image from Pixabay: pixabay.com/photos/glacial-valley-lake-geological-828863

Next Generation Science Standards + Common Core State Standards		
	Performance Expectations We suggest you tailor the lesson to meet the PE(s) for your grade level.	**2-ESS2-2.** Develop a model to represent the shapes and kinds of land and bodies of water in an area. **2-ESS1-1**. Use information from several sources to provide evidence that Earth events can occur quickly or slowly. **4-ESS1-1**. Identify evidence from patterns in rock formations and fossils in rock layers to support an explanation for changes in a landscape over time. **5-ESS2-1**. Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact. **MS-ESS2-2**. Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales. **MS-ESS3-1**. Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes. **HS-ESS2-1**. Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.
	Crosscutting Concepts	• Cause and Effect • Energy and Matter • Patterns • Scale, Proportion, and Quantity • Stability and Change
	Science & Engineering Practices	• Developing and Using Models • Constructing Explanations and Designing Solutions • Engaging in Argument from Evidence • Obtaining, Evaluating, and Communicating Information
	Disciplinary Core Ideas	**ESS1: Earth's Place in the Universe** **ESS2.A: Earth's Materials and Systems** **ESS2.D: Weather and Climate** **ESS3: Earth and Human Activity** (if anthropomorphic climate change and its effect on glaciers s incorporated, as listed in the Enrich / Extend section) **ESS3.D: Global Climate Change** **PS1: Matter and Its Interactions**

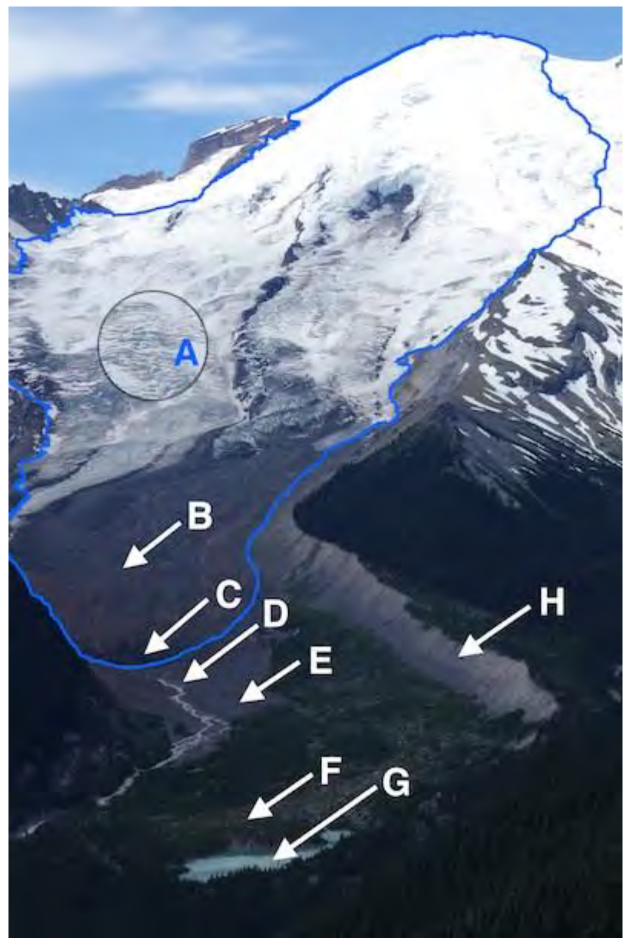
Common Core State Standards English Lang. Arts	**Writing**	4, 10
	Speaking & Listening	1, 2
	Language Standards	1, 2, 3, 6
	Writing Standards Science & Technical Subjects	4, 7, 10
Math CCSS	Math can be incorporated to meet the standards at your grade level and/or to reinforce concepts learned previously. See the Enrich / Extend section for ideas.	

Teacher Background

Glaciers are areas of snow and ice that build up via **precipitation** of **snow** over hundreds or thousands of years. All glaciers **flow** downhill due to the force of **gravity**. The force of gravity compresses the layers of snow into solid ice. It acts like a "brittle solid until the pressure upon it is equivalent to the weight of about 50 meters (165 ft) of ice. Once that load is surpassed ice behaves as a plastic material, and flow begins" (Lutgens, Tarbuck, and Tasa 2012).

Glaciers usually flow very slowly (a few centimeters a day), but some can move much faster (50 m/165 ft or more per day). These "galloping glaciers" occur in areas with more dramatic slope and/or when they are melting more quickly.

Glaciers can be as small as a football field or enormous **ice sheets**, like the Greenland and Antarctic ice sheets. Snow and ice are added to glaciers in the **area of accumulation**, through the process known as **accumulation**. They still cover almost 10% of Earth's land area (mostly in the polar regions) and hold about 69% of all freshwater. Almost all glaciers around the world are **receding** at unprecedented rates due to **climate change**.



Emmons Glacier on Mt. Rainier, Washington: What do you think the letters are marking? Test your hypotheses on the Mt. Rainier NPS site: nps.gov/mora/learn/nature/glacier-features.htm

Glaciers pick up rocks as large as houses as they flow, a process known as **plucking**. The rocks, soil, and debris at the bottom of glaciers grind the land surface like sandpaper through **abrasion** as they flow downhill, transporting the worn away material through the process of **erosion**. (See the previous lesson for more about the other types of erosion.)

Glaciers can also transform the landscape through **deposition**. The material that is picked up can be moved hundreds or thousands of kilometers before it is deposited on the land due to:

- **Melting** (water changing from a solid ice to liquid water in **meltwater streams**) and/or
- **Sublimation** (when ice turns directly into the gas water vapor).
- Ice can also break off into a large water body, such as the ocean or a lake, a process known as **calving**. The complete process of removing surface ice from a glacier via the three methods (melting, sublimation, and calving) is known as **ablation**.

Massive calving in Greenland is shown in this NASA photo. Learn more about the phenomenon and what is happening there:
jpl.nasa.gov/news/news.php?release=2006-023

The **glacial budget** describes the balance between accumulation and ablation of snow and ice—how much the glacier is growing or shrinking. Inputs normally exceed outputs in the upper, mountainous (higher **elevation**) areas of a glacier, while the reverse is generally true in lower elevation areas. The **line of equilibrium** marks the area where inputs and outputs of snow and ice are balanced.

Glacial landforms are those created by the powerful erosional force of glaciers, which act like bulldozers on the land, as well as glacial deposition.

Diagram of an alpine (mountain) glacier

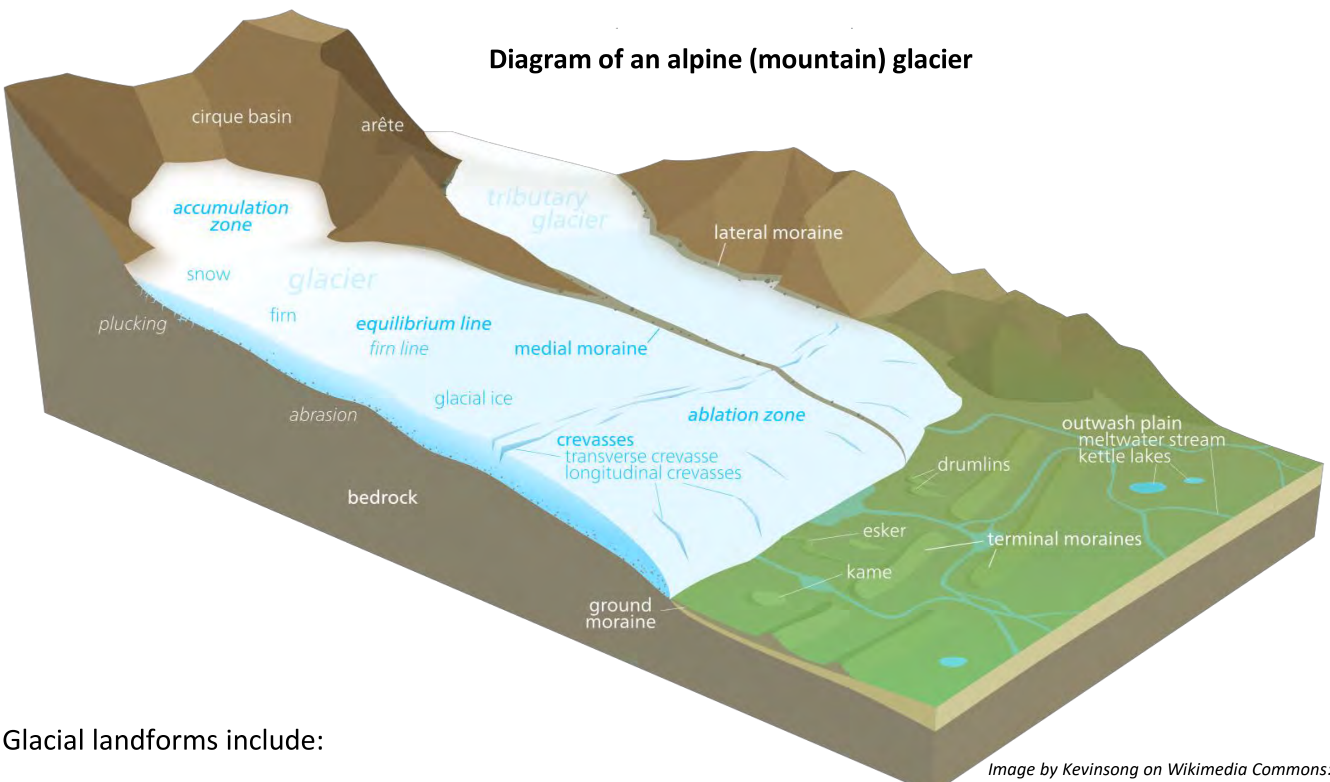


Image by Kevinsong on Wikimedia Commons: *en.wikipedia.org/wiki/File:Glacier_diagram.svg*

Glacial landforms include:

- **U-shaped valleys** with steep walls and flat bottoms (as opposed to V-shaped valleys formed by rivers). The erosive action of glaciers works along the entire valley, which widens it and steepens the walls.

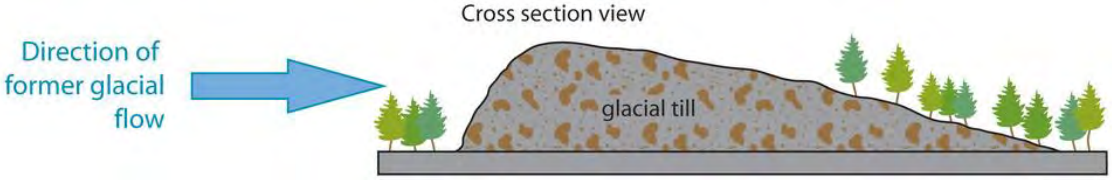
- **Fjords**: Long, U-shaped valleys that are open to the ocean with submerged floors. Long valleys with steep sides carved by glaciers that are not open to the sea are called **troughs**.
- **Glacial erratics**: Boulders left behind by melting glaciers. We can find many of these scattered around our Northwest landscapes.
- **Hanging valleys** are carved by smaller glaciers that flow into a larger glacier, the way a smaller stream can join a river. They appear to hang above the larger valley. Additional details about them are on the NPS website: nps.gov/articles/ushapedvalleysfjordshangingvalleys.htm.
- **Moraines** are rocks and dirt that have been moved and deposited by a glacier. Learn more and view a diagram of different types: nsidc.org/cryosphere/glaciers/gallery/moraines.html
- **Drumlins** are "…teardrop-shaped hills of rock, sand, and gravel that formed under moving glacier ice. They can be up to 2 kilometers (1.25 miles) long." Learn more: nsidc.org/cryosphere/glaciers/gallery/drumlins.html

Bidalveil Fall is a hanging valley in Yosemite National Park.

NPS: nps.gov/articles/ushapedvalleysfjordshangingvalleys.htm

Pixabay: pixabay.com/photos/backpacker-hiking-glacial-moraine-2052867

Diagram of a drumlin
Cross section view



NSIDC: nsidc.org/cryosphere/glaciers/gallery/drumlins.html

- **Grooves and striations** are carved into bedrock by boulders and rocks dragged along by glaciers: nsidc.org/cryosphere/glaciers/gallery/grooves.html
- **Chatter marks** are "gauges chipped out of bedrock" by rocks dragged on the bottom of glaciers: nsidc.org/cryosphere/glaciers/gallery/chattermarks.html.

Virginia Hill, NSIDC: nsidc.org/cryosphere/glaciers/gallery/grooves.html

- An **arête** is a "thin, crest of rock left after two adjacent glaciers have worn a steep ridge into the rock." Learn more: nsidc.org/cryosphere/glaciers/gallery/aretes.html
- A **horn** (like the famous Matterhorn) is created when "glaciers erode three or more arêtes, usually forming a sharp-edged peak."
- **Cirques** are "concave, circular basins carved by the base of a glacier as it erodes the landscape." Images of a cirque and the Matterhorn are at nsidc.org/cryosphere/glaciers/gallery/aretes.html.

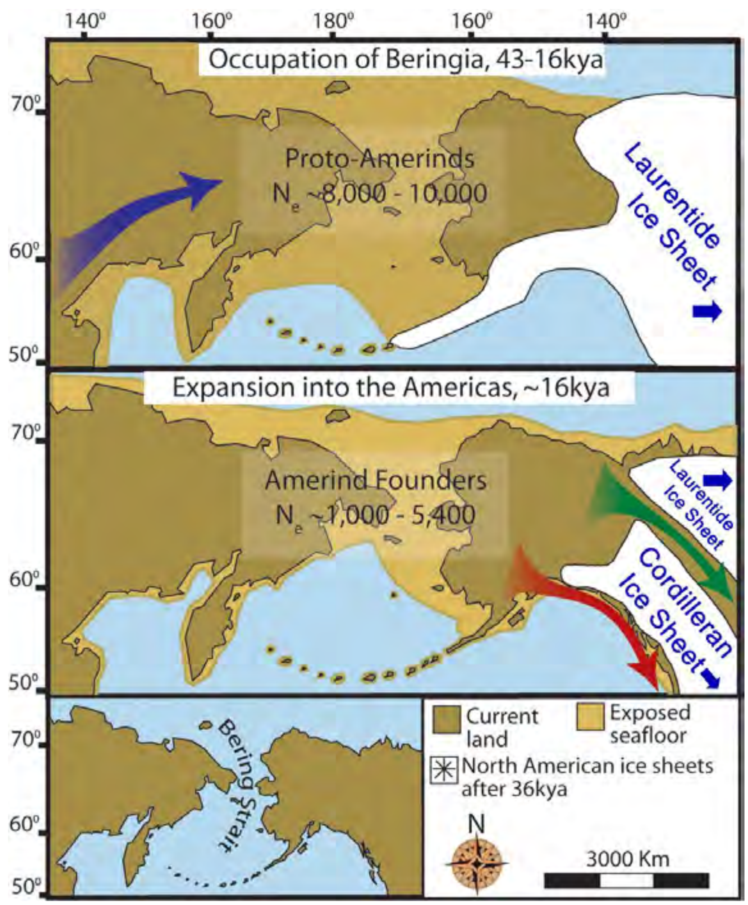
Glacier National Park's "Garden Wall" is made up of steep arêtes carved by glaciers.
NPS: nsidc.org/cryosphere/glaciers/gallery/aretes.html

Ice Ages

Earth's climate fluctuates over time and has resulted in long cool periods dominated by massive glaciers sometimes more than two miles (3 km) thick covering significant portions of the globe. Known as ice ages, the last long stretch of them (interspersed with warmer **interglacial** periods) began around 2.6 million years ago at the start of the **Pleistocene Epoch**. The climate began to cool at that time and led to the formation of large continental ice sheets, including the **Cordilleran Ice Sheet** that covered much of present-day Western Canada and the northwestern U.S. The Pleistocene continued until the end of the Last Glacial Period about 11,700 years ago, when the warmer interglacial period we are now living in began.

Effects of the Ice Ages on the Landscape

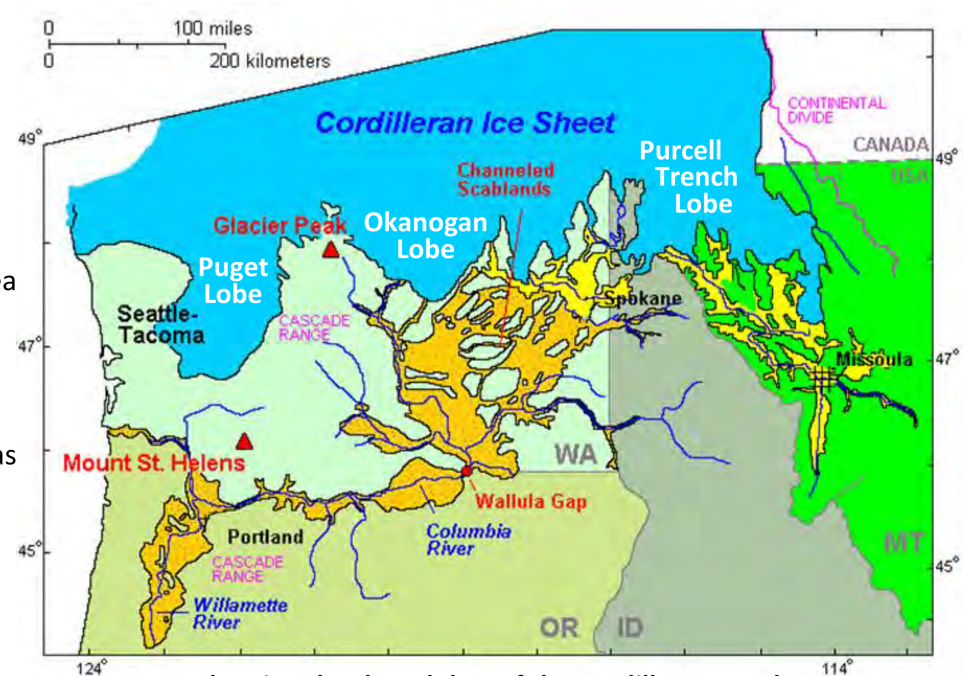
The Cordilleran Ice Sheet descended towards the Pacific Northwest of the United States and created ideal conditions for the catastrophic floods which shaped Northwest landscapes. In Canada, the ice carved the topography—scraping and grinding the original mountains into dust. This dust, known as **loess**, was carried by winds and rain and deposited over much of the inland Pacific Northwest as fine sediment. Many modern-day wheat fields in Washington sit atop these massive loess deposits.



A gap opened between the Cordilleran and Laurentide Ice Sheets about 13,000 years ago that allowed Clovis peoples to walk south into North and South America (green arrow). Recent evidence supports the theory that pre-Clovis hunters migrated south along a coastal route at least 15,000 years ago (red arrow).
Adapted from a Creative Commons image and research article on PLOS ONE:
journals.plos.org/plosone/article/figure?id=10.1371/journ

During periods of the furthest ice extent, three major lobes of the Cordilleran Ice Sheet extended into the United States.

- The **Puget Lobe**, which extended over Puget Sound and Seattle, covered the area in 3,000 feet of ice.
- To the east of the Cascades, the **Okanogan Lobe** in the Okanogan Valley extended as far south as Dry Falls, Washington.
- In the Idaho panhandle, the **Purcell Trench Lobe** carved Lake Pend Oreille into the landscape.



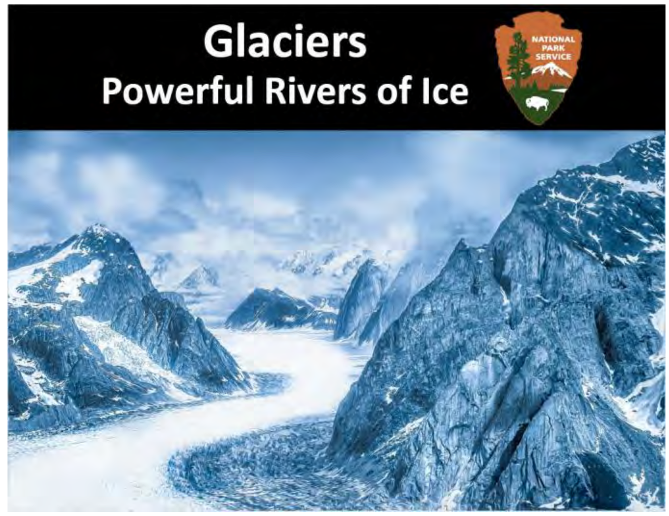
Map showing the three lobes of the Cordilleran Ice Sheet. The areas of the Ice Age Floods are shown in orange and yellow.
Adapted from a Wikimedia Commons image from USGS data: *commons.wikimedia.org/wiki/File:Map_missoula_floods.gif*

Materials + Preparation

- **For the "Glacial Erosion Models" activity you'll need these (or similar) for each model:**
  - A baking sheet or plate
  - Soft clay or Play-Doh to model "bedrock" on the sheet
  - "Glaciers": Ice cubes with small rocks and/or sand (added to the water before freezing for 24 hours to ensure completely frozen); plastic cups with ice can be used instead of ice cube trays
  - Model soil/loose rock: Loose dry sand and small rocks in a small container; any flour to model soil and loose rocks covering the "bedrock"
  - Copies of the "Glaciers: Rivers of Ice" handout for each student found at the end of the lesson and/or science notebooks for students to record predictions and observations
  - *Optional:* A drop or two of blue food coloring can be added to the ice

Any-size baking sheet, pan, or plate will work as a foundation for the "Glacial Erosion Models"

- **Prepare to show the "Glaciers: Bulldozing Rivers of Ice" PowerPoint presentation as an interactive, phenomenon-based visual aide**; feel free to adapt for your students
- Data projector and computer
- Access to Internet and/or library for research
- *Optional:* Review the sources and watch the videos listed at the end of the lesson for additional background information. You could also share one or more of the videos with your students and discuss them.



Teaching Suggestions in the 5E Model

Engage

1. **Options to engage students with scientific phenomena, activate prior knowledge, and stimulate critical thinking** (2–20 min.)
   - **Pose a question and/or tell a hypothetical story to help students think about how glaciers are formed and act on the land.** (2 – 5 min.)
     - You might say, "Imagine that you live in a rocky, mountainous area. What would happen if the climate changed so that it became cold enough for most of our **precipitation** to fall as snow? It never gets warm enough each year to melt all the snow for thousands of years. What would happen to the snow, and how might this change lead to other changes to the land over thousands of years?"
     - Give the students a minute or two to think about it and jot down their ideas in science notebooks in words and pictures. Then they can turn to a partner to share their ideas and record any others they brainstorm in their notebooks.
     - After a minute or two, ask the groups to share their best ideas and discuss as a class.
   - **Students create models of glaciers.**
     - Take the ice cubes with frozen rocks out of the freezer about 10 minutes before you start the activity to let them warm up and melt a bit. Show the ice cube trays (or plastic cups with ice) to students when you are ready to start; tell them that the ice represents snow that didn't melt, year after year, for thousands of years. The weight of all the snow piling up smashed the snowflakes and now they are solid ice more than TWO MILES (THREE KILOMETERS) THICK, which is how thick some of these huge areas of ice—called **glaciers**—got during the Last Glacial Period. Ask them to imagine ice above us that stretches higher than the top of Mt. Hood (if you are near a different mountain, you might say more than twice as high a mountain near you, etc.).

- Pass out baking sheets or plates with a piece of clay or Play-Doh at least the size of your fist to groups of 3–5 students. Ask them to spread it out on the bottom of the plate or pan to create a model of land with a mountain and a valley with a riverbed. It will be similar to the model they made in the last lesson, but at a smaller scale, and it doesn't need to cover the bottom of the plate or tray.
- While the students work, pass out dry sand and/or small rocks in small containers to the groups. Tell them that they can integrate sand and rocks into their models; the surface of the ground may be loose soil, so they can add a dusting of sand to represent it. There can also be hard rock under the soil, called bedrock, so they can place some small rocks into the clay to represent bedrock. The rocks can stick above the surface of the clay or be hidden in it with sand on top. The exposed areas represent exposed rock and loose boulders.
- Circulate through the groups to answer questions—and ask them—to clarify understanding. Once they have their models set up, check to make sure that there is a "mountain" with sand/rock and a valley with a streambed. Give students a warning a minute or two before they will have to stop working on their models.
- While students finish their models, dump out the ice cubes into a bowl and walk around to the groups to hand them one of the cubes. Tell them that snow has been accumulating on their mountain for over a thousand years, and now it is a MASSIVE glacier, represented by the ice cube. Give the cube to the group and ask them to add it to their models where the snow and ice will have been accumulating the most. Discuss how that should be high up on their mountain, where it is usually coldest.

- **Show a short video clip of a glacier and discuss the phenomenon.** (2 – 5 min.) Consider turning the sound off to encourage students to think about the phenomenon rather than have it explained to them. You might choose a short clip to show at this point, then show the rest during the Explain portion of the lesson. Options include:

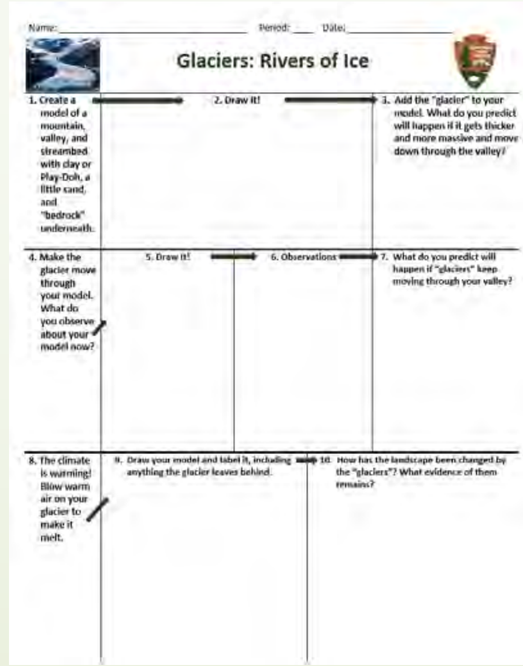
  - "How Do Glaciers Move?" (7:03) PBS: youtu.be/RnlPrdMoQ1Y
  - "Yosemite Nature Notes 12: Glaciers" (8:32). NPS: nps.gov/media/video/view.htm?id=025615A1-1DD8-B71B-0B94871F3814C7E3

Then ask students to discuss with a partner what effects they think glaciers have on our landforms. They can record their ideas in science notebooks.

Explore

2. Students experiment with flowing "glaciers." (5–7 min.)

- Ask students to create glacier models as described above if they have not yet done so.
- Pass out copies of the "Glaciers: Rivers of Ice" activity sheet for each student found at the end of the lesson, or students can take out their science notebooks to record predictions and observations. Explain that they should draw a simple sketch of their model.
- Ask students to predict what will happen if the "glacier" keeps getting more massive and moves down through the "valley" of their model. They should record their ideas on the activity sheet or in science notebooks, then they can let go of the ice to let it slide down the mountain, lifting one side of the plate or pan slightly to help it move. What force makes it move? (It flows downhill slowly because of gravity, just like real glaciers). Then they can move the cube back up to the mountain again; what happens to it and the ground as they push the "glacier" through the model firmly with their hand? They should push down on it as it moves, imagining it is massive and heavy like a real glacier. They should then record the results of their experiment on the activity sheet and/or in science notebooks.
- They can run the experiment a few more times, moving the ice through the model from the top of the mountain, through the "valley," to the edge of the model. Observations should be recorded on the activity sheet or in their notebooks.
- Circulate to answer any questions. When the groups are mostly finished recording their observations, tell them that the climate is warming, like the way it did at the end of the Last Glacial Period that ended about 11,700 years ago. They can blow warm air on their "glaciers" and/or make it rain on them (by adding water) to make them melt. Then they can draw and label their models, including anything the glacier leaves behind. They should also describe in writing how the landscape has been changed by the "glaciers," including the evidence of glaciers that remains.


Name: ______ Period: ___ Date: ______

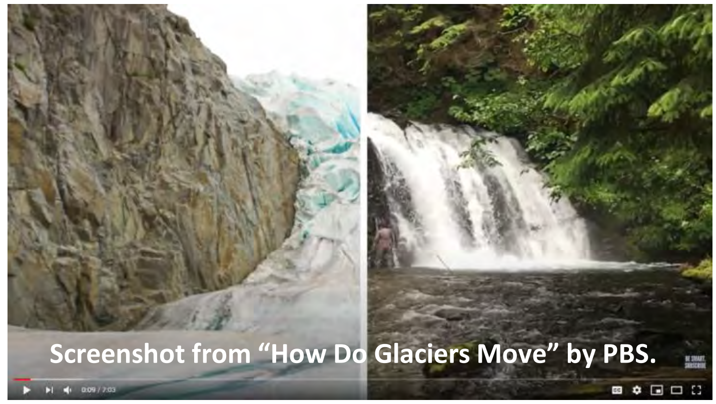
Glaciers: Rivers of Ice

1. Create a model of a mountain, valley, and streambed with clay or Play-Doh, a little sand, and "bedrock" underneath.
2. Draw it!
3. Add the "glacier" to your model. What do you predict will happen if it gets thicker and more massive and move down through the valley?
4. Make the glacier move through your model. What do you observe about your model now?
5. Draw it!
6. Observations
7. What do you predict will happen if "glaciers" keep moving through your valley?
8. The climate is warming! Blow warm air on your glacier to make it melt.
9. Draw your model and label it, including anything the glacier leaves behind.
10. How has the landscape been changed by the "glaciers"? What evidence of them remains?

Explain

3. Discuss glaciers and how they move. (5 – 10 min.)

- This can first be done as a think-pair-share activity before discussing it as a group with the support of the "Glaciers: Bulldozing Rivers of Ice" PowerPoint presentation as an interactive visual aide. You might choose to show and discuss a short video to help explain the concepts, too, such as "How Do Glaciers Move?" (7:03) from PBS: youtu.be/RnlPrdMoQ1Y.

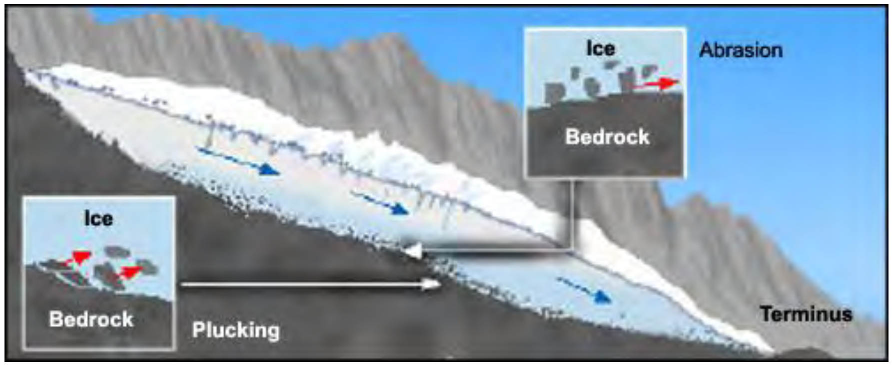


Screenshot from "How Do Glaciers Move" by PBS.

- Write (or point to) the word "**glacier**" on the board and explain that it comes from the French word for ice—*glace* (derived from the Latin). Discuss how it is what the student models represent: an accumulation of snow and ice that flows downhill from the force of **gravity**.
- Discuss the activity with questions such as those below and visuals from the presentation. Adjust the amount of terminology you use/introduce based on the level and prior knowledge of your students.
  - Is what happened to your landscapes what you predicted?
  - What did the "glaciers" do to your "valley" and why? (It should have made the bottom of the valley flatter, and wider, with steeper sides, the way real glaciers do. Explain how glacial valleys are called **U-shaped valleys** and write the term on the board. Ask the students to discuss how they got their name. Then ask them to compare the shape to a valley carved by a river. They should discuss with their group and think of a letter of the alphabet that might describe the shape of a valley created by flowing water. Discuss how and why these are called **V-shaped valleys**. (Their erosive force is usually concentrated in the bottom of the valley, cutting deeper year after year, whereas glaciers tend to erode a wider area, because of their height and their sand paper-like bottom and sides).

U-shaped valley carved out by glaciers shown in the "Glaciers: Rivers of Ice" presentation.
Pixabay: pixabay.com/photos/glacial-valley-lake-geological-828863

- What happened to the "soil," "boulders," and "bedrock" represented by the sand and rocks? (They should have been picked up and carried along by the glacier, similar to how a bulldozer would move them. Explain that this is called **plucking**. Write the term on the board and discuss how it is a type of erosion like the other types you explored in the last class.



Plucking: Glaciers as bulldozers
Learn more about this and other phenomena on NPS' "How Glaciers Change the Landscape" page: nps.gov/articles/howglacierchangethelandscape.htm

- What happened to the height of the mountain? (It got shorter as the ice with rock and sand on the bottom rubbed it away like sandpaper, as glaciers do with real mountains.)
- Did they make any other observations about the "land" after the "glaciers" moved through? (They may have noticed lines cut into the clay, like the **striations** found in formerly glaciated landscapes, or lines of sand that were piled up, like **moraines**. You might incorporate more concepts into the discussion from the Teacher Background section and the additional sources at the end of the lesson, depending on the level of your students. In addition to other glacial landforms, you might discuss other ways glaciers and ice cause erosion, such as **freeze-thaw weathering**: ice freezing in cracks, which expands and can break off rock. You might have students research other interesting glacial land forms, as well, and present what they learned through a variety of projects as explain in the Enrich / Extend section.
- What happened when the climate got warmer? What evidence of the glaciers remained? (There were rocks left behind—like the random boulders, known as **glacial erratics,** we find scattered around our Northwest landscapes.) Write the term on the board with a quick sketch of a couple erratics like those you might find in your area.

Yeager Rock, Washington: a house-sized erratic resting on a moraine
Wikimedia Commons: *commons.wikimedia.org/wiki/Glacial_erratic#/media/File:Yeager-Rock-Erractic-PB110039.JPG*

- Draw a quick model on the board which helps explain visually how some solid ice also changes directly into the gas **water vapor** in the process known as **sublimation**.
- Relate the crosscutting concept of cause and effect into your discussion, and how glaciers, like liquid water, travel via the path of least resistance and settle in areas of lower elevations relative to the system in which it moves. Students can discuss and/or

experiment with other ways in which the force of gravity can act on water as both a solid and liquid to **erode** and **transport** materials from areas of high potential energy (those that are steep) and low energy (those that are flat).

  - Discuss the movement of **sediment** as it relates to their models and actual glacial areas. For example, explain how powdery **loess** was created by glaciers that eroded mountains; loess makes up much of the soil upon which Northwest wheat farmers depend.
- Ask students to point out these features on their models as you discuss them, and they can draw and label them in their science notebooks and/or on their activity sheets.

Loess covers the rolling fertile farmlands of the Palouse Hills, NE of Walla Walla

Wikimedia Commons:
commons.wikimedia.org/wiki/File:Palouse_hills_northeast_of_Walla_Walla.jpg

- Tell students that erosion can occur because of human activities, as well. Ask, "What human activities can cause erosion?" Discuss some of the ways, such as construction sites that disturb the ground, clearcutting of forests, and overgrazing by livestock (such as cows and sheep).
- The PowerPoint can also be used as a review game at the end of the lesson or at a future date. Ask students to get into pairs or small groups and record answers to the questions on screen before you show the answers. You can add additional questions by duplicating the slides in the Slide Sorter.

Extend / Enrich

- **Ask students to create short research projects, videos, skits, labeled dioramas, etc. about the different types of glacial landforms and how they were created.**
  - Giving students a choice of the type of project they do and encouraging them to be creative maximizes their intrinsic motivation. This will also result in a variety of different types of projects that will be more interesting for the other students and you to learn from.
  - They can make short presentations to the rest of the class about them with photographs and/or illustrations. Ideally, these would be photographs they took of nearby landforms and/or illustrations they created.
  - They could also create short videos and/or humorous skits about the landforms and how they were created.
- **View more short videos about glaciers, or give students choices of them to watch with a partner, recording notes in science notebooks in words and pictures. You might use the opportunity to discuss climate change, how the Earth's glaciers are melting, and what we might do to reverse the trend.** Options include:
  - "Why Bill Nye Wants You to Care About Melting Glaciers" (5:50): labroots.com/trending/videos/10047/why-bill-nye-wants-you-care-about-melting-glaciers

- "Photo Evidence: Glacier National Park is Melting." National Geographic: youtu.be/ur4I8tYnxP4

- "Glaciers Lost in Time." Nature: youtu.be/cKxLtnIYjBk. Supporting article "180,000 Forgotten Photos Reveal the Future of Greenland's Ice" here: nature.com/news/180-000-forgotten-photos-reveal-the-future-of-greenland-s-ice-1.20335
- "How Do Glaciers Shape the Landscape?" (2:30): youtu.be/loI584OFVpE
- "Glaciers with Chocolate" (5:52). MIT K12 Videos: youtu.be/wK-SQD3fhrI

- **Connect the lesson with physical science by exploring the albedo effect (reflectivity) and how melting glaciers and sea ice are creating a feedback loop leading to more warming in Earth's system.**

  The "Albedo, Melting Ice, and Feedback Loops" lesson plan from the Bay Area E-STEM Institute (BAESI) is a good place to start: baesi.org/albedo-melting-ice-and-feedback-loops-lesson-plan. The lesson integrates physical science with Earth science and climate change. More lessons in the series are at baesi.org/teaching-climate-change-earth-science-with-other-sciences.

- **Another way to connect the lesson with physical science is through an exploration of how glaciers and sea ice affect Earth's energy budget.** This can incorporate concepts such as the electromagnetic spectrum, wavelengths, and energy transfer. "Earth's Delicate Energy Balance" lesson from the California Academy of Sciences also includes a good video and still images: calacademy.org/educators/earths-delicate-energy-balance

- **Connect the lesson with life science by asking students to brainstorm and research ways different animal species and ancestors of modern humans may have been impacted by spreading and retreating glaciers.**

- **Read fictional and/or non-fiction books that help teach about glaciers.** Options include:
  - *How Glaciers Shaped Earth* by Jane P. Gardner: books.google.com/books/about/How_Glaciers_Shaped_Earth.html?id=GJ6AxAEACAAJ
  - *Mighty Glaciers* (with free supporting resources): raz-kids.com/main/BookDetail/id/68/from/quizroom/languageId/1
  - *Real World Math: Glaciers* by Barbara A. Somervill: getepic.com/book/12525416/real-world-math-glaciers

- **Take the students on a field study to observe the effects of glacial erosion first-hand.**
  - Great locations can be found on an interactive map from the Ice Age Floods Institute: iafi.org/floodscapes. You can reach out to experts from your local chapter with questions: iafi.org/local-chapters.

- Lake Roosevelt National Recreation Area is one good option for field studies: nps.gov/laro. Bring binoculars to better observe the glacial geologic features if you have them!

- **Invite a geologist or amateur ice age expert to speak to your class about their work or show a video of a geologist explaining interesting nearby phenomena caused by glaciers.**
  - If possible, take your class on a field study with the support of a geologist or passionate amateur who can explain their work and the rocks/natural history of the area.
  - Experts may be available from the Ice Age Floods Institute, the National Park Service, a local tribe, Univ. of Idaho Ext., WA Dept. of Geology, Oregon State Univ. Ext. Service, the Bureau of Land Management (BLM), etc.

Evaluate

4. **Ask students to draw a large, detailed model of glacial erosion and how it can transform landscapes. (10 min.)**

   Encourage students to add labels and **annotations** (more detailed explanations of the features of the diagrams).

5. **Ask students to compare their model(s) to actual glaciers and glacial landforms in writing. (5 – 10 min.)**

   Ask students to write in science notebooks about how their model(s) were and were not good representations of actual glaciers found in the world today, as well as the massive ones from the Last Glacial Period. Encourage students to use the new terminology you discussed.

6. **Lead a closing class discussion about the guiding questions of the lesson, upon which students could also reflect in writing.**
   - What are glaciers?
   - Why and how do glaciers move?
   - How do glaciers change our landforms?
   - What is the evidence of the Ice Ages? How did they transform our area?
   - How can humans impact glaciers?

   Record student participation in discussion and thank students for thoughtful contributions.

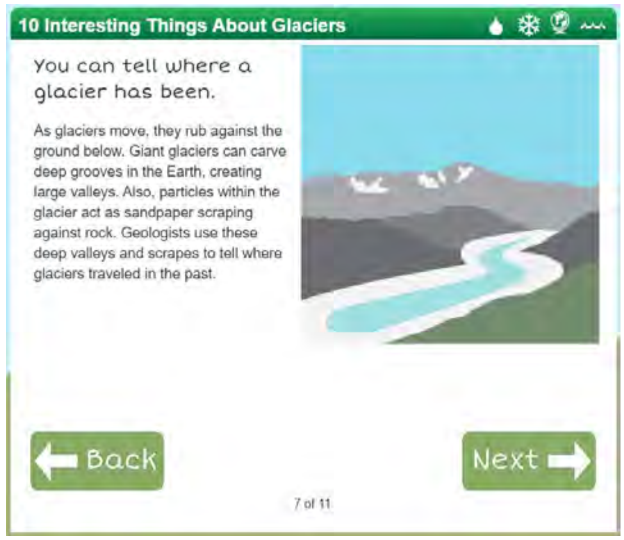
7. **Have students reflect on how glacial erosion and other types of erosion have transformed our landforms over time.**
   - This can be done orally with a partner and/or the whole class, as well as in writing in science notebooks and/or on their activity sheets. You may also ask students to reflect on how eroded materials become part of soil, how they can help plants, and/or how they can impact water quality for wildlife and humans in rivers and streams.

- This should include a discussion of the negative aspects of erosion, as well as the positive, so you might ask students to use a graphic organizer to help them analyze which aspects are positive, which are negative, and which impacts can be both positive and negative. A Venn diagram is one good tool for this purpose. You might show a video to help students better understand the negative impacts of erosion, such as "Soil Erosion Round the World – Causes and Solutions." DW News: youtu.be/s0F2c1ECuo4

8. **Review student notebooks, completed handouts, and any other projects**.

   Display completed student projects to celebrate their work and teach others about erosion and the other forces that created our landforms.

Expand Knowledge + Skills



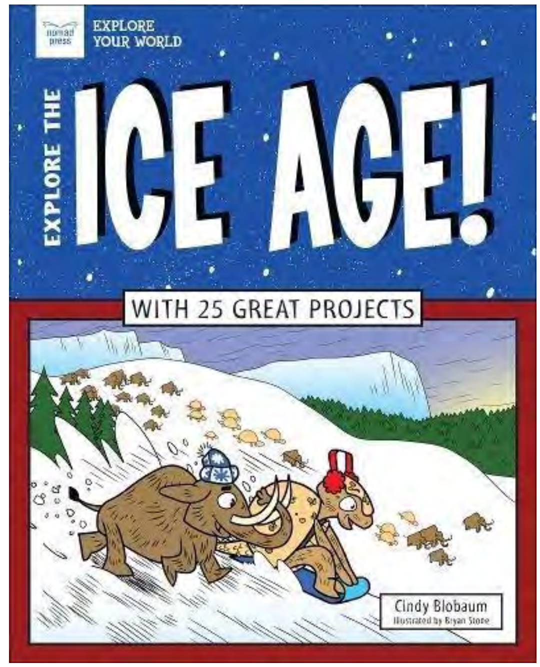
Screenshot of one of the animations in "10 Interesting Things About Glaciers." NASA: climatekids.nasa.gov/10-things-glaciers

Background on Glaciers + Last Ice Age

- "10 Interesting Things About Glaciers." NASA: climatekids.nasa.gov/10-things-glaciers
- "Glacier." National Geographic: nationalgeographic.org/encyclopedia/glacier
- "Glacier Landforms: Erratics." National Snow & Ice Data Center: nsidc.org/cryosphere/glaciers/gallery/erratics.html
- "Glacier Landforms: Moraines." National Snow & Ice Data Center: nsidc.org/cryosphere/glaciers/gallery/moraines.html
- "Glaciers." NE Geology Kids: onegeology.org/extra/kids/earthprocesses/glaciers.html
- "Glaciers and Glacial Landforms." NPS: nps.gov/subjects/geology/glacial-landforms.htm
- "How Did the Ice Age End?" American Museum of Natural History: amnh.org/explore/ology/earth/ask-a-scientist-about-our-environment/how-did-the-ice-age-end
- "How Do Glaciers Affect Land?" National Snow & Ice Data Center: nsidc.org/cryosphere/glaciers/questions/land.html
- "Illustrated Glossary of Alpine Landforms." Virtual Geography Department Project: www4.uwsp.edu/geo/faculty/lemke/alpine_glacial_glossary/index.html
- "The Life of a Glacier." National Snow & Ice Data Center: nsidc.org/cryosphere/glaciers/life-glacier.html

- Lutgens, F., Tarbuck, E., and Tasa, D. (2012). *Essentials of Geology (11th Ed.)*. Prentice Hall.
- Strahler, A.N. & Strahler, A.H. (1989). *Elements of Physical Geography (4th Ed.)*. John Wiley & Sons.
- "Washington's Glacial Geology." WA State Dept. of Natural Resources: dnr.wa.gov/programs-and-services/geology/glaciers

Lessons / Units



- Blobaum, C. (2017). "Explore the Ice Age! With 25 Great Projects" Nomad Press: nomadpress.net/nomadpress-books/ice-age
- The glacier modeling activity in the lesson was inspired by:
  - "Ice in Action" from Montana State Univ. Ext. Service: montana.edu/everest/resources/documents/lesson05/Lesson05_Ice_in_Action.pdf
  - "Make a Mini-Glacier!" Kid's Crossing. National Center for Atmospheric Research: eo.ucar.edu/kids/wwe/ice4.htm
- "Glaciers Then and Now." UCAR Center for Science Education: scied.ucar.edu/activity/%EF%BB%BFglaciers-then-and-now
- "Google Earth Tours of Glacier Change." Mauri Pelto: serc.carleton.edu/NAGTWorkshops/climatechange/activities/21214.html
- "Rock Paper Glacier." rockpaperglacier.wordpress.com/glacier-basics-for-kids/glacier-activities

Videos

- "All About Glaciers for Kids: How Glaciers Form and Erode to Create Landforms." Free School: youtu.be/qqsTS67BKmA
- "Glaciers Lost in Time." Nature: youtu.be/cKxLtnIYjBk. Supporting article "180,000 Forgotten Photos Reveal the Future of Greenland's Ice" here: nature.com/news/180-000-forgotten-photos-reveal-the-future-of-greenland-s-ice-1.20335
- "Glaciers with Chocolate" (5:52). MITK12Videos: youtu.be/wK-SQD3fhrI
- "How Do Glaciers Move?" (7:03). PBS: youtu.be/RnlPrdMoQ1Y

- “How Do Glaciers Shape the Landscape?” (2:30): youtu.be/loI584OFVpE
- “Massive Glacier Calvings Caught on Camera” (25:00). Some are icebergs—choose a clip of glaciers to show to your students, such as the one starting at 9:47: youtu.be/u3q3g996cHk
- “Visiting the Most Vulnerable Place on Earth: The 'Doomsday Glacier” (9:09). PBS: youtu.be/UQ782Nz2VHs
- “Why Bill Nye Wants You to Care About Melting Glaciers” (5:50): labroots.com/trending/videos/10047/why-bill-nye-wants-you-care-about-melting-glaciers
- “Yosemite Nature Notes 12: Glaciers” (8:32—you might choose a short clip to show). NPS: nps.gov/media/video/view.htm?id=025615A1-1DD8-B71B-0B94871F3814C7E3
- More short videos on NeoK12: neok12.com/Glaciers.htm

Articles (non-fiction reading for students and additional background)

- “Are Greenland’s Galloping Glaciers Slowing Down?” National Snow & Ice Data Center (NSIDC): nsidc.org/cryosphere/icelights/2013/06/are-greenland%E2%80%99s-galloping-glaciers-slowing-down
- Brawlower, T. & Bice, D. “Ancient Climate Events: Pleistocene Glaciation.” Penn State College of Earth and Mineral Sciences: e-education.psu.edu/earth103/node/636
- Daley, J. (2016). “First Humans Entered the Americas Along the Coast, Not Through the Ice.” *Smithsonian:* smithsonianmag.com/smart-news/humans-colonized-americas-along-coast-not-through-ice-180960103
- “The First Americans.” (2012). *Scientific American:* scientificamerican.com/article/the-first-americans
- Lindsey, R. (2020). “Climate Change: Glacier Mass Balance.” Climate.gov. NOAA: climate.gov/news-features/understanding-climate/climate-change-glacier-mass-balance
- Mann, C. (2013). “The Clovis Point and the Discovery of America’s First Culture.” *Smithsonian:* smithsonianmag.com/history/the-clovis-point-and-the-discovery-of-americas-first-culture-3825828

Standards

- More information about the Next Generation Science Standards, including a link to the *Framework for K-12 Science Education* to which this lesson was aligned: nextgenscience.org/framework-k%E2%80%9312-science-education.
- More information about the Common Core State Standards and links to the complete documents: corestandards.org

Name: ____________________________________ Period: ____ Date: ____________________

Glaciers: Rivers of Ice

1. Create a model of a mountain, valley, and streambed with clay or Play-Doh, a little sand, and "bedrock" underneath.

2. Draw It!

3. Add the "glacier" to your model. What do you predict will happen if it gets thicker and more massive and move down through the valley?

4. Make the glacier move through your model. What do you observe about your model now?

5. Draw It!

6. Observations

7. What do you predict will happen if "glaciers" keep moving through your valley?

8. The climate is warming! Blow warm air on your glacier to make it melt.

9. Draw your model and label it, including anything the glacier leaves behind.

10. How has the landscape been changed by the "glaciers"? What evidence of them remains?

Theories + Stories of Northwest Landforms

Subjects: Science, Writing, Speaking & Listening, Art, Environmental Education

Grades: Adaptable for K–12

Duration: 50 minutes or more

Vocabulary

- Catastrophism
- Columbia River Gorge
- Coulee
- Elder
- Grand Coulee
- Traditional / tradition
- Uniformitarianism

Overview

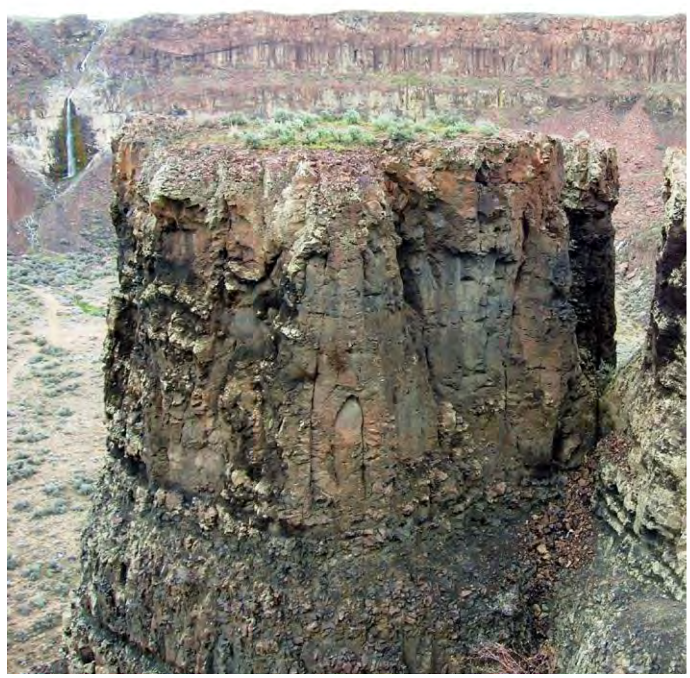
This lesson presents students with mysterious images of—or an experience visiting—dramatic Northwest landscapes and asks them to hypothesize about their origins. Working in teams, they use their observation skills, what they know about rocks, erosion, and glaciers, and readings about scientific theories and Northwest Native American stories passed down from generation to generation to help them formulate their own hypotheses. (For emerging readers, you might tell them about the theories and share stories orally.) Then they record their ideas about the theories and stories in writing and create labeled diagrams that explain what they think created the dramatic NW landforms. Groups present their ideas and labeled diagrams to the class and discuss which theory—catastrophism, uniformitarianism, or both—best explains our awe-inspiring landforms of coulees, the Columbia River Gorge, etc.

Guiding Questions

- What are the theories and stories about how our dramatic Northwest landforms were created?
- What are catastrophism and uniformitarianism?
- What are the human connections to our landforms?

Objectives

- Students will hypothesize about what caused the dramatic landforms of the Northwest, including coulees, the Columbia River Gorge, far-flung erratics, and giant ripples.
- Students will read about and reflect on the theories of catastrophism and uniformitarianism, as well as Native American stories about floods and the creation of Northwest landforms.
- Students will create labeled models of Northwest landforms that explain their ideas about how they were created.
- Students will present their theories and models to the class and discuss whether they think catastrophism, uniformitarianism, or both were responsible for Northwest landforms and why.



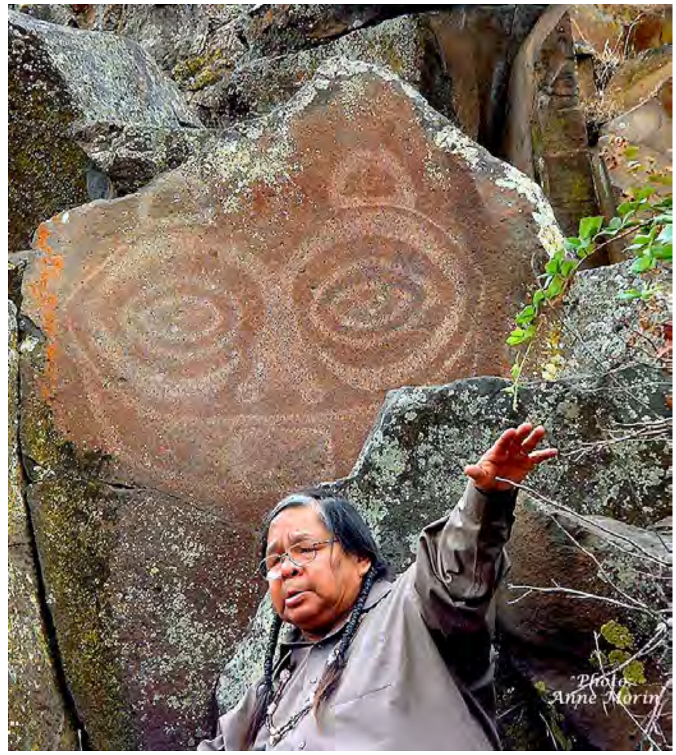
Basalt columns created by cooling lava; they were eroded by the Ice Age Floods, but keep that a mystery for now.

"Cliff near Vantage, Washington" Creative Commons: flickr.com/photos/brewbooks/372907487

Next Generation Science Standards + Common Core State Standards		
	Performance Expectations We suggest you tailor the lesson to meet the PE(s) for your grade level.	**2-ESS1-1**. Use information from several sources to provide evidence that Earth events can occur quickly or slowly. **4-ESS1-1**. Identify evidence from patterns in rock formations and fossils in rock layers to support an explanation for changes in a landscape over time. **5-ESS2-1**. Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact. **MS-ESS2-2**. Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales. **MS-ESS3-1**. Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes. **HS-ESS2-1**. Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.
	Crosscutting Concepts	• Cause and Effect • Energy and Matter • Patterns • Scale, Proportion, and Quantity • Stability and Change
	Science & Engineering Practices	• Developing and Using Models • Constructing Explanations and Designing Solutions • Engaging in Argument from Evidence • Obtaining, Evaluating, and Communicating Information
	Disciplinary Core Ideas	**ESS1: Earth's Place in the Universe** **ESS2.A: Earth's Materials and Systems** **PS1: Matter and Its Interactions**
Common Core State Standards English Lang. Arts	**Writing**	4, 10
	Speaking & Listening	1, 2
	Language Standards	1, 2, 3, 6
	Writing Standards Science & Technical Subjects	4, 7, 10
Math CCSS	Measurement & Data • Describe and compare measurable attributes. • Represent and interpret data.	

Teacher Background

Native Americans have inhabited North America for at least 15,000 years, possibly much longer. They therefore likely experienced the catastrophic Ice Age Floods, but conclusive archaeological evidence has not yet been found. The accepted belief that 400–1200 feet of fast-moving water covered the widespread areas impacted by the Floods helps explain the lack of evidence, but what we do have are oral traditions of floods and how landforms were created that were passed down through oral traditions by tribes throughout the Northwest.



Ed Edmo, Shoshone-Bannock elder, poet, playwright, traditional storyteller, and lecturer on Northwest tribal culture. He stands in front of She Who Watches (Tsagaglalal).
Photo by Anne Morin; used by permission

Traditional stories include one by the Palouse tribe about Big Beaver fighting four giant brothers. The brothers speared Big Beaver five times, with the huge beast gouging out the canyon at Palouse Falls in present-day Southeast Washington in the process. The once smooth-flowing Palouse River then cascaded down the steep canyon walls, which still show the deep gouges made by Big Beaver's claws. The massive boulder found where the Palouse flows into the Snake River is said to be Big Beaver's heart.

Other Native American stories discuss huge floods, such as this Kalapuya passage: "Now the water (flood) came up (rose). And some of the people, the large birds carried them (up) on their backs. They took them to a big mountain (Pike's Peak or Mary's Peak, west of Corvallis). All those people went to that big mountain there. Now the water was coming up higher. All the country was filled with water.…" (Jacobs, 1945, p. 111). "A Tualatin Kalapuya ancient story tells how things came to be. Long ago the Tualatin country was filled with many people. There was nothing of sickness. These people became the stars. The next generation of people became the pebbles. During the next age, there was a flood and the people became the water beings (salmon, steelhead, whale, Water Being, seal, etc.)" (Lewis, 2016, par. 5).

The traditional stories that seek to explain Northwest landforms and evidence of floods are joined by two scientific theories:

- **Catastrophism** is a geologic theory that landscape features are mostly formed from catastrophic events. This includes sudden, violent, rare events like earthquakes, volcanoes, floods, landslides, and asteroid impacts. The theory holds these events can quickly change the landscape on a large scale, and potentially even impact living things around the world. The widespread impacts are thought to be separated by long periods of inactivity.

In the Western world, catastrophism has its roots in Judeo-Christian ideas. James Ussher, an Anglican Archbishop, claimed in the mid-1600s that the world was created dramatically by God in 4004 BCE. This idea gained wide acceptance and was supported by other scholars of the Bible (Lutgens, Tarbuck, and Tasa, 2012, p. 4). Many religions from around the world have stories of catastrophic events like floods from times when Earth was thought to be much younger in age than we know today.

As a scientific theory, catastrophism gained support in the early 1800s by scientist Georges Cuvier, often considered the “father of paleontology”, after he noticed when digging in France an abundance of fossils (presumably caused by mass die-offs) followed by large gaps in the fossil record. Cuvier avoided religious and philosophical considerations and focused on what could be observed and supported through scientific inquiry.

- **Uniformitarianism** is the theory that landscapes were shaped through slow, continuous, uniform processes and that these processes are/were mostly the same in the past, present, and future. It argues that we can observe processes like vulcanism (volcanoes) and erosion by water, wind, and glaciers and know that they have happened before and will happen again. This theory is used to explain many dramatic landforms throughout the world, such as the Grand Canyon and the Cascade and Rocky Mountains.

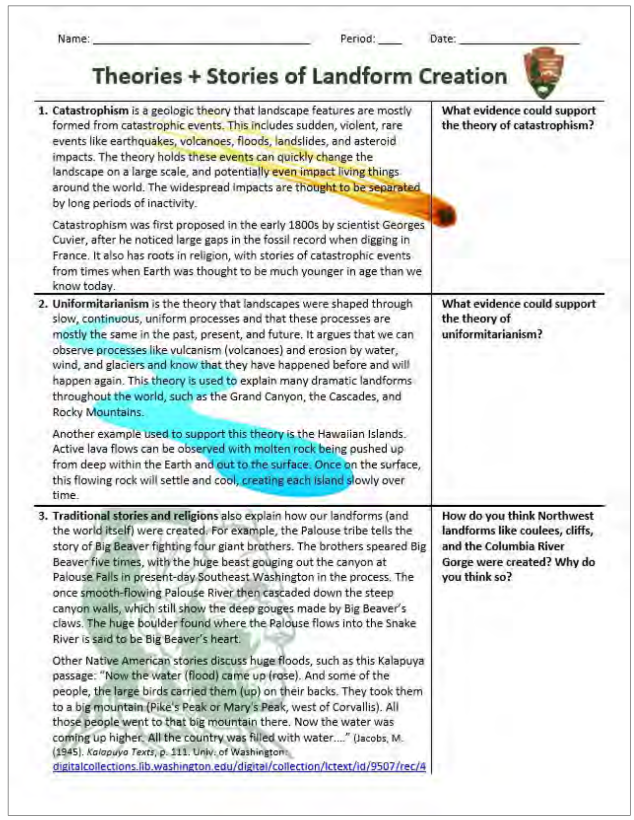
The spectacular phenomenon of the Grand Canyon is explained by uniformitarianism.
Photo by AlexW93, Pixabay:
pixabay.com/photos/grand-canyon-canyon-arizona-2491980

Another example used to support this theory is the Hawaiian Islands. Active lava flows can be observed with molten rock being pushed up from deep within the Earth and out to the surface. Once on the surface, this flowing rock will settle and cool, creating each island slowly over time.

Uniformitarianism, sometimes called gradualism, was first proposed by James Hutton. He is often called “the father of modern geology” and the theory is a key principle of modern geology. Another key figure in modern geology is Charles Lyell, who supported the theory in his influential book *Principles of Geology*, published in 1830.

The lesson asks students to form their own theories to explain dramatic Northwest landforms in light of what they have been learning in the unit after visiting or viewing awe-inspiring photographs of them, as well as learning about the stories and theories above. Modern geology holds that Earth’s processes are generally slow, but that catastrophic events have also had profound impacts. Landforms were created by both uniform, observable processes like erosion, as well as catastrophic events like the Ice Age Floods and meteor impacts, but the lesson is most engaging and impactful if students play the role of scientists considering the different theories.

Materials + Preparation



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Theories + Stories of Landform Creation

1. **Catastrophism** is a geologic theory that landscape features are mostly formed from catastrophic events. This includes sudden, violent, rare events like earthquakes, volcanoes, floods, landslides, and asteroid impacts. The theory holds these events can quickly change the landscape on a large scale, and potentially even impact living things around the world. The widespread impacts are thought to be separated by long periods of inactivity. Catastrophism was first proposed in the early 1800s by scientist Georges Cuvier, after he noticed large gaps in the fossil record when digging in France. It also has roots in religion, with stories of catastrophic events from times when Earth was thought to be much younger in age than we know today.	**What evidence could support the theory of catastrophism?**
2. **Uniformitarianism** is the theory that landscapes were shaped through slow, continuous, uniform processes and that these processes are mostly the same in the past, present, and future. It argues that we can observe processes like vulcanism (volcanoes) and erosion by water, wind, and glaciers and know that they have happened before and will happen again. This theory is used to explain many dramatic landforms throughout the world, such as the Grand Canyon, the Cascades, and Rocky Mountains. Another example used to support this theory is the Hawaiian Islands. Active lava flows can be observed with molten rock being pushed up from deep within the Earth and out to the surface. Once on the surface, this flowing rock will settle and cool, creating each island slowly over time.	**What evidence could support the theory of uniformitarianism?**
3. **Traditional stories and religions** also explain how our landforms (and the world itself) were created. For example, the Palouse tribe tells the story of Big Beaver fighting four giant brothers. The brothers speared Big Beaver five times, with the huge beast gouging out the canyon at Palouse Falls in present-day Southeast Washington in the process. The once smooth-flowing Palouse River then cascaded down the steep canyon walls, which still show the deep gouges made by Big Beaver’s claws. The huge boulder found where the Palouse flows into the Snake River is said to be Big Beaver’s heart. Other Native American stories discuss huge floods, such as this Kalapuya passage: “Now the water (flood) came up (rose). And some of the people, the large birds carried them (up) on their backs. They took them to a big mountain (Pike’s Peak or Mary’s Peak, west of Corvallis). All those people went to that big mountain there. Now the water was coming up higher. All the country was filled with water….” (Jacobs, M. (1945). *Kalapuya Texts*, p. 111. Univ. of Washington. digitalcollections.lib.washington.edu/digital/collection/lctext/id/9507/rec/4	**How do you think Northwest landforms like coulees, cliffs, and the Columbia River Gorge were created? Why do you think so?**

- If developmentally appropriate for students in your class, prepare copies of the “Theories + Stories of Landform Creation” activity and/or the “Coyote Makes N’CheWana (the Columbia River)” activity found at the end of the lesson for each student. For emerging readers, you might tell them about the theories and share stories orally.
- Prepare to show the “Landforms of the Northwest” PowerPoint presentation; feel free to adapt it for your students.
- *Optional:* Print out sets of the landform images for student groups to use while doing the “Theories + Stories of Landform Creation” activity.
- Pencil or pen for each student
- Colored pencils, markers, and/or crayons that students can share
- Data projector and computer
- *Optional:* Science notebooks
- *Optional:* Document camera (connected to data projector)
- *Optional:* Review the sources and watch the videos listed at the end of the lesson for additional background information. You could also share one or more of the videos with your students and discuss them.

Teaching Suggestions in the 5E Model

Engage

1. **Options to engage students with scientific phenomena, activate prior knowledge, and stimulate critical thinking** (2–10 min. or more)
   - **Visit an area with signs of Ice Age Floods and/or show images from the “Landforms of the Northwest” presentation.**

- It is especially engaging if you can visit an area with dramatic signs of the Floods, such as the Grand Coulee or Columbia River Gorge, but the awe-inspiring scenes in the presentation also provide compelling phenomenon to drive student inquiry.
- Ask students, "What forces created the landforms?" They can record their ideas in science notebooks and discuss them with a partner. Other ideas for questions are included in the slide notes of the PowerPoint.
- You might discuss student ideas as a class, such as that erosion and/or glaciers carved out the rock and deposited the boulders, but don't reveal the mysteries of the Ice Age Floods yet, so students can be scientists forming hypotheses and considering them in light of more information.

- **Invite a storyteller or elder from a local tribe to share creation stories and/or stories of floods.**

  Review the "Guidelines for Working with Native Communities" by Zoltán Grossman of Evergreen State College for support with respectful ways to ask, visit, and host elders and others from native communities: sites.evergreen.edu/zoltan/wp-content/uploads/sites/358/2018/01/NativeCulturalRespectGuidelines.pdf.

- **Show a short video clip of dramatic NW landforms and have students do a think-pair-share to discuss their ideas about the phenomenon.** (2–5 min.)
  - Turn the sound off to encourage students to think about the phenomenon rather than have it explained to them. You might show from 0:08–1:15 (or another clip) of "Ice Age Floods, Lake Missoula, Bonneville Flood and the Columbia River Basalts" (16:17). HugeFloods: youtu.be/i1BFb_uYlFQ.
  - Have the video open to the correct place in the clip when you turn on the data projector so students do not see the name of the video, otherwise you will give away the mystery.

Explore

2. **Students consider different theories and stories of how NW landforms were created.** (15–25 min.)
   - If developmentally appropriate for students in your class, prepare for students to read and complete the "Theories + Stories of Landform Creation" activity found at the end of the lesson. For emerging readers, you might tell them about the theories and share stories orally. Or you might choose to read through the content together as a whole class for younger students.
   - If students have the necessary reading skills, ask them to choose a partner or small group of 3–4 students. While they are organizing themselves, pass out copies of the "Theories + Stories of Landform Creation" activity found at the end of the lesson for each student. Adjust groups, if necessary, to partner better readers with developing readers and ensure all students are included in a group, etc.
   - Ask students to read about the different theories and stories of how NW landforms were created. As they do, they can discuss their ideas and record them on their activity sheets and/or in science notebooks. If you are allowing

them to write directly on the sheets, tell them that they can finish their answers on the back if they need more space.

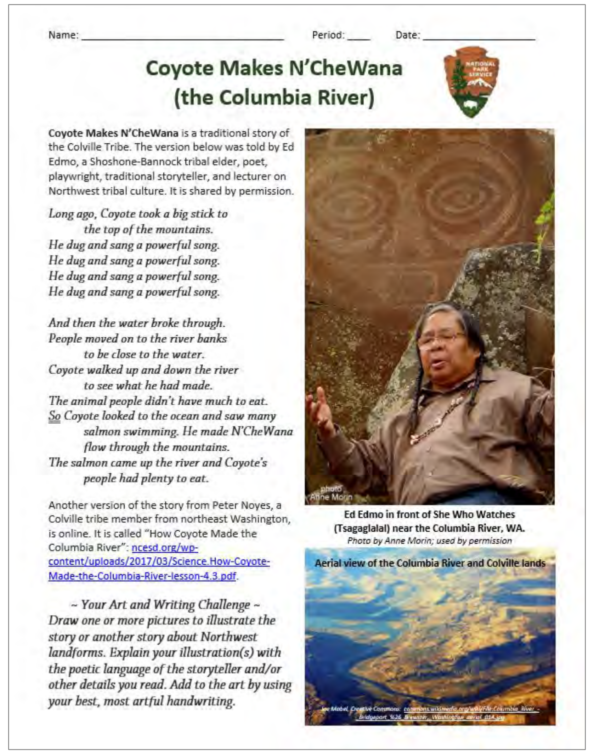
- Tell students that they should also draw and label a diagram (or more than one) that explains how they think our landforms were created. This can be done on the back of the activity sheet or in science notebooks. You can also pass out colored pencils, markers, and/or crayons that they can use to color their models.
- Circulate to answer any questions. When the groups begin to finish recording their ideas and drawing their models, tell them that they should be ready to share them with the class. They will be able to make their short presentations as a group, showing their diagrams with the document camera (if available). Or they can take a picture of them and email them to you to display with the data projector.

Explain

3. Students share and discuss their theories and diagrams. (10–15 min.)

- Ask groups to come forward and explain their thoughts about the theories. They can show their labeled diagrams with the document camera or digital images that explain what they think created the NW landforms.
- After students present, have a closing discussion about the theories of catastrophism, uniformitarianism, and stories of how Northwest landforms were created.
- Ask students to vote for one of these options for how the landforms were created and record the number of votes for each choice:
    - **Catastrophism:** massive floods, huge volcanic eruptions, asteroid impacts, fights among huge animals and giants, etc. If they choose this option, what specific catastrophic events do they think were most responsible and why?
    - **Uniformitarianism:** gradual action of volcanoes, erosion, glaciers, etc.
    - **Both** catastrophic events and gradual action of natural processes; if they chose this option ask them to commit to the dramatic Northwest landforms being more the results of catastrophic events or gradual ones. Which specific forces or events do they think had the most impact?
- Ask students to analyze the voting data in science notebooks or via a spreadsheet to calculate the percentages of the class that chose each option. They can work together in groups to perform the calculations and create graphs with labels that show the data visually.
- After groups finish making their calculations, discuss them as a class. If necessary, review how to calculate percentages and create graphs to visualize the data.
- Tell students that they will be exploring more clues about what created the landforms in the next class.

Extend / Enrich



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Coyote Makes N'CheWana (the Columbia River)

Coyote Makes N'CheWana is a traditional story of the Colville Tribe. The version below was told by Ed Edmo, a Shoshone-Bannock tribal elder, poet, playwright, traditional storyteller, and lecturer on Northwest tribal culture. It is shared by permission.

Long ago, Coyote took a big stick to
the top of the mountains.
He dug and sang a powerful song.
He dug and sang a powerful song.
He dug and sang a powerful song.
He dug and sang a powerful song.

And then the water broke through.
People moved on to the river banks
to be close to the water.
Coyote walked up and down the river
to see what he had made.
The animal people didn't have much to eat.
So Coyote looked to the ocean and saw many
salmon swimming. He made N'CheWana
flow through the mountains.
The salmon came up the river and Coyote's
people had plenty to eat.

Another version of the story from Peter Noyes, a Colville tribe member from northeast Washington, is online. It is called "How Coyote Made the Columbia River": ncesd.org/wp-content/uploads/2017/03/Science.How-Coyote-Made-the-Columbia-River-lesson-4.3.pdf.

~ Your Art and Writing Challenge ~
Draw one or more pictures to illustrate the story or another story about Northwest landforms. Explain your illustration(s) with the poetic language of the storyteller and/or other details you read. Add to the art by using your best, most artful handwriting.

Ed Edmo in front of She Who Watches (Tsagaglalal) near the Columbia River, WA.
Photo by Anne Morin; used by permission

Aerial view of the Columbia River and Colville lands

- **Have students read "Coyote Makes N'CheWana (the Columbia River)" and complete the art/writing activity found at the end of the lesson.**
- **Have a class debate between the groups of students supporting the three options—catastrophism, uniformitarianism, and both.**

  Each group can analyze and discuss the landscape features and construct an argument as to why they think that their theory is the correct one to explain the landscape. You can show visuals from the PowerPoint presentation to support the discussion. They should make sure to support their arguments with evidence and comparison to geologic processes that they understand from other information in the unit and any additional knowledge and experience they may have.
- **Have students explore additional Native American resources.**

  The Confederated Tribes of the Colville Reservation lists many excellent resources: colvilletribes.com/history-archaeology. Multimedia resources are listed on the bottom of the page and downloadable documents can be accessed at the top left of the page, such as the *Book of Legends*: colvilletribes.com/s/Book_of_legends_for_pdf_10-31-11.pdf. Additional resources are listed in the "Expand Knowledge + Skills" section at the end of the lesson.
- **Take students on a more involved field study to observe the Northwest landforms first-hand.**

  Good locations to take your class include:
  - Lake Roosevelt National Recreation Area: nps.gov/laro
  - Dry Falls—once the world's largest waterfall. Interesting article with video from the *Statesman Journal*: statesmanjournal.com/story/travel/outdoors/2018/07/20/sun-lakes-dry-falls-state-park-washington-best-things-do/797006002
  - Many more great locations can be found on an interactive map from the Ice Age Floods Institute: iafi.org/floodscapes.
- **The PowerPoint presentation can be used again at the end of the next lesson—"Mystery of the Channeled Scablands"**—so students can explain the phenomena in the images in light of what was learned by J. Harlan Bretz, Joseph "J.T." Pardee, NASA observers, and other scientists. Students can again get into pairs or small groups to discuss their ideas about the phenomena and record them in science notebooks.

Evaluate

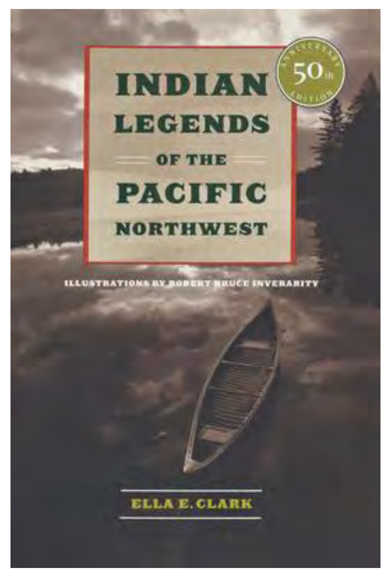
4. **Review student notebooks, completed activity sheets, and labeled diagrams**.
5. **Lead a closing class discussion about some or all of the guiding questions of the lesson, upon which students could also reflect in writing, such as:**
    - What are the stories and theories about how the canyons and other landforms of the Northwest were created?
    - What are stories that Native Americans have told for many generations about floods and creation of our Northwest landforms?
    - What is catastrophism?
    - What is uniformitarianism?

    Record student participation in the discussion and thank students for thoughtful contributions.
6. **Instead of, or in addition to an all-class discussion, have students think about and discuss some or all of the questions above as a "think, pair, share" activity.**

    Students can record their ideas in science notebooks.

Expand Knowledge + Skills

Background on Catastrophism, Uniformitarianism, and Oral Traditions



- "Catastrophism." Univ. of Illinois "The Foundation of Modern Geology" site: publish.illinois.edu/foundationofmoderngeology/catastrophism
- Clark, E. (2003, 1958). *Indian Legends of the Pacific Northwest*. University of California Press. It includes over 100 tribal tales, including "Other Stories of the Great Flood." Inexpensive used copies: alibris.com/Indian-legends-of-the-Pacific-Northwest-Ella-Elizabeth-Clark/book/3194922
- Confederated Tribes of the Colville Reservation cultural resources: https://www.colvilletribes.com/history-archaeology; *Book of Legends*: cct-hsy.com/about-us
- Jacobs, M. (1945). Kalapuya Texts, p. 111. Univ. of Washington: digitalcollections.lib.washington.edu/digital/collection/lctext/id/9507/rec/4
- Kramer, B. (2016). "Palouse Falls 'A Site of Wonder" for Thousands of Years." *The Spokesman-Review*: spokesman.com/stories/2016/may/20/washingtons-palouse-falls-a-site-of-wonder-for-tho
- Lewis, D. (2017). "Kalapuyan Eyewitnesses to the Megaflood in the Willamette Valley." NDNHistory Research: ndnhistoryresearch.com/2017/04/08/kalapuyan-eyewitnesses-to-the-megaflood-in-the-willamette-valley
- Lewis, D. (2016). "Origin of the Tualatin Kalapuyans." *The Cedar Mill News:* cedarmillnews.com/legacy/1016/originofthetualatinkalapuyans.html
- Lutgens, F., Tarbuck, E., and Tasa, D. (2012). *Essentials of Geology.* Prentice Hall

- Robinson, R. (2017). “Did You Know? Palouse Falls.” The Mountaineers: mountaineers.org/blog/did-you-know-palouse-falls
- Scheck, R. “Native Palouse Falls Creation Story.” Ice Age Flood Explorer: floodexplorer.org/items/show/14
- Strahler, A.N., & Strahler, A.H. (1989). *Elements of Physical Geography (4th Ed.)*. John Wiley & Sons
- Thompson, A. (1971). The Early History of the Palouse River and Its Names. *The Pacific Northwest Quarterly, 62*(2), 69-76: www.jstor.org/stable/40488909
- “Uniformitarianism.” National Geographic: nationalgeographic.org/encyclopedia/uniformitarianism
- “Uniformitarianism.” Wikipedia: en.wikipedia.org/wiki/Uniformitarianism
    - “James Hutton.” Wikipedia: en.wikipedia.org/wiki/James_Hutton
    - “Charles Lyell.” Wikipedia: en.wikipedia.org/wiki/Charles_Lyell
- Wilson, W. & Gardner, J. (2017). “Legends of the Northern Paiute.” Oregon State Univ. Press: oregon.gov/ode/students-and-family/equity/NativeAmericanEducation/Documents/SB13%20Curriculum/Materials_Legends%20of%20the%20Northern%20Paiute%20as%20told%20by%20Wilson%20Wewa.pdf

Lessons / Units

- “4th Grade Tribal History Lesson Plans.” Oregon Dept. of Education: oregon.gov/ode/students-and-family/equity/NativeAmericanEducation/Pages/4th-Grade-Tribal-History-Lesson-Plans.aspx
    - “Oral Traditions.”: oregon.gov/ode/students-and-family/equity/NativeAmericanEducation/Documents/SB13%20Curriculum/G4_ELA_Lesson%20Plan_Oral%20Traditions_2SP.pdf
    - “Storytelling Planning Worksheet.”: oregon.gov/ode/students-and-family/equity/NativeAmericanEducation/Documents/SB13%20Curriculum/Materials_Storytelling%20Planning%20Chart.pdf
    - “Post Story Chart.”: oregon.gov/ode/students-and-family/equity/NativeAmericanEducation/Documents/SB13%20Curriculum/Materials_Post%20Story%20Chart.pdf
- “Grand Ronde Tribal History” curriculum. Confederated Tribes of Grand Ronde: grandronde.org/history-culture/culture/curriculum
- “Theories of Geological Evolution: Catastrophism vs. Uniformitarianism.” Spiral: spiral.ac/lesson-plan-ideas/clips/lessons/theories-of-geological-evolution-catastrophism-vs-uniformitarianism

Videos

- Zentner, N., & Foster, T. HUGEfloods.com videos: nickzentner.com/#/2-minute-geology
    - Zentner, N., & Foster, T. (2013). “Columbia River Basalt Group - Related to Cascade Volcanoes?” youtu.be/9UBFSXu9UHY
    - Zentner, N., & Foster, T. (2014). “Ice Age Floods, Lake Missoula, Bonneville Flood and the Columbia River Basalts.” youtu.be/i1BFb_uYlFQ

Name: ____________________________________ Period: ____ Date: ____________________

Theories + Stories of Landform Creation

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What evidence could support the theory of catastrophism?

2. **Uniformitarianism** is the theory that landscapes were shaped through slow, continuous, uniform processes and that these processes are mostly the same in the past, present, and future. It argues that we can observe processes like vulcanism (volcanoes) and erosion by water, wind, and glaciers and know that they have happened before and will happen again. This theory is used to explain many dramatic landforms throughout the world, such as the Grand Canyon, the Cascades, and Rocky Mountains.

   Another example used to support this theory is the Hawaiian Islands. Active lava flows can be observed with molten rock being pushed up from deep within the Earth and out to the surface. Once on the surface, this flowing rock will settle and cool, creating each island slowly over time.

What evidence could support the theory of uniformitarianism?

3. **Traditional stories and religions** also explain how our landforms (and the world itself) were created. For example, the Palouse tribe tells the story of Big Beaver fighting four giant brothers. The brothers speared Big Beaver five times, with the huge beast gouging out the canyon at Palouse Falls in present-day Southeast Washington in the process. The once smooth-flowing Palouse River then cascaded down the steep canyon walls, which still show the deep gouges made by Big Beaver's claws. The huge boulder found where the Palouse flows into the Snake River is said to be Big Beaver's heart.

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How do you think Northwest landforms like coulees, cliffs, and the Columbia River Gorge were created? Why do you think so?

Coyote Makes N'CheWana (the Columbia River)

Coyote Makes N'CheWana is a traditional story of the Colville Confederated Tribes from northeast Washington. The version below was told by Ed Edmo, a Shoshone-Bannock tribal elder, poet, playwright, traditional storyteller, and lecturer on Northwest tribal culture. It is shared by permission.

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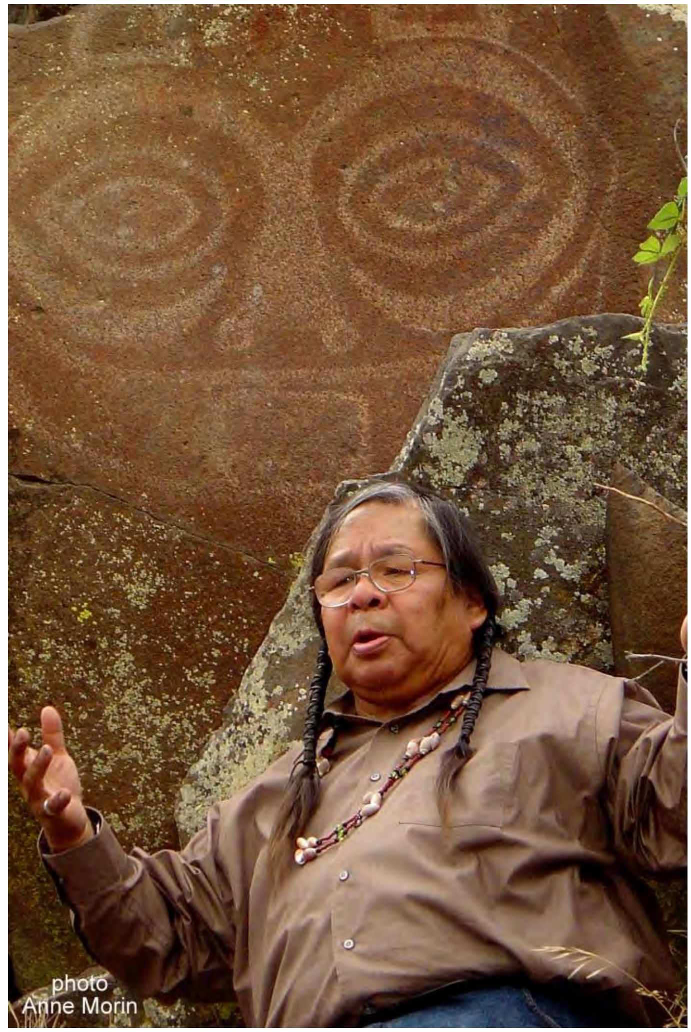
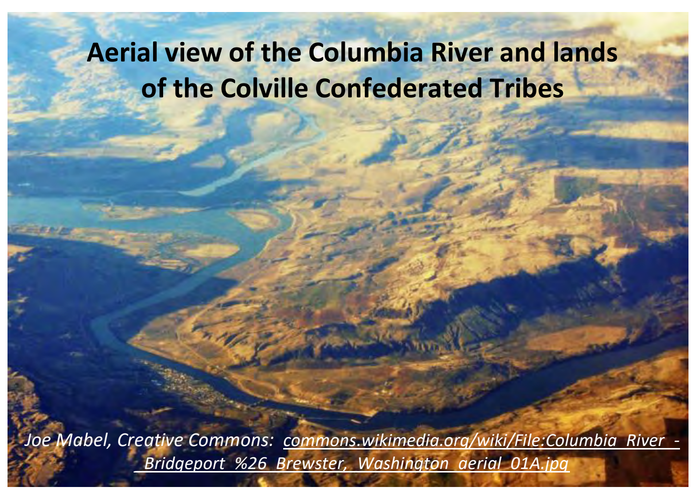
He dug and sang a powerful song.

And then the water broke through.
People moved on to the river banks
to be close to the water.
Coyote walked up and down the river
to see what he had made.
The animal people didn't have much to eat.
So Coyote looked to the ocean and saw many
salmon swimming. He made N'CheWana
flow through the mountains.
The salmon came up the river and Coyote's
people had plenty to eat.



Ed Edmo in front of She Who Watches (Tsagaglalal) near the Columbia River, WA.
Photo by Anne Morin; used by permission



Aerial view of the Columbia River and lands of the Colville Confederated Tribes

Joe Mabel, Creative Commons: commons.wikimedia.org/wiki/File:Columbia_River_-_Bridgeport_%26_Brewster,_Washington_aerial_01A.jpg

Another version of the story from Peter Noyes, a member of the Colville Confederated Tribes, is online. It is called "How Coyote Made the Columbia River": ncesd.org/wp-content/uploads/2017/03/Science.How-Coyote-Made-the-Columbia-River-lesson-4.3.pdf.

~ Your Art and Writing Challenge ~

Draw one or more pictures to illustrate the story or another story about Northwest landforms. Explain your illustration(s) with the poetic language of the storyteller and/or other details you read. Add to the art by using your best, most artful handwriting.

Mystery of the Channeled Scablands

Overview

Students investigate the "Mystery of the Channeled Scablands," a nonfiction reading with phenomena-based images and critical thinking questions, about the cataclysmic flood theory first proposed by J Harlen Bretz. It guides students through the evidence Bretz and J.T. Pardee discovered as students try to solve the mystery. Optional Engage activities include a simulation of stream ripples (through a steam table or other means), to give students a chance to think about what caused the phenomenon. These observations can help connect students to the massive ripples several meters high discovered in the Northwest that are part of the evidence of Ice Age Floods. Other Engage options include a field study at a site with evidence of Ice Age Floods and a story/scenario activity. A variety of additional Enrich / Extend activities are listed to help you meet the needs of all learners.

Subjects: Science, Writing, Speaking & Listening, Art, Environmental Education

Grades: Adaptable for K–12

Duration: 40 minutes or more

Vocabulary

- J Harlen Bretz
- Cataclysmic
- Channeled Scablands
- Erratics
- Glacial Lake Missoula
- Ice dam
- Mystery
- J.T. Pardee
- Plunge pools

Guiding Questions

- What was the controversy of how the Channeled Scablands were created? Why were J Harlen Bretz' ideas so controversial?
- What was the evidence of the Ice Age Floods? How were Bretz' ideas tested and supported?

Objectives

- Students will read a compelling narrative about the Scabland Puzzle and the clues that led to the cataclysmic Ice Age Floods theory and answer critical thinking questions in writing.
- Students will participate in a discussion about the observable phenomena that led to the theory eventually being proven 50 years after it was first proposed.
- Students will discuss their theories about the causes of observable phenomena in the classroom and/or during field study orally and in writing.

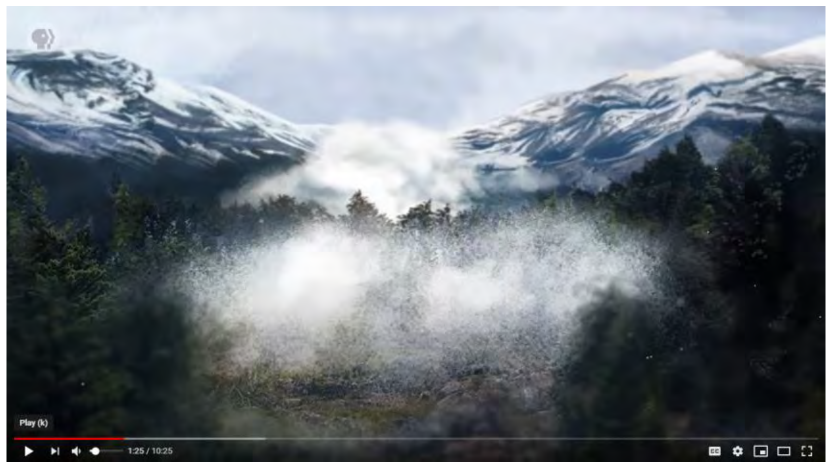
How the Channeled Scablands in Washington were formed was a mystery until well into the 20th Century.
Image by Rear Admiral Harley D. Nygren, NOAA: *flickr.com/photos/noaaphotolib/5436016515*

Next Generation Science Standards + Common Core State Standards		
	Performance Expectations We suggest you tailor the lesson to meet the PE(s) for your grade level.	**2-ESS2-2.** Develop a model to represent the shapes and kinds of land and bodies of water in an area. **2-ESS1-1**. Use information from several sources to provide evidence that Earth events can occur quickly or slowly. **4-ESS1-1**. Identify evidence from patterns in rock formations and fossils in rock layers to support an explanation for changes in a landscape over time. **5-ESS2-1**. Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact. **MS-ESS2-2**. Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales. **MS-ESS3-1**. Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes. **HS-ESS2-1**. Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.
	Crosscutting Concepts	• Cause and Effect • Energy and Matter • Patterns • Scale, Proportion, and Quantity • Stability and Change • Systems and System Models
	Science & Engineering Practices	• Developing and Using Models • Constructing Explanations and Designing Solutions • Engaging in Argument from Evidence • Obtaining, Evaluating, and Communicating Information
	Disciplinary Core Ideas	**ESS1: Earth's Place in the Universe** **ESS2.A: Earth's Materials and Systems** **ESS2.D: Weather and Climate** **PS1: Matter and Its Interactions**

Common Core State Standards English Lang. Arts	**Writing**	4, 10
	Speaking & Listening	1, 2
	Language Standards	1, 2, 3, 6
	Writing Standards Science & Technical Subjects	4, 7, 10
Math CCSS	Math can be incorporated to meet the standards at your grade level and/or to reinforce concepts learned previously. See the Enrich / Extend section for ideas.	

Teacher Background

- Read the "Mystery of the Scabland Puzzle" student reading/activity at the end of the lesson.
- Watch one or more of the videos listed in the lesson, such as:
    - "How 7,000 Years of Epic Floods Changed the World" (10:25) from PBS Eons: youtu.be/YWZgfPGtQEs.
    - "Glacial Lake Missoula" (18:51): youtu.be/wJo8m4oKc6k.
    - "Killer Floods" (54:10, especially the clips about the Scablands that start at 7:15 and 20:15; huge MT ripples discussed at 27:00 with good visuals; collapse of the ice dam explained with good visuals at 29:15). NOVA, PBS (you may need to be a member with a PBS Passport account to view): pbs.org/wgbh/nova/video/killer-floods. The video is available on Netflix at netflix.com/title/81121182 and free in a lower resolution at dailymotion.com/video/x6c4qdr.
- Review the information in the previous lessons about erosion, glaciers, rocks and how they were formed, and stories/theories of the formation of Northwest landscapes.



Screenshot from "How 7,000 Years of Epic Floods Changed the World" by PBS Eons.

Materials + Preparation


Name: ______________________ Period: ___ Date: ______________

Mystery of the Channeled Scablands

He couldn't understand how the towering cliffs carved through basalt could have gotten there. How about huge erratics (random boulders) that were far south of the glacial edge during the ice ages? These were two of the many questions swirling in the mind of J. Harlen Bretz in the 1920s. He thought it would be impossible for normal rivers—or even enormous glaciers like those of the ices ages—to ever create landscapes of such magnitude. The only explanation that made sense to him was that a cataclysmic flood hundreds of feet high had swept through the area.

When Bretz presented his theory to renowned geologists, they thought it was ridiculous. They argued that the formations he described were caused by uniform erosion of glaciers and liquid water.

Writing about the Channeled Scablands of Eastern Washington, Bretz said, "The channels run uphill and downhill, they unite and they divide, they head on the back-slopes and cut through the summit; they could not be more erratically and impossibly designed." Bretz knew he was right, but there were missing pieces of the puzzle that he needed to prove his theory. The most important of these was, "Where could that much water have come from?"

1. **Where do YOU think that much water could have come from?** Brainstorm your ideas below in words and pictures. Record your theories before you read more.

Dry Falls, Grand Coulee, WA: Its 400-foot (122-meter) cliffs were once the site of the largest waterfall in the world.

J. Harlen Bretz, revolutionary scientist

Channeled Scablands, Washington

Erratics south of glacial edge in Washington

- Make copies of the "Mystery of the Scabland Puzzle" activity for each student. You can save the copies for future classes by having students answer questions in science notebooks, rather than directly on the sheets.
- Set up for the "Watershed/Erosion Models" activity. You'll need these (or similar) for each model:
    - Baking pan with dry sand or dirt; can also be done in an area with sand or dry dirt without pans
    - Rocks (ideally of different types in a container) that students can integrate into their models
    - Stick to represent a logjam in the river
    - Spray bottle or container of water (16–32 ounce or ½ liter works well)
    - Copies of the "Watershed Models" handout for each student found at the end of the lesson and/or science notebooks for students to record predictions and observations
    - Colored pencils, markers, and/or crayons
- Prepare to show images with evidence of Ice Age Floods, such as those in the "Landforms of the Northwest" PowerPoint presentation as an interactive visual aide; feel free to adapt for your students
- Data projector and computer
- Access to Internet and/or library for research
- *Optional:* Set up a stream table or prepare to show students the phenomenon of stream ripples as explained below.
- *Optional:* Review the sources and watch the videos listed at the end of the lesson for additional background information. You could also share one or more of the videos with your students and discuss them.

Teaching Suggestions in the 5E Model

Engage

1. **Options to engage students with scientific phenomena, activate prior knowledge, and stimulate critical thinking** (2–20 min.)
    - **Visit an area with signs of cataclysmic Ice Age Floods.**

      Options include:
        - Sites along the Ice Age Floods National Geological Trail, such as those listed here: nps.gov/iafl/planyourvisit/placestogo.htm.

- Many more great locations to take your class can be found on an interactive map from the Ice Age Floods Institute: iafi.org/floodscapes. For example, there may be Ice Age Flood erratics found in a nearby area, or cliffs carved by the floods, such as those in the Columbia River Gorge and Lake Roosevelt National Recreation Area: nps.gov/laro. Dry Falls is another great choice: parks.state.wa.us/251/Dry-Falls.

Dry Falls in Washington was once the largest waterfall in the world—by far!

During the field study, ask the students:

- What (phenomenon) caused this? (Reinforce the word "phenomenon" if they are familiar with it, or leave it out for very young students.)
- Include questions specific to the site, such as "Did you know that glaciers did not spread this far south during the Ice Age? How could what look like huge glacial erratics have gotten here?"
- Bring binoculars, if you have them, to observe features in more detail.

- **Share the phenomenon of sand ripples with your students.** (3 – 5 min.)
  - This could be during a field study to a nearby stream, or in a stream table (or smaller model if one is not available), that simulates those in a fast-moving stream.
  - When students arrive for class, ask them to observe the sand formations and then turn to a partner to explain how they got there. After a couple minutes, discuss how it was fast-moving water that formed them.
  - You can build or purchase one or more stream tables for this activity and many others. MrHollister.com is one of a number of sites that lists instructions for how to create stream tables inexpensively (under $50): mrhollisterphoto.com/stream-table.html.
  - A long underbed storage bin, such as those sold at Target, is an easy option to turn into a stream table, too. More ideas can be found in the "Stream Table Models of Erosion and Deposition" lesson found here: geo.arizona.edu/sites/www.geo.arizona.edu/files/Stream%20Table1.pdf.

- **Connect phenomena students have observed with amazing phenomena caused by Ice Age Floods.** (2 – 5 min.)
  - Tell students a story based on the real-life observations of the scientists discussed in the “Mystery” activity below, such as “Imagine you are a geologist—a scientist who studies rocks and what they can tell us about Earth’s past. While you are out exploring Eastern Washington, you discover towering cliffs 400 feet (122 meters) high, and signs of a massive waterfall—the largest in world history. As you continue on your journey, you find what seem to be glacial erratics—huge boulders that are very different from other nearby rocks. But you know that the glaciers did not reach this far south during the Ice Ages. You also discover Channeled Scablands that stretch for many miles, which you think must have been carved by enormous flows of water—much more than the gradual flows of today’s rivers. And the braided Palouse hills and signs of massive natural plunge pools have you thinking of new theories that would explain the dramatic landforms.”
  - Show images of Ice Age Flood-caused phenomena, such as huge ripples 50 feet high and 200–500 feet apart in Camas Prairie, MT, and the horseshoe-shaped canyon of Dry Falls, WA, that was formed by what was once the world’s largest waterfall. Good examples are provided in the “Landforms of the Northwest” PowerPoint presentation and in the other sources and videos listed at the end of the lesson.
  - Ask students to turn to a partner and discuss their ideas about what might explain these strange phenomena. They should record their ideas in science notebooks and support them with evidence from the story and visuals.

Explore

2. **Students read “The Mystery of the Channeled Scablands” and complete the critical thinking questions with a partner or small group.** (10–20 min.)
   - Pass out copies of the student activity found at the end of the lesson to each student. Ask them to read it with a partner or small group of 3–4 students.
   - Tell them that they should complete the questions on the handouts as they go, without reading ahead, so they will get to play the role of scientists solving the mystery. You might ask them to record their answers in science notebooks if you would like to reuse the handouts.
   - Circulate to answer any questions. When a group finishes reading and answering the questions, give them options for activities to deepen their knowledge of and interest in Ice Age Floods, such as those listed in the Enrich / Extend section.

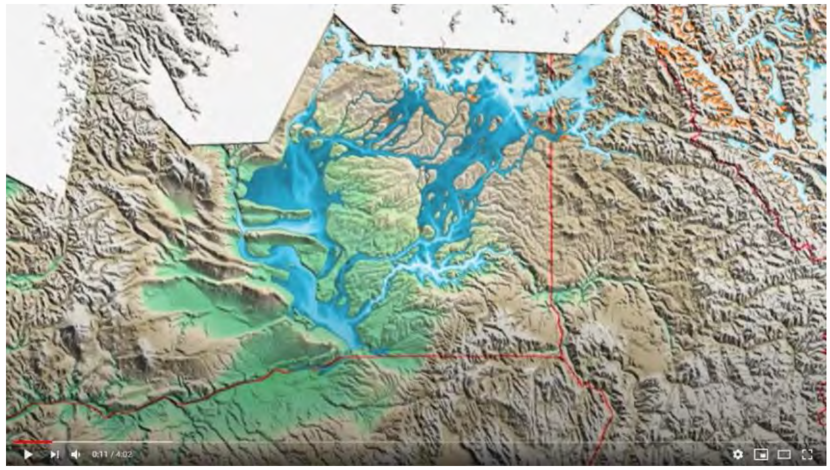
2. **Have students watch all or part of a video about the Ice Age Floods and do a think-pair-share to discuss it.** (5 – 20 min.)

This can be done after groups finish the “Mystery” activity to add to their understanding and stimulate additional thinking. Options include the videos listed at the end of the lesson and “Glacial Lake Missoula” (18:51); students can use the link to it found below the map on the activity: youtu.be/wJo8m4oKc6k. They can record their ideas about the video and any additional questions you pose in science notebooks.

Explain

3. **Discuss the concepts presented in the “Mystery” activity and student ideas.** (5 – 10 min.)

- Discuss the activity with questions such as those below.
    - What does **cataclysmic** mean? Is that a good word to describe what happened during the Ice Age Floods? Discuss how the initial flow rate of flood waters after the ice dam broke is estimated to have been up to 1,000,000 cubic meters of water PER SECOND—an almost unfathomable amount of water. You might use a short animation from the “Glacial Lake Missoula Flood.mov” video as a visual aide: youtu.be/27BP4CL66Tk. “In less than a day, half of Lake Missoula drained, and a vast area of central Washington lay scoured.” The massive flow of water moved at up to 65 miles per hour, creating the incredible force that created many of our most dramatic landscapes in the Northwest.



Screenshot of animation in “Glacial Lake Missoula Flood.mov”

    - What evidence of cataclysmic floods did **J Harlen Bretz** and **J.T. Pardee** find? (huge cliffs in basalt rock, unexplained erratics, enormous ripples that transformed landscapes)
    - What caused the huge amounts of water to flow so fast? (breaking of ice dam that allowed Glacial Lake Missoula to drain suddenly)
    - What did J.T. Pardee find near Missoula, MT that helped support Bretz’s theories? (evidence of Glacial Lake Missoula that could have provided the massive amounts of water for Bretz’s proposed flood)
    - Is the area of our town shown on the map? Would it have been covered by Ice Age Floods and/or the Cordilleran Ice Sheet?
    - What modern rivers flow through sites of the Ice Age Floods? (Columbia, Snake, Yakima, Clark Fork)

- In what ways might the Ice Age Floods have created the dramatic landscapes around these rivers? (incredible amounts of erosion that carved the Grand Coulee and Columbia River Gorge, deposits of huge erratics, Channeled Scablands, ripples several meters high in Montana and elsewhere)
    - You might show images and/or video clips to support the discussion, such as, "Giant Current Ripples Created by the Ice Age Floods": youtu.be/MMbsGHVzXRU.
    - More good visuals are found here: brucebjornstad.com/erratic-behavior.

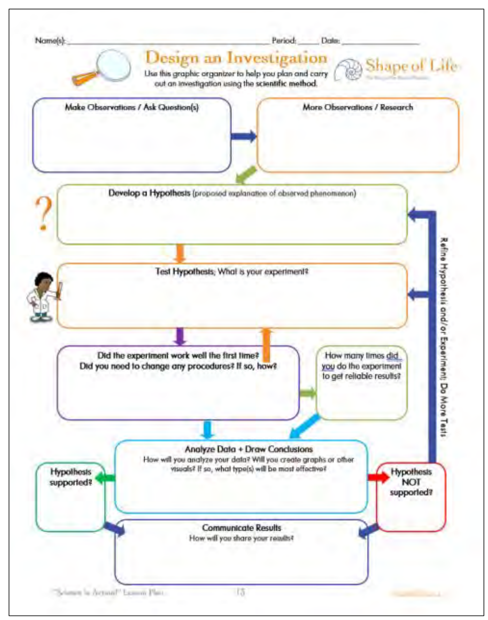
Massive ripples, Camas Prairie, Montana
Image by Tom Foster, shared via Creative Commons: *flickr.com/photos/ice_age_floods/2913196137*

- Ask student how, specifically, they think huge erratics were moved during the Ice Age Floods. Discuss how it was primarily by floating downstream in huge icebergs. When the icebergs finally melted, the boulders remained.
    - You might show "Erratic Boulders - Rafted in Icebergs by the Ice Age Floods" (2:36) as a visual aide: youtu.be/kL_h-dJ_wdo.
    - "Ice-Rafted Erratics and Bergmounds" (4:56) provides a nice video tour of them with aerial footage: youtu.be/RHaXQigQE08.
- Where do the students think the last image in the activity was taken? (Mars). What evident supports their answer? (huge ripples caused by cataclysmic floods on Mars referenced in the reading, red/brown earth without vegetation—the "Red Planet"—and meteorite impacts that we don't usually see so obviously on Earth)
- How might the students be able to help solve the continuing mysteries of the Ice Age Floods? How many there were? Could ice dams have burst in Washington, too? (they could look for evidence of repeated floods, like huge cutout grooves in cliffs at different heights and evidence of floods in different areas)

- Relate the crosscutting concept of cause and effect into your discussion, and how water travels via the path of least resistance and settles in areas of lower elevations relative to the system in which it moves. If you have a stream table or other area to experiment, students can try using a maximum amount of water to test its effects: erosion, transport of large amounts of sand from areas of high potential energy (those that are steep) and low energy (those that are flat), different "landforms" that are created, etc. Students can point out these features in the models as you discuss them, and they can draw and label them in their science notebooks. Then students can compare them with evidence of the Ice Age Floods that we can observe today.

Extend / Enrich

- **Provide students with options for extension activities, such as designing an experiment to simulate how the ice dam burst and impacted the land, as well other activity options below.**
    - Show the video clip in "How 7,000 Years of Epic Floods Changed the World" (10:25) from PBS Eons youtu.be/YWZgfPGtQEs from 6:15 to 6:46. It explains how ice is less dense than water and would have floated up, allowing liquid water to pass underneath, adding to the tremendous pressure that had already built up from the 2,000-foot-deep lake, that would have destroyed the ice dam.
    - Ask the students to design and run an experiment to test this effect on a small scale. One option would be for them to create a clay mold to represent the dam across the middle of a rectangular cake pan. This could be filled with water and the pan could immediately be put in a freezer. After it had frozen, the clay could be carefully removed, leaving the "ice dam." (A flat-head screwdriver or chisel could be helpful for gently removing the clay.) Water could be added to fill one side of the pan, and a layer or dry sand or dirt on the other side.
    - Student hypotheses, procedures, observations and results should be recorded in science notebooks and/or using a graphic organizer. A good "Design an Investigation" organizer is found at the end of the "Scientists in Action!" lesson from Shape of Life: shapeoflife.org/sites/default/files/Science_in_Action_Lesson-Shape_of_Life_FINAL.pdf



- **Ask students to explore the Floodscapes Interactive Map from the Ice Age Floods Institute and create their own maps and/or research more about the various locations.**
    - Students can explore Ice Age Flood sites near your school and other areas they may have visited—or would like to visit—at iafi.org/floodscapes.
    - They should record details about at least 5 interesting locations in science notebooks or electronically.
    - Students can create their own hand-drawn or computer-generated maps with the locations they chose to help tell the story of the evidence of Ice Age Floods found in your area (or another area they are most interested in). A video

that explains how students and/or you can create your own interactive Google Maps is at youtu.be/Az-Qg6fzcw8.

    - Completed projects can be presented to the class and/or displayed on classroom or school walls to help teachers and other students learn about the cataclysmic Ice Age Floods and how they are still in evidence today in local landscapes.

- **Teach students how to read topographical maps which they can use to help them create their own maps.**

  You can display topographical maps centered on particular places here: search.mytopo.com/searchplaces?searchstate=WA.

- **More Ice Age Flood mapping activities are explained in the "Glacial Lake Missoula Nature Discovery Traveling Trunk" curriculum.**

  It is freely available from the Montana Natural History Center website: montananaturalist.org/wp-content/uploads/Glacial-Lake-Missoula-Curriculum-1.pdf.

- **Students choose interesting animals to research that lived (and went extinct) during this period.**
    - They can work in small groups of 3 – 4 to research animals that lived in the area. Animals that groups can choose from include:
        - Bison latifrons (giant bison)
        - Camelops
        - Dire wolf
        - Giant short-faced bear
        - Harlan's ground sloth
        - Mastodon
        - Musk ox (muskox, musk-ox)
        - Saber-toothed cat (saber-toothed tiger)
        - Lesser short-faced bear
        - Woolly mammoth
    - Students can create projects on large sheets of paper, poster board, or using a computer. These can be presented to the rest of the class and displayed on class and/or school walls. Details you might ask them to include:
        - Common & scientific name
        - Detailed illustration with interesting adaptations labeled and/or annotated; they might also include an illustration of a human for scale
        - Size: height, weight, length
        - Diet
        - Predators
        - Habitat
        - Other interesting details scientists have hypothesized about from their fossil record and/or an understanding of the behaviors of the animal's living modern relatives (similar species) around the world
    - Students might also brainstorm and research ways that animals and plants living in the area might have been impacted by the Ice Age Floods, including disruptions to migration routes and food sources.

    - More ideas for the activity are listed in Lesson 3 of the "Glacial Lake Missoula" curriculum linked above. For example, they list instructions to create a "Land Bridge Model" to provide students with a hands-on way to build understanding of how animals and humans migrated between Asia and North America during the ice ages. There is also an extension for students to create their own fossil.
    - Interesting articles about the animals that you might use as non-fiction readings are on the Western Digs website: westerndigs.org/category/paleontology.

- **Students can create large diagrams and/or dioramas to illustrate geologic features.**

  These could be phenomena found at locations such as Grand Coulee/Dry Falls, WA, the Columbia River Gorge, Camas Prairie, MT, etc.

- **Students can create new games that help other students explore evidence of Ice Age Floods.**
    - Encourage them to create engaging game boards, cards, and/or other resources to make the games more fun and educational.
    - This can be an especially good activity to enrich students who complete their other projects quickly, as well as benefit the rest of the students who can play the completed games.
    - Invite younger students, families, and/or school administrators into your class to play the games and to hear presentations from your class as part of a celebratory culminating activity for the unit.

- **Invite an Ice Age Floods expert to speak to your class about their work or show a video of a geologist explaining interesting nearby phenomena.**
    - If possible, take your class on a field study with the support of a geologist or passionate amateur who can explain their work and the rocks/natural history of the area.
    - Several interesting Oregon Field Guide videos are listed on the "Take A Virtual Roadtrip Through Oregon's Fascinating Geology" page from Oregon Public Broadcasting (OPB): opb.org/news/article/geology-oregon-thunder-eggs-caves-canyons-waves. "Columbia Gorge Geology Tour" is one of the videos that includes animations of basalt lava flows: opb.org/television/video/orf-2810-02-digi.
    - Experts may be available from the Ice Age Floods Institute (IAFI), National Park Service, a local tribe, Univ. of Idaho Ext., WA Dept. of Geology, Oregon State Univ. Ext. Service, the Bureau of Land Management (BLM), etc. Local chapters and experts of IAFI are listed at iafi.org/local-chapters.

- **Read more non-fiction articles with your students about the floods and evidence for them, such as those listed at the end of the lesson.**

Evaluate

4. **Lead a closing class discussion about the guiding questions of the lesson, upon which students could also reflect in writing.**

    - What was the controversy of how the scablands were created?
    - Why were J Harlen Bretz's ideas so controversial?
    - What was the evidence of the Ice Age Floods?
    - How were Bretz's ideas tested and supported?

    Record student participation in discussion and thank students for thoughtful contributions.

5. **Instead of, or in addition to an all-class discussion, have students think about and discuss some or all of the questions above as a "Think, Pair, Share" activity.**

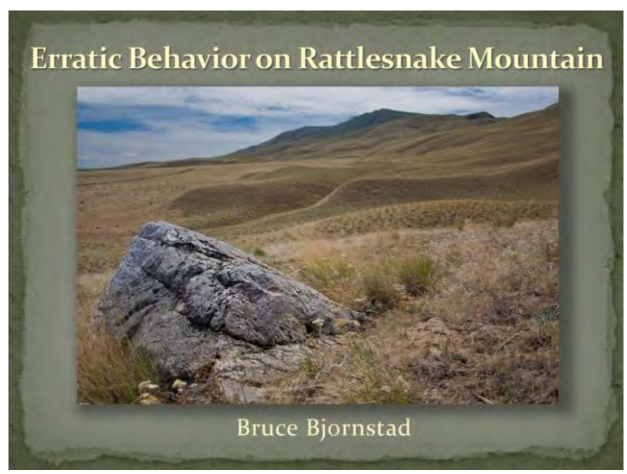
    Students can record their ideas in science notebooks.

6. **Review student notebooks, completed handouts, and any other projects**.

    Display completed student projects to celebrate their work and teach others about Ice Age Floods and how they transformed our landscapes.

Expand Knowledge + Skills

Background on Theories of the Channeled Scablands + Missoula Floods



- Allen, J.A., Burns, M., and Burns, S. (2009). *Cataclysms on the Columbia: The Great Missoula Floods (2nd Ed.)*. books.google.com/books?id=jeTESR-vvJ4C
- Baker, V.R. (1978). *The Channeled Scabland: A Guide to the Geomorphology of the Columbia Basin*. books.google.com/books?id=4PIt1U-o3oQC
- Bjornstad, B. "Erratic Behavior on Rattlesnake Mountain": 12c2f97e-e9de-9620-eeb5-c0d53388ee06.filesusr.com/ugd/12afd0_5add5fc658c0e0ec2bd4617da40bc059.pdf
- "Channeled Scablands." Wikipedia: en.wikipedia.org/wiki/Channeled_Scablands
    - "Channeled Scablands: Overview." Steven Dutch: web.archive.org/web/20131013023820/http://www4.uwsp.edu/geo/projects/geoweb/participants/dutch/vtrips/scablands0.htm
- "Glacial Lake Missoula." Tom Foster: hugefloods.com/LakeMissoula.html

- “Ice Age Floods Study of Alternatives Section D—Background.” Jones & Jones Architects and Landscape Architects, National Park Service: nps.gov/iceagefloods/d.htm
- “An Introduction to the Ice Age Floods.” Ice Age Floods Institute: iafi.org/about-the-ice-age-floods/introduction
- “J Harlen Bretz.” Wikipedia: en.wikipedia.org/wiki/J_Harlen_Bretz
- “J Harlen Bretz.” Illinois State Geological Survey: isgs.illinois.edu/j-harlen-bretz
- Lutgens, F., Tarbuck, E., and Tasa, D. (2012). *Essentials of Geology.* Prentice Hall.
- O’Connor, J.E., & Costa, J.E. (2004). “The World's Largest Floods, Past and Present.” pubs.usgs.gov/circ/2004/circ1254/pdf/circ1254.pdf
- Rojas-Burke, J. (2010). “Geologists Find a Way to Simulate the Great Missoula Floods.” oregonlive.com/news/2010/02/geologists_find_a_way_to_simul.html
- Soennichsen, J. *Washington's Channeled Scablands Guide: Explore and Recreate Along the Ice Age Floods National Geologic Trail*. Mountaineers Books: books.google.com/books?id=ywRkHH3GVRoC
- Thompson, R. *GigaFlood*: gigaflood.com/gigaflood_book.html
- Weis, P.L., & Newman, W.L. (1976). *The Channeled Scablands of Eastern Washington: The Geologic Story of the Spokane Flood.* npshistory.com/publications/geology/inf/72-2/index.htm

Lessons / Units

- “Floods! Erosion by Water.” Illinois Mathematics and Science Academy: digitalcommons.imsa.edu/cgi/viewcontent.cgi?article=1001&context=model_ngss_lessons_4_5
- “Glacial Lake Missoula Nature Discovery Trunk Curriculum.” Montana Natural History Center: montananaturalist.org/wp-content/uploads/Glacial-Lake-Missoula-Curriculum-1.pdf
- “The Ice Age Floods Through the Western Channeled Scablands.” Bruce Bjornstad: web.gps.caltech.edu/~mpl/Ge121a_Scablands/Ice_Age_Floods.pdf
- “Mystery of the Megaflood.” NOVA: pbs.org/wgbh/nova/megaflood
    - Teacher’s Guide: pbs.org/wgbh/nova/teachers/programs/3211_megafloo.html
    - Good information page: pbs.org/wgbh/nova/megaflood/fantastic.html

Videos

- "Columbia River Gorge Geology." (22:21). HugeFloods: youtu.be/w7eqBtc2tv0
- "Erratic Boulders - Rafted in Icebergs by the Ice Age Floods." (2:36). HugeFloods: youtu.be/kL_h-dJ_wdo
- "The Floods." (6:17). KSPS Documentaries (PBS): pbs.org/video/floods-hp8otm
- "Glacial Lake Missoula." (30:59). Ice Age Flood Institute: youtu.be/8w_uTgXv-0c
- "Glacial Lake Missoula." (18:51). HugeFloods: youtu.be/wJo8m4oKc6k
- "How 7,000 Years of Epic Floods Changed the World." SciShow: https://youtu.be/YWZgfPGtQEs
- "Ice Age Floods, Lake Missoula, Bonneville Flood and the Columbia River Basalts." (16:17). HugeFloods: youtu.be/i1BFb_uYlFQ
- "Ice-Rafted Erratics and Bergmounds." (4:56). Ice Age Floodscapes: youtu.be/RHaXQigQE08
- "Killer Floods." (54:10, especially the clips about the Scablands that start at 7:15 and 20:15; huge MT ripples discussed at 27:00 with good visuals; collapse of the ice dam explained with good visuals at 29:15). NOVA, PBS (you may need to be a member with a PBS Passport account to view): pbs.org/wgbh/nova/video/killer-floods. The video is available on Netflix at netflix.com/title/81121182 and in a lower resolution at dailymotion.com/video/x6c4qdr.
- "The Massive Flood That Triggered an Ice Age." SciShow: youtu.be/qMVhR26NRsk
- "Missoula Floods Video: An Animated Illustration of One Scenario." (3:50). DK Merrick: youtu.be/G_LRo3wIT34
- "Scupted by Floods." (56:58). KSPS Documentaries (PBS): pbs.org/video/ksps-documentaries-sculpted-by-floods-the-northwests-ice-age-legacy

Standards

- More information about the Next Generation Science Standards, including a link to the *Framework for K-12 Science Education* to which this lesson was aligned: nextgenscience.org/framework-k%E2%80%9312-science-education.
- More information about the Common Core State Standards and links to the complete documents: corestandards.org

Name: ___________________________________ Period: ____ Date: ___________________

Mystery of the Channeled Scablands

He couldn't understand how the towering cliffs carved through basalt could have gotten there. How about huge erratics (random boulders) that were far south of the glacial edge during the ice ages? These were two of the many questions swirling in the mind of J Harlen Bretz in the 1920s. He thought it would be impossible for normal rivers—or even enormous glaciers like those of the ices ages—to ever create landscapes of such magnitude. The only explanation that made sense to him was that a cataclysmic flood hundreds of feet high had swept through the area.

When Bretz presented his theory to renowned geologists, they thought it was ridiculous. They argued that the formations he described were caused by uniform erosion of glaciers and liquid water.

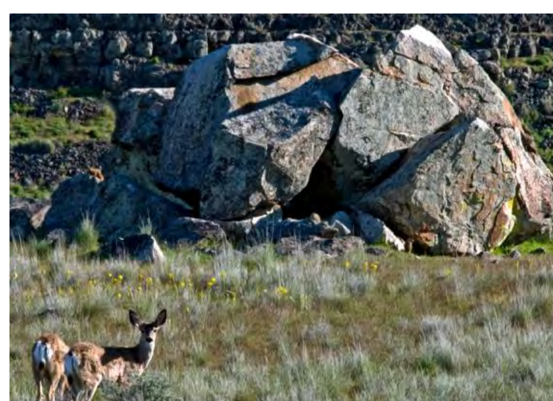
Writing about the Channeled Scablands of Eastern Washington, Bretz said, "The channels run uphill and downhill, they unite and they divide, they head on the back-slopes and cut through the summit; they could not be more erratically and impossibly designed." Bretz knew he was right, but there were missing pieces of the puzzle that he needed to prove his theory. The most important of these was, "Where could that much water have come from?"

1. **Where do YOU think that much water could have come from?** Brainstorm your ideas below in words and pictures. Record your theories before you read more.

Dry Falls, Grand Coulee, WA: Its 400-foot (122-meter) cliffs were once the site of the largest waterfall in the world.
commons.wikimedia.org/wiki/File:Dry_Falls_(Washington).jpg

J Harlen Bretz, revolutionary scientist
creationwiki.org/File:Harlen_Bretz.jpg

Channeled Scablands, Washington
flickr.com/photos/noaaphotolib/5436016515



Erratics south of glacial edge in Washington
Screenshot from "Erratic Boulders" by permission: youtu.be/kL_h-dJ_wdo

Around the same time, a geologist named Joseph "J.T." Pardee found evidence of a massive 2,000 cubic kilometer (500 cubic mile) glacial lake near Missoula, Montana. Pardee realized his Glacial Lake Missoula formed when a massive wall of ice in Idaho trapped glacial meltwater behind it as a dam.

Pardee never wrote about how the lake eventually drained, but he knew the water had gone somewhere. Even without evidence of a break in the ice dam, Bretz gradually accepted that Glacial Lake Missoula was the most likely source of the cataclysmic flood he proposed, but most geologists still dismissed his ideas.

Geologist Joseph "J.T." Pardee
en.wikipedia.org/wiki/Joseph_Pardee#/media/File:Joseph_Pardee_1909_portrait.jpg

Areas of the Ice Age Floods that occurred about 18 - 15,000 years ago (and their source—Glacial Lake Missoula).
Adapted with permission from a screenshot in "Glacial Lake Missoula": youtu.be/wJo8m4oKc6k. Check it out!

2. Is the place where you live shown on this map? Would your home have been under cataclysmic flood waters and/or the Cordilleran Ice Sheet about 15,000 years ago?

3. What modern rivers flow through sites of the Ice Age Floods?

4. In what ways might the Ice Age Floods have created the dramatic landscapes around these rivers?

Bretz's theory was the simplest explanation for the Channeled Scablands, but he still needed evidence of a break in the ice dam. Pardee, like his glacial lake, released a forceful new piece of evidence in 1940. Camas Prairie in Montana contained hills that looked exactly like the ripple marks in a fast-moving stream—except these giant ripples were 15 meters (50 feet) high and 150 meters (500 feet) apart. Only a sudden release of incredible amounts of water could have made these!


Massive ripples, Camas Prairie, Montana (note 18 wheeler truck for scale)

Image by Tom Foster, shared via Creative Commons: flickr.com/photos/ice_age_floods/2913196137

During excavation for the Grand Coulee Dam, geologists found underwater gravel deposits and more giant ripple marks made by incredible currents of water throughout the Columbia Basin. Bretz came back to examine the area again and noticed that irregular weathering on certain buttes indicated that multiple floods had occurred, some smaller than others. Lake Missoula's ice dam must have broken and reformed as the ice sheet retreated and advanced again. This happened about 15,000 years ago, when the Channeled Scablands were carved.


Newly completed Grand Coulee Dam, 1942

It wasn't until the launch of the Landsat satellite imagery system in 1972 that all doubt was removed. The images taken from space looked exactly like Bretz's hand-drawn maps of the Channeled Scablands. Millions of miles away, the Mariner 9 spacecraft was also taking pictures of cataclysmic flood scablands–on Mars. Bretz's ice age flood theory was now fully supported. The mystery was solved, 50 years after his revolutionary ideas were first dismissed. Bretz lived to receive the praise of the Geological Society of America, receiving the Penrose Medal in 1979, their highest award.

5. Where do you think the image above was taken? What evidence of dramatic events do you observe that transformed the landscape?

Today, geologists continue to investigate other mysteries about the Ice Age Floods. For instance:

- How many floods were there?
- Could there have been ice dams that burst in what is now Washington to unleash other cataclysmic floods?

6. What evidence could you look for to help solve the continuing mysteries?

Exploring Evidence of Ice Age Floods

Overview

Perhaps the best way to engage your students and inspire them to learn more about the Ice Age Floods is by taking them on more in-depth field studies to investigate evidence first hand. This lesson provides activities you might conduct during field studies, as well as steps to prepare for the field work and supporting activities.

- We suggest you first present the features you observe during your field studies as mysteries for the students to decode. They can work in pairs or small groups to apply what they have been learning in the unit to explain observable geologic features, recording their ideas and illustrations in field journals or science notebooks.
- Discuss student theories as a class, with you and/or a local expert clarifying their ideas, answering questions, and helping them build understanding about how your local landforms were created.
- Additional options include a story to help students imagine what it would have been like to be in the area at the time of a catastrophic flood, a modeling activity that can be done in the outdoor environment and compared to evidence of the Ice Age Floods, and photojournalism that can be shared with your local community. A variety of other Enrich / Extend activities are listed to help you meet the needs of all learners.

Subjects: Science, Writing, Speaking & Listening, Art, Environmental Education

Grades: Adaptable for K–12

Duration: 40 minutes or more, plus travel time to and from your field study site(s)

Vocabulary

- Cataclysmic
- Channeled Scablands
- Columbian mammoth
- Erosion
- Erratics
- Glacial Lake Missoula
- Ice dam
- Ice Age Floods
- Mastodon
- Saber-toothed cat

Guiding Questions

- What evidence of Ice Age Floods can we find in our local areas?
- How were observable features such as huge erratic rocks, canyons, cliffs, and giant ripples in the earth added to our environment and/or created?
- How do those observable features compare to other phenomenon we can observe, such as those formed by flowing water on a smaller scale?

Erratics south of glacial edge in Washington
Screenshot from "Erratic Boulders" video used by permission: youtu.be/kL_h-dJ_wdo

Objectives

- Students will visit an area with evidence of Ice Age Floods and try to decode the mysteries of how the geologic features were formed, recording their observations.
- Students will discuss their theories about the causes of the geologic formations orally with a partner or small group and as a class.
- Students will read (or listen to) a story to help them imagine what it would have been like to be in the area at the time of a catastrophic flood and create illustrations of what the site might have looked like back then after the flood waters receded and now.
- Students will orally discuss critical thinking questions outside at the field site.

The Columbia River Gorge has breathtaking views—and dramatic evidence of Ice Age Floods.
Wikimedia Commons:
commons.wikimedia.org/wiki/File:Columbia_river_gorge_from_crown_point.jpg

Next Generation Science Standards + Common Core State Standards		
NEXT GENERATION SCIENCE STANDARDS	**Performance Expectations** We suggest you tailor the lesson to meet the PE(s) for your grade level.	**2-ESS2-2.** Develop a model to represent the shapes and kinds of land and bodies of water in an area. **2-ESS1-1**. Use information from several sources to provide evidence that Earth events can occur quickly or slowly. **4-ESS1-1**. Identify evidence from patterns in rock formations and fossils in rock layers to support an explanation for changes in a landscape over time. **5-ESS2-1**. Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact. **MS-ESS2-2**. Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales. **MS-ESS3-1**. Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes. **HS-ESS2-1**. Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.

	Crosscutting Concepts	• Cause and Effect • Energy and Matter • Patterns • Scale, Proportion, and Quantity • Stability and Change • Systems and System Models
	Science & Engineering Practices	• Developing and Using Models • Constructing Explanations and Designing Solutions • Engaging in Argument from Evidence • Obtaining, Evaluating, and Communicating Information
	Disciplinary Core Ideas	**ESS1: Earth's Place in the Universe** **ESS2.A: Earth's Materials and Systems** **ESS2.D: Weather and Climate** **PS1: Matter and Its Interactions**

Common Core State Standards English Lang. Arts COMMON CORE STATE STANDARDS INITIATIVE PREPARING AMERICA'S STUDENTS FOR COLLEGE & CAREER	**Writing**	4, 10
	Speaking & Listening	1, 2
	Language Standards	1, 2, 3, 6
	Writing Standards Science & Technical Subjects	4, 7, 10
Math CCSS	Math can be incorporated to meet the standards at your grade level and/or to reinforce concepts learned previously. See the Enrich / Extend section for ideas.	

Teacher Background

- Read "When the Floods Came" student reading/activity at the end of the lesson.
- Watch one or more of the videos listed in the lesson, such as "Glacial Lake Missoula" (18:51): youtu.be/wJo8m4oKc6k.
- Review the information in the previous lessons about erosion, glaciers, rocks and how they were formed, and stories/theories of the formation of Northwest landscapes.

Name: ______ Period: ___ Date: ______

When the Floods Came

It is 13,000 B.C.E. and you are stalking prey high above the river. A hungry saber-toothed cat—a *Smilodon*—you are using the cover of tall grass and strong winds blowing in the other direction to sneak up on a young mastodon. Just as you are about to pounce, you hear a tremendous roar, much louder than anything you have ever heard, coming from down by the river. Terrified, you bound up the mountain for higher ground and don't stop until your legs and lungs burn with exhaustion.

When you look back down toward where you had been hunting, it is covered in rushing flood waters. Whole trees have been swept up, and they are barrelling down through the engorged river like sticks. The water is a deep brown from the land that has been swept away, too, and a massive iceberg rams through with the trees and other debris, a catastrophic torrent of massive muck.

As the bursting river is forced around a bend, the iceberg is rammed into the hillside with tremendous force—**"CRAAAAAASH!"** The shock waves travel up through the ground under your paws. You jump with terror and scramble up still higher toward the top of the mountain. From your high vantage point, you can see animals being swept by in the cataclysm below: enormous full-grown woolly mammoths, mastodons, and giant bison with horns more than 2 meters (7 feet) long.

You keep watching the nightmarish scene below, until you can't keep your eyes open and you are asleep. When you wake, the flood waters are still rushing by with the same unbelievable force, but the iceberg has been pushed up onto the mountainside and lodged there. Your hunger pangs and curiousity get the better of you, and you cautiously make your way down toward the water's edge to see if anything edible might have gotten lodged there, too.

As you approach the iceberg, you hear the faint sound of an animal in distress, barely audible above the roar of rushing water. You leap off in that direction, and the sound grows louder as you near the other side of the pyramid of ice. Slowing your pace, you creep forward until you see it. The rushing torrent has slammed a giant bison into the ice with enough force that one of its gigantic horns has become stuck in it. It is struggling to break free, but it can't get traction on the slippery ice, mud, and rushing water surging past its hind legs.

It's a deadly risk, but if you don't eat, you'll die. You creep toward the preoccupied beast, and when you are close enough to strike, do so without hesitation. With one giant leap you reach your prey with a tremendous roar and gnashing of your sword-like teeth. The buffalo's throat is severed and you jump back out of danger before it even knows what has happened. It bleeds out quickly from your expert incisions, and when it stops moving, you approach your feast. This, too,

Materials + Preparation

- Prepare to take your students to one or more areas with evidence of Ice Age Floods:
  - Experts from the following groups may be available to give your students a tour: Ice Age Floods Institute (IAFI), National Park Service, a local tribe, Univ. of Idaho Ext., WA Dept. of Geology, Oregon State Univ. Ext. Service, the

Bureau of Land Management (BLM), etc. Local chapters and experts of IAFI are listed at iafi.org/local-chapters.

- Sites along the Ice Age Floods National Geologic Trail, such as those listed here: nps.gov/iafl/planyourvisit/placestogo.htm.
- Many more great locations to take your class can be found on an interactive map from the Ice Age Floods Institute: iafi.org/floodscapes.
- Lake Roosevelt National Recreation Area: nps.gov/laro
- Dry Falls—once the world's largest waterfall: parks.state.wa.us/251/Dry-Falls
- Tualatin, OR has a fossilized partial skelet of a mastodon and outdoor sites to visit: willamettevalleypleistocene.com/tualatir ice-age-trails. More about the mastodon: tualatinoregon.gov/community/tualatins mastodon and tualatinoregon.gov/sites/default/files/file tachments/community/page/4810/mastc on.pdf

Artist's depiction of a mastodon next to a human for scale
Wikimedia Commons: commons.wikimedia.org/wiki/File:Mastodon%2BHuman.jpg

- Ice Age Floods erratics found in a nearby area.

- Make copies of the "When the Floods Came" reading/activity for each student. You can save the copies for future classes by having students answer questions/illustrate in field guides or science notebooks, rather than directly on the sheets.
- *Optional:* Review the sources and watch the videos listed at the end of the lesson for additional background information. You could also share one or more of the videos with your students and discuss them.

Teaching Suggestions in the 5E Model

Engage

1. **Prepare the students to participate in a field study outdoors.** (10 min. or more)
   - Do this a week or more before the planned exploration and pass out a field study permission/photo release form, such as the one provided at the end of the curriculum. Tell them how excited you are to take them to your favorite site(s), but that they won't be able to come unless they return the form signed by a parent or guardian.
   - Tell students the goal for the field study and discuss the behaviors that will enable a successful outdoor exploration as a class.
   - Consider doing a short field study in the schoolyard until trust is built and student behavior is appropriate for outdoor learning. Scavenger hunts, journaling, scientific sketching, and observing nearby geologic features, plants, and wildlife such as birds and insects are all activities that can be done outdoors yet close to the classroom.

- Remind students of procedures and behaviors that will be needed for the trip, such as “low-impact sight, sound, touch,” “walk in a single file,” etc.
- Always clarify just before leaving what the activities and expectations are for the field study (e.g. count and record, identify, observe, sketch, listen).
- When you arrive, show the students around the site and discuss rules to stay safe.
- Point out boundaries to students at the edge of where they can explore.
- Work with students to pass out any materials to the class, either before you leave the classroom or at the site.

2. **Show a short video clip and ask students if the scenario is realistic.** (1–2 min.)

    - Show students a short clip of an ice dam breaking and/or a cataclysmic flood, such as this one in *Ice Age 2: The Meltdown* (0:53): youtu.be/um7PIAxYpJI.
    - Ask them if the phenomena of the ice dam bursting and causing a cataclysmic flood could have actually happened, and how they might investigate the question at locations in the Northwest. Discuss how scientists do believe catastrophic floods flowed through the area, caused by the breaking of at least one ice dam and the sudden release of the water of Lake Missoula (that was the size of Lake Ontario—one of the Great Lakes) over a 2-day period.

Scene from *Ice Age 2: The Meltdown*
youtu.be/um7PIAxYpJ

    - Tell students that you will visit an area with evidence of cataclysmic Ice Age Floods so they can investigate the clues.

3. **Visit an area with evidence of Ice Age Floods and ask students to record theories about how geologic phenomena were created.** (Will vary)

    - Prepare to take your students to one or more areas with evidence of Ice Age Floods.
        - Ideally get the support of an expert, such as those available from the Ice Age Floods Institute: iafi.org/local-chapters.
        - Many great locations to take your class can be found on an interactive map from the Ice Age Floods Institute: iafi.org/floodscapes.
        - Sites along the Ice Age Floods National Geologic Trail are listed at nps.gov/iafl/planyourvisit/placestogo.htm, such as:

- Shoshone Falls, ID: tfid.org/309/Shoshone-Falls
- Lake Roosevelt National Recreation Area: nps.gov/laro
- Dry Falls—once the world's largest waterfall: parks.state.wa.us/251/Dry-Falls

Shoshone Falls, ID

Frank Schulenburg, Wikimedia Commons: en.wikipedia.org/wiki/Shoshone_Falls#/media/File:Shoshone_Falls,_Idaho.jpg

- Discuss safety considerations and remind students about appropriate behaviors. Discuss any signals you will use to communicate in the field.
- During the field study, ask the students:
  - "What (phenomenon) caused this?" (Reinforce the word "phenomenon" if they are familiar with it, or leave it out for very young students.) For example, you might be exploring Ice Age Floods erratics found in a nearby area.
  - Include questions specific to the site, such as:
    - "Did you know that glaciers did not spread this far south during the last Ice Age? How could what look like huge glacial erratics have gotten here?" Ask the students to turn to a partner and discuss their ideas about what might explain these strange phenomena. They should record their ideas in science notebooks and support them with evidence from the site and details they have been learning in class over the course of the Ice Age Floods unit.
    - "How could those enormous ripples have appeared in the ground?"
    - If you visit Dry Falls, WA or a similar area: "How did those towering cliffs 400 feet (122 meters) high get there?"
    - Ask questions about additional geologic features beyond those created by the floods, such as:
      - How did the rocks form that created those cliffs? What types of rock(s) are they made of?
      - How was this valley created?
    - After students have had a chance to discuss these ideas and explore with a partner or small group, you might ask them to observe quietly on their own, recording their ideas in field journals.

Explore

3. **Students read about amazing phenomena caused by Ice Age Floods and draw/label their effects.** (5–15 min.)

    - Find a good place for students to sit and/or stand to read a story based on historical evidence, such as "When the Floods Came," found at the end of the lesson. Pass out copies of the reading/activity to each student. Ask them to read it and complete the activities with a partner or small groups of 3–4. For grade K – 3 students you might read it as a class or tell the students the story.
    - Tell them that they should complete the questions/drawings on the handouts and/or in science notebooks if you would like to reuse the handouts or provide them with more space for their illustrations.
    - Circulate to answer any questions. When a group finishes reading and answering the questions, give them options for activities to deepen their knowledge of and interest in Ice Age Floods, such as those listed in the Enrich / Extend section.

4. **Have students explore the effects of erosion first hand if you are in an area near a stream or river.**

    - For example, they could look for patterns along the edge of a flowing stream or river and compare them to the dramatic geologic features created during the Ice Age Floods.
    - If you are in a sandy area, such as a beach, or an area with loose dirt, students could experiment with pouring water over an area—a gentle shower and a simulated flood.
    - Ask them to reflect on the crosscutting concept of cause and effect and write about it in science notebooks/field guides. For example, how water travels via the path of least resistance and settles in areas of lower elevations relative to the system in which it moves. (It travels from areas of high potential energy (those that are high/steep) to lower areas, creating different landforms as the force of the water moves the earth.)
    - Students can draw and label models of their experiments in science notebooks. Then students can compare their results to evidence of the Ice Age Floods that you observe during the field study.

Explain

5. **Discuss the concepts presented in the activity and student ideas.** (5–10 min.)

- Discuss the activity with questions such as those below.
    - How is the evidence of cataclysmic floods we have seen at this site and in our classroom studies similar to and different from the descriptions in the story?
    - How did the large erratic boulders get here? (They were part of huge icebergs that floated through the area and melted.)

- "How could those enormous ripples have appeared in the ground?" (The incredible amounts of flowing water created them, like ripples in a stream, but on a much larger scale. They can be observed in areas throughout the flood zone in places as far away as Montana and Vancouver, WA. A good analysis with images of Vancouver is found in the *GigaFloods* book chapter by Rick Thompson available free online (with images of the ripples on pages 12 – 13): gigaflood.com/Giga%20Flood%20Chapter%208.pdf.
- "How did those towering cliffs 400 feet (122 meters) high get there?" (signs of a massive waterfall—the largest the world has ever seen—and tremendous amounts of water rushing with incredible force at more than 100 km/hour)
- How did the rocks form that created those cliffs? What types of rock(s) are they? (They may be volcanic basalt—the most common rock in the Northwest due to our intense periods of vulcanism with enormous lava flows millions of years ago.)
- How was this valley created? (If there is a river at the bottom of it and it is V-shaped, the river also carved the valley, in addition to the floods; if you are farther north in northern Idaho, for instance, and it is U-shaped, a glacier likely also carved the valley. Ask local experts.)

Some of the discussion questions can be presented as a game, in which groups compete to answer the most questions correctly. This will reinforce what they have been learning in a fun way during your memorable field studies. These might include:

- What caused the huge amounts of water to flow so fast and powerfully that it was capable of moving icebergs and carving cliffs in solid rock? (breaking of ice dam that allowed Glacial Lake Missoula to drain suddenly)
- Do you remember the name of the first scientist that had the theory of the catastrophic flood, and what was the evidence of it? (J. Harlen Bretz: Channeled Scablands, massive cliffs carved in solid rock, huge plunge pools, huge erratics far south of the former glacial edge, etc.)
- What is the term we use to describe Bretz's revolutionary theory for how the dramatic landforms of the Channeled Scablands, Columbia Gorge, and Willamette Valley were carved? (catastrophism)
- What evidence at this site supports Bretz's theory?
- What did J.T. Pardee find near Missoula, MT that helped support Bretz's theories? (evidence of Glacial Lake Missoula that could have provided the massive amounts of water for Bretz's proposed flood)
- What modern rivers flow through sites of the Ice Age Floods? (Columbia, Snake, Yakima, Clark Fork) In what ways might the Ice

Age Floods have created the dramatic landscapes around these rivers? (incredible amounts of erosion that carved the Grand Coulee and Columbia River Gorge, deposits of huge erratics, Channeled Scablands, ripples several meters high in Montana and elsewhere)

  - How, specifically, were these huge erratics moved here during the Ice Age Floods? Discuss how it was primarily by floating downstream in huge icebergs. When the icebergs finally melted, the boulders remained.

  - How might the students be able to help solve the continuing mysteries of the Ice Age Floods, such as how many there were and whether ice dams could have burst in Washington, too? (they could look for more evidence of repeated floods, like huge cutout grooves in cliffs at different heights and evidence of floods in different areas)

6. **Students can document the site as photojournalists to share what they learned.** (5 – 10 min.)

   - Ask students to take photographs and/or illustrate the area's geologic features. These can be used with their notes from the field study to create articles that can be shared with the rest of the school and/or broader community.

   - You might also ask the students to make community presentations about their field studies. If so, provide a rubric such as the one at the end of first lesson in the curriculum so students know the key areas they should focus on.

Extend / Enrich

- **Students can record the GPS coordinates of the features they observe.** (5 min.)

  These can be incorporated into maps, as described in the next activity option. In addition to standalone GPS devices, smartphone apps are also available, such as "Record my GPS position," a free app for iPad/iPhone, Android, and Windows phone.

- **Ask students to create maps and/or research more about the locations they visited.** (15 min. or more)

  - Students can explore Ice Age Flood sites near your school and other areas they may have visited—or would like to visit—at the Ice Age Floods Institute's interactive map: iafi.org/floodscapes. They can record details about at least 5 interesting locations in science notebooks or electronically.

  - Students can create their own hand-drawn or computer-generated maps with the locations they chose to help tell the story of the evidence of Ice Age Floods found in your area (or another area they are most interested in). A video which explains how students and/or you can create your own interactive Google Maps is at youtu.be/Az-Qg6fzcw8.

  - Completed projects can be presented to the class and/or displayed on classroom or school walls to help teachers and other students learn about the cataclysmic Ice Age Floods and how they are still in evidence today in area landscapes.

- **Have students create journals prior to visiting the field site.** (10 min.)
    - Find a Field Journaling lesson, including a description of one way to make a journal, in the list of "Rangeland Plants" lessons on the Idaho Rangeland Resource Commission's website: idrange.org/education-2/lessons-and-activities. Cornell's BirdSleuth site also has excellent information on nature journaling: www.birdsleuth.org/nature-journaling.
    - You might share excerpts of the journals of Lewis and Clark, such as these from May 3, 1806, on their way upriver: lewisandclarkjournals.unl.edu/item/lc.jrn.1806-05-03#lc.jrn.1806-05-03.01.
- **Incorporate elements of *10-Minute Field Trips* by Helen Ross.**

  It could be especially helpful if you do short preparatory studies with your students. The full-text article of *10-Minute Field Trips: A Teacher's Guide to Using the Schoolgrounds for Environmental Studies* is here: eric.ed.gov/?id=ED344732.
- **More Ice Age Floods mapping activities are explained in the "Glacial Lake Missoula Nature Discovery Traveling Trunk" curriculum.**

  It is freely available from the Montana Natural History Center website: montananaturalist.org/wp-content/uploads/Glacial-Lake-Missoula-Curriculum-1.pdf.
- **Ask students to create a poem, such as a haiku, to go with their observations, etc.**
- **Students choose interesting animals to research that lived (and went extinct) during this period.**

  See details about ways to organize projects in the Enrich / Extend section at the end of the previous lesson.
- **Students can create new games that help other students explore evidence of Ice Age Floods.**

  Encourage them to use information such as what they learned during their field studies to create engaging game boards, cards, and/or other resources to make the games more fun and educational.
- **Show a video to help you explain interesting nearby phenomena.**

  Several interesting Oregon Field Guide videos are listed on the "Take A Virtual Roadtrip Through Oregon's Fascinating Geology" page from Oregon Public Broadcasting (OPB): opb.org/news/article/geology-oregon-thunder-eggs-caves-canyons-waves. "Columbia Gorge Geology Tour" is one good option: opb.org/television/video/orf-2810-02-digi.
- **Read non-fiction articles with your students about the floods and evidence for them, such as those listed at the end of the lesson.**

Evaluate

7. **Ask students to reflect in writing about their field study.** (5–15 min.)
    - Ask students to write in journals or science notebooks about the site(s) and their experience there. Ideally this can be done at the field site, if time allows, but it can also be done back in the classroom.

- Provide prompts that help them go beyond the basic geologic features, such as:
  - Use all your senses as you reflect on the site. What sights, sounds, smells, etc. will you want to remember about the place?
  - What might it have been like here thousands of years ago when the Ice Age Floods came through?
  - What might it have been like millions of years ago when these rocks were formed?
  - What was it like to be on your own in nature, observing quietly? What did you like and not like about it? Did it help you to make more complete observations? If so, why?
  - How does your study of nature compare to other places where you spend time?

8. **Have students think about and discuss some or all of the questions above as a "Think, Pair, Share" activity.**

   Students can record their ideas in science notebooks.

9. **Review student notebooks, completed handouts, and any other projects**.

   Display completed student projects, such as maps and annotated illustrations, to celebrate their work and teach others about Ice Age Floods and how they transformed our landscapes.

Expand Knowledge + Skills

Background on Ice Age Floods + Geology

- Allen, J.A., Burns, M., and Burns, S. (2009). *Cataclysms on the Columbia: The Great Missoula Floods (2nd Ed.)*. https://books.google.com/books?id=jeTESR-vvJ4C
- Baker, V.R. (1978). *The Channeled Scabland: A Guide to the Geomorphology of the Columbia Basin*. books.google.com/books?id=4PIt1U-o3oQC
- "Glacial Lake Missoula." Tom Foster: hugefloods.com/LakeMissoula.html
- "An Introduction to the Ice Age Floods." Ice Age Floods Institute: iafi.org/about-the-ice-age-floods/introduction
- "J Harlen Bretz." Wikipedia: en.wikipedia.org/wiki/J_Harlen_Bretz
- O'Connor, J.E., & Costa, J.E. (2004). "The World's Largest Floods, Past and Present." pubs.usgs.gov/circ/2004/circ1254/pdf/circ1254.pdf
- "Saber-toothed Cats." National Park Service: nps.gov/whsa/learn/nature/saber-toothed-cats.htm
- Weis, P.L., & Newman, W.L. (1976). *The Channeled Scablands of Eastern Washington: The Geologic Story of the Spokane Flood.* npshistory.com/publications/geology/inf/72-2/index.htm

Resources on Field Studies Locations

- "Erratic Behavior on Rattlesnake Mountain." Bruce Bjornstad: 12c2f97e-e9de-9620-eeb5-c0d53388ee06.filesusr.com/ugd/12afd0_5add5fc658c0e0ec2bd4617da40bc059.pdf

- "Field Trip Guides." Ice Age Floods Institute: iafi.org/general-reference-media/field-trip-guides
- "Ice Age Floods National Geologic Trail: Places to Go." National Park Service: nps.gov/iafl/planyourvisit/placestogo.htm
- "Ice Age: The Link to the Columbia Gorge." Columbia Gorge Discovery Center: gorgediscovery.org/discover/exhibits-programs/ice-age/
- Soennichsen, J. *Washington's Channeled Scablands Guide: Explore and Recreate Along the Ice Age Floods National Geologic Trail*. Mountaineers Books: books.google.com/books?id=ywRkHH3GVRoC

Lessons / Units

- "Floods! Erosion by Water." Illinois Mathematics and Science Academy: digitalcommons.imsa.edu/cgi/viewcontent.cgi?article=1001&context=model_ngss_lessons_4_5
- "Glacial Lake Missoula Nature Discovery Trunk Curriculum." Montana Natural History Center: montananaturalist.org/wp-content/uploads/Glacial-Lake-Missoula-Curriculum-1.pdf
- "The Ice Age Floods Through the Western Channeled Scablands." Bruce Bjornstad: web.gps.caltech.edu/~mpl/Ge121a_Scablands/Ice_Age_Floods.pdf
- "Mystery of the Megaflood." NOVA: pbs.org/wgbh/nova/megaflood
  - Teacher's Guide: pbs.org/wgbh/nova/teachers/programs/3211_megafloo.html
  - Good information page: pbs.org/wgbh/nova/megaflood/fantastic.html

Videos

- "Columbia River Gorge Geology" (22:21). HugeFloods: youtu.be/w7eqBtc2tv0
- "Erratic Boulders - Rafted in Icebergs by the Ice Age Floods" (2:36). HugeFloods: youtu.be/kL_h-dJ_wdo
- "The Floods" (6:17). KSPS Documentaries (PBS): pbs.org/video/floods-hp8otm
- "Glacial Lake Missoula" (18:51). HugeFloods: youtu.be/wJo8m4oKc6k
- "Glacial Lake Missoula" (30:59). Ice Age Floods Institute: youtu.be/8w_uTgXv-0c
- "Ice Age Floods, Lake Missoula, Bonneville Flood and the Columbia River Basalts" (16:17). HugeFloods: youtu.be/i1BFb_uYlFQ
- "Ice-Rafted Erratics and Bergmounds" (4:56). Ice Age Floodscapes: youtu.be/RHaXQigQE08
- "Missoula Floods Video: An Animated Illustration of One Scenario" (3:50). DK Merrick: youtu.be/G_LRo3wIT34
- "Sculpted by Floods" (56:58). KSPS Documentaries (PBS): pbs.org/video/ksps-documentaries-sculpted-by-floods-the-northwests-ice-age-legacy

Standards

- More information about the Next Generation Science Standards, including a link to the *Framework for K-12 Science Education* to which this lesson was aligned: nextgenscience.org/framework-k%E2%80%9312-science-education.
- More information about the Common Core State Standards and links to the complete documents: corestandards.org

Name: ____________________________________ Period: ____ Date: ____________________

When the Floods Came

It is 13,000 B.C.E. and you are stalking prey high above the river. A hungry saber-toothed cat—a *Smilodon*—you are using the cover of tall grass and strong winds blowing in the other direction to sneak up on a young Columbian mammoth. Just as you are about to pounce, you hear a tremendous roar, much louder than anything you have ever heard, coming from down by the river. Terrified, you bound up the mountain for higher ground and don't stop until your legs and lungs burn with exhaustion.

When you look back down toward where you had been hunting, it is covered in rushing flood waters. Whole trees have been swept up, and they are barrelling down through the engorged river like sticks. The water is a deep brown from the land that has been swept away, too, and a massive iceberg rams through with the trees and other debris, a catastrophic torrent of massive muck.

As the bursting river is forced around a bend, the iceberg is rammed into the hillside with tremendous force—"**CRAAAAAASH!**" The shock waves travel up through the ground under your paws. You jump with terror and scramble up still higher toward the top of the mountain. From your high vantage point, you can see animals being swept by in the cataclysm below: enormous full-grown Columbian mammoths, mastodons, and giant bison with horns more than 2 meters (7 feet) long.

You keep watching the nightmarish scene below, until you can't keep your eyes open and you are asleep. When you wake, the flood waters are still rushing by with the same unbelievable force, but the iceberg has been pushed up onto the mountainside and lodged there. Your hunger

pangs and curiousity get the better of you, and you cautiously make your way down toward the water's edge to see if anything edible might have gotten lodged there, too.

As you approach the iceberg, you hear the faint sound of an animal in distress, barely audible above the roar of rushing water. You leap off in that direction, and the sound grows louder as you near the other side of the pyramid of ice. Slowing your pace, you creep forward until you see it. The rushing torrent has slammed a giant bison into the ice with enough force that one of its gigantic horns has become stuck in it. It is struggling to break free, but it can't get traction on the slippery ice, mud, and rushing water surging past its hind legs.

It's a deadly risk, but if you don't eat, you'll die. You creep toward the preoccupied beast, and when you are close enough to strike, do so without hesitation. With one giant leap you reach your prey with a tremendous roar and gnashing of your sword-like teeth. The buffalo's throat is severed and you jump back out of danger before it even knows what has happened. It bleeds out quickly from your expert incisions, and when it stops moving, you approach your feast. This, too, is a terrible risk, with the debris-filled flood waters flowing past so quickly, but hunger impels you back.

As you chomp down on the delicious free range buffalo meat, you keep your eyes on the flood waters and have to leap back more than once as massive trees more than 100 meters (330 feet) flow past too close for comfort with calamatous noises of destruction. But your hunger keeps sending you back until your stomach fills to bursting. You climb back up to higher, drier ground and rest in a grove of pine trees.

You stay nearby the buffalo carcass for more than a week, venturing down the hill each day to gorge yourself on the tasty meat. Gradually, the flood waters subside a bit and warm summer sunlight begins to melt the iceberg. The bison—now mostly just bones thanks to the handiwork of your serrated steak-knife teeth—is now firmly on dry land and you can survey the scene as you finish your breakfast. Towering ridges of mud can be seen nearby, 10 times taller than your muscular frame, formed by the torrential waters as they flowed over the land. Vast sections of hillside have been torn away, creating cliffs where gentle slopes once stood. It is a scene of destruction, and you stride away on your powerful legs to seek better hunting grounds.

At the end of the summer, you make your way back to the area and survey the scene. Where the towering iceberg once stood there is now only a group of large boulders on a pile of sand. You leap up on top of one of the massive rocks 10 feet tall and lie down to sunbathe. The days and nights have been getting colder, and you don't know how many more perfect days you might have like this before the brutal winter returns. Sprawled out on your safe lookout, you doze off, marveling at how you survived the cataclysmic flood and now find yourself resting on this strange boulder that had appeared from nowhere.

1. **Where did the erratic boulders come from?**

2. **Draw and label a picture below or on separate paper of what the scene might have looked like at the end of the story.**

3. **Draw a present-day area with evidence of Ice Age Floods. Label the details that help us know that the area was covered in cataclysmic floods.**

Visionary Scientists + Their Discoveries

Overview

J. Harlen Bretz was just one of countless individuals who moved us forward on our path of scientific discovery. This lesson asks students to think about and discuss other visionary and/or revolutionary scientists, inventors, and mathematicians, then choose one to research and present about to the rest of the class.

Numerous ideas for visionaries are listed on the activity sheet at the end of the lesson, or students can select someone they have learned about elsewhere or that they know personally. Enrich / Extend options are listed, including ways to guide students through the process of developing their own scientific investigations and more ways to help cultivate the next generation of visionaries.

Guiding Questions

- Which visionary and/or revolutionary scientists and discoveries have had a transformative effect on our world?
- What has been the legacy of those influential people?
- In what ways can students pursue their interests in STEM fields?

Objectives

- Students will research and describe orally and in writing an individual with visionary and/or revolutionary ideas in their STEM field and how their discoveries have had a transformative impact.
- Students will be able to discuss the paths these influential people have taken and the obstacles they had to overcome to pursue their interests in STEM fields.
- Students will demonstrate skills in research, organizing information, presenting it to others, and working together collaboratively.

Subjects: Science, Speaking & Listening, Writing, Art / Design

Grades: Adaptable for K–12

Duration: Two 50-minute class periods or one long period; can be extended to a week or more to allow time for students to prepare engaging presentations and present to small groups

Vocabulary
- Chemist
- Engineer
- Geologist
- Inventor
- Legacy
- Life science
- Mathematician
- Physical science
- Physicist
- Programmer
- Revolutionary
- Visionary

Alfred Wegener (left) **+ Rasmus Villumsen in Greenland shortly before they perished during a harrowing scientific expedition**
Wikimedia Commons:
commons.wikimedia.org/wiki/File:Wegener_Expedition-1930_026.jpg

Next Generation Science Standards + Common Core State Standards		
Next Generation Science Standards	**Performance Expectations**	• Will vary based on the scientists studied and any Enrich / Extend activities conducted. • You can tailor the lesson to meet PE(s) for your grade level.
	Crosscutting Concepts	Will vary based on the scientists studied and any Enrich / Extend activities conducted.
	Science & Engineering Practices	• Engaging in Argument from Evidence • Obtaining, Evaluating, and Communicating Information
	Disciplinary Core Ideas	Will vary based on the scientists studied and any Enrich / Extend activities conducted.
Common Core State Standards English Lang. Arts	**Reading**	1, 2, 4, 9, 10
	Writing	1, 4, 10
	Speaking & Listening	1, 2, 4, 5, 6
	Language Standards	1, 2, 3, 6
	Writing Standards Science & Technical Subjects	4, 7, 10

Teacher Background

Most students are engaged by personal stories and tales of discovery and achievement, especially those in which the individuals needed to overcome significant challenges. The research and presentation projects, as well as the group Engage activity described below, tap into this natural affinity for learning about inspiring people. The activity also seeks to help breakdown stereotypes and help all students realize that they, too, can be visionary—perhaps even revolutionary—scientists, engineers, inventors, and mathematicians.

Florence Nightingale
Wikimedia Commons:
en.wikipedia.org/wiki/File:Florence_Nightingale._Coloured_lithograph._Wellcome_V0006579.jpg

Materials + Preparation

- Copies of the activity sheets found at the end of the lesson for each student:
  - "Visionary Scientists + Their Discoveries"
  - "Visionary Scientist Presentation" rubric
- Data projector and computer
- Access to Internet and/or library/classroom books for research
- *Optional:* Arrange for a visit to the school library and support from the school librarian and/or technology specialist.

- *Optional:* Take out books from the library about visionary scientists to have in your classroom. Engage and inspire students with artfully designed biographies, such as *Work it Girl: Mae Jemison*: goodreads.com/book/show/51198988-work-it-girl.

Teaching Suggestions in the 5E Model

Engage

1. **Options to engage students with scientific phenomena, activate prior knowledge, and stimulate critical thinking** (2–20 min.)

    - **Share an interesting phenomenon with students linked to a visionary scientist, inventor, or mathematician.** (2 min.)

        - One option is to show students simple computer code and the program it executes. Simple activities that provide an easy way to do this are available from the Hour of Code website**:** hourofcode.com**.**

        - Ask students if they know who invented and improved programming languages used to program our computers. Discuss how one of them was Grace Hopper, who also created the first compiler, which computer engineers use to convert programs into machine code that can be read and executed by a computer. Show them one or more pictures of her, such as this one in which she is leading a team of programmers on an early computer: flickr.com/photos/8212496@N06/493885707.

Admiral Grace Hopper leads Navy programming team
flickr.com/photos/8212496@N06/493885707

        - She achieved the rank of Rear Admiral in the U.S. Navy through decades of service there, an honor and level of responsibility achieved by only a select few, equivalent to a general in the U.S. Army, Air Force, or Marines. She retired at age 79—the oldest-serving officer in the U.S. military. Those roles, let alone her visionary achievements that helped revolutionize the field of computing, may not fit the stereotypes of what a computer scientist or high-ranking military officer looks like.

    - **Students select research subjects as a group.** (5–10 min.)

        - Ask students to form groups of 3–5. Tell them they must include at least 1 student they haven't worked with before/recently.

        - Pass out copies of the "Visionary Scientists + Their Discoveries" activity while they organize themselves. Reshuffle groups, if necessary, to ensure that the usual student cliques have at least one new person in them. (Ensure everyone feels included in their group.)

- Ask them to read the instructions on the activity sheet. They should each complete the following two steps in collaboration with each other:

    1. Check off all of the individuals they would like to learn more about. You might ask students to choose from among a smaller group of scientists depending on grade level and/or your particular goals for the lesson. Rick Reynolds can provide editable versions of the activity sheet and any other curriculum files if you would like to modify them: rick@engagingeverystudent.com.
    2. Rank them from 1 – 5. Ask them to rank only people that they do not know much, if anything, about. Encourage them to include at least one woman and one person of color (who is/was not Caucasian/white) in their lists. Explain that these are people that often had to overcome incredible obstacles like misogyny (prejudice against women), racism, and being made to feel that they did not belong among the established scientists, engineers, and inventors (who were mostly white men in the U.S. and Europe until recently). They deserve special recognition, because they often had to overcome tremendous obstacles.


Name: ______________________ Period: ____ Date: ______________

Visionary Scientists + Their Discoveries

The scientists, inventors, engineers, and mathematicians below helped change the world and/or our understanding of it. **Step 1:** Check off the people you would like to learn more about. **Step 2:** Rank your choices from 1–5 with numbers to the left of the check boxes. You will be creating a persuasive presentation about one of your top choices and how their contributions were visionary or revolutionary.

Earth + Space Science

- ☐ **Mary Anning**—self-taught paleontologist; important fossils finds
- ☐ **Aristotle**—spherical Earth; contributed to all scientific fields + philosophy
- ☐ **Florence Bascom**—volcanoes / volcanic rocks; cycles of erosion
- ☐ **Sophia Brahe**—accurate data supported heliocentrism; horticulture
- ☐ **J. Harlan Bretz**—catastrophic Ice Age Floods in Northwest
- ☐ **Georges Cuvier**—catastrophism; "father of paleontology"
- ☐ **Subrahmanyan Chandra**—black holes; structure and evolution of stars
- ☐ **Ernst Chladni**—meteoritics; acoustics
- ☐ **Nicholas Copernicus**—heliocentrism (Sun-centered universe)
- ☐ **Robert L. Folk**—sedimentary rocks; nanoparticles
- ☐ **Galileo Galilei**—observational astronomy; scientific method
- ☐ **Caroline Herschel**—discovered 8 comets and 14 nebulae
- ☐ **Stephen Hawking**—origin of universe; black holes
- ☐ **Johannes Kepler**—elliptical orbits; mathematics
- ☐ **Charles David Keeling**—Keeling Curve; anthropomorphic climate change
- ☐ **Maria Mitchell**—astronomer who discovered comet; sunspots
- ☐ **Pythagoras**—spherical Earth; mathematics
- ☐ **Adam Reiss**—dark energy; expanding universe
- ☐ **Charles Richter**—earthquake prediction / Richter scale
- ☐ **Vera Rubin**—galaxy rotation; data to support theory of dark matter
- ☐ **Neil deGrasse Tyson**—cosmology, science education
- ☐ **Charles D. Walcott**—stratigraphy (study of rock layers); ancient species
- ☐ **Alfred Wegener**—plate tectonics / continental drift

Life Science

- ☐ **Frances Arnold**—bioengineering / directed evolution
- ☐ **Elizabeth Blackwell**—first female M.D. in U.S.; hospital for women + children
- ☐ **Elizabeth Blackburn**—telomeres, molecular biologist
- ☐ **George Washington Carver**—agricultural scientist / inventor
- ☐ **Charles Darwin**—natural selection / theory of evolution
- ☐ **Leonardo da Vinci**—described systems like capillary action in detail; inventions
- ☐ **A.E. Douglass**—dendrochronology (tree-ring dating)
- ☐ **Gertrude Belle Elion**—drugs to treat cancer, malaria, and other diseases
- ☐ **Alexander Fleming**—penicillin antibiotics
- ☐ **Jane Goodall**—chimpanzee behavior
- ☐ **Dorothy Crowfoot Hodgkin**—X-ray crystallography
- ☐ **Percy Julian**—chemical synthesis of medicinal drugs
- ☐ **Mae C. Jemison**—first African American female astronaut; weightlessness

Stephen Hawking experiences zero gravity

Alfred Wegener (left) + Rasmus Villumsen in Greenland

George Washington Carver

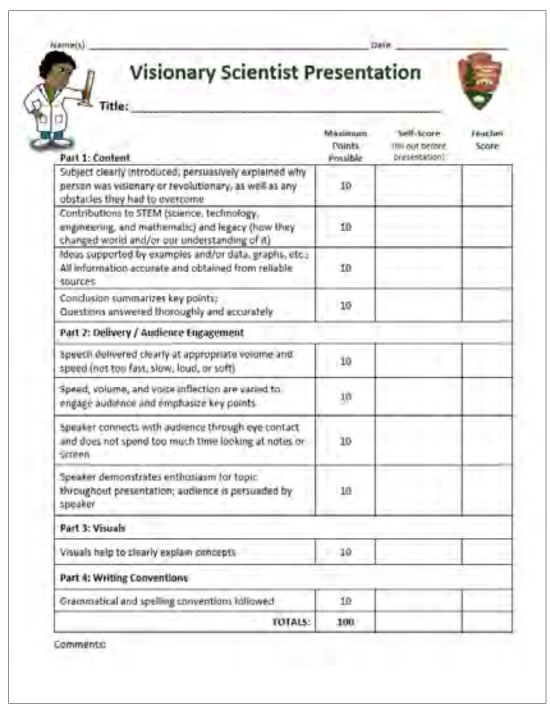
- Show students the available books about the visionaries, if you have any, or take your students to the library. Tell them they can also use the Internet to learn more about the people and their discoveries before they decide.
- Tell students that there are three goals for the activity:

    1. To be able to able to research the people and areas of discovery they find the most interesting.
    2. To discuss all of the people they ranked from 1– 5 with each other. This will help them choose subjects that sound interesting to all members of the group. This could mean that they might pick a person they ranked lower, so that all of the group members can learn about scientists and discoveries that they are particularly interested in when it is time for them to

present to each other. Explain that they will only be presenting in the small groups, so they will want their audience to be engaged by what they each have to say.

3. To learn more about a field in STEM (science, technology, engineering, and mathematics) that they might want to pursue. For example, if they are interested in technology, they might want to study a visionary computer scientist. If they like to create 3-D models or items, they might choose an engineer or inventor to learn more about the path they took to achieve their vision. If they like math, they could choose either a mathematician or one of the many types of scientists that use math extensively in their jobs, such as astronomers and those in the physical sciences, like chemistry and physics. If they like learning about the Earth, they could choose a geologist or someone working to better understand environmental systems and ways to protect them. Tell them that there are many rewarding STEM jobs that go unfilled each year because there are not enough people that have the training needed, so this is a great opportunity to learn more about careers in STEM fields.

- Explain that the people listed are only a few of the countless visionaries who have helped to change the world and/or our understanding of it. They can feel free to choose another STEM professional they would like to present about, including local people they know who might be able to visit the class.
- Give students time to complete the activity, walking around to answer any questions. Encourage them to look up people on the Internet or using classroom resources to help them decide who they would like to research. If you were able to arrange a visit to the school library, a librarian and/or technology specialist can also assist the class with finding resources.
- After students have all chosen someone that they and their group members are interested in learning more about, they should raise their hands so you can visit the group and record their choices using a copy of the activity sheet or electronically. Then students can begin the research process. Give each student a copy of the "Visionary Scientist Presentation" rubric (found at the end of the lesson) and ask them to read through it carefully so they know what to focus on for their presentations. Tell them that they will fill out their column of the rubric before handing it to you when it is time for them to present.



Name(s) ______ Date ______

Visionary Scientist Presentation

Title: ______

Part 1: Content	Maximum Points Possible	Self-Score (fill out before presentation)	Teacher Score
Subject clearly introduced; persuasively explained why person was visionary or revolutionary, as well as any obstacles they had to overcome	10		
Contributions to STEM (science, technology, engineering, and mathematic) and legacy (how they changed world and/or our understanding of it)	10		
Ideas supported by examples and/or data, graphs, etc.; All information accurate and obtained from reliable sources	10		
Conclusion summarizes key points; Questions answered thoroughly and accurately	10		
Part 2: Delivery / Audience Engagement			
Speech delivered clearly at appropriate volume and speed (not too fast, slow, loud, or soft)	10		
Speed, volume, and voice inflection are varied to engage audience and emphasize key points	10		
Speaker connects with audience through eye contact and does not spend too much time looking at notes or screen	10		
Speaker demonstrates enthusiasm for topic throughout presentation; audience is persuaded by speaker	10		
Part 3: Visuals			
Visuals help to clearly explain concepts	10		
Part 4: Writing Conventions			
Grammatical and spelling conventions followed	10		
TOTALS:	100		

Comments:

Explore

2. **Students conduct research and prepare their presentations.** (40 min. or more)

    - Briefly review strategies for conducting research, such as those presented by Oregon School Librarians for elementary students: elementary.educator.oslis.org/learn-to-research. Their tips for secondary students are at secondary.educator.oslis.org.

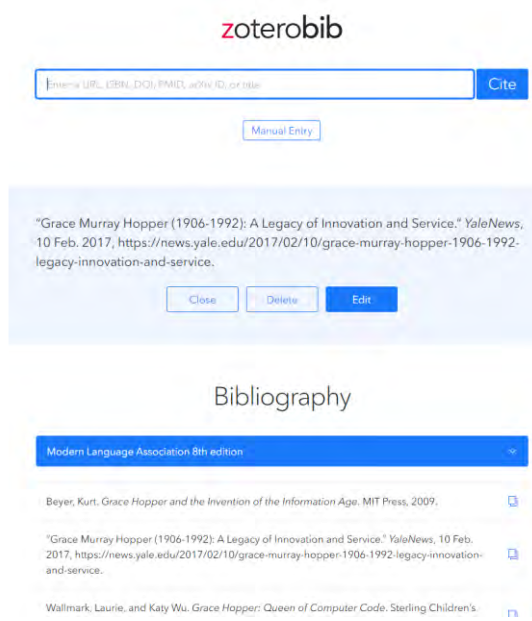
    - Discuss with students how to evaluate the reliability of sources, with tips such as those presented at the sites above and the "Teaching Adolescents How to Evaluate the Quality of Online Information" page from Edutopia: edutopia.org/blog/evaluating-quality-of-online-info-julie-coiro. You might specifically discuss Wikipedia (en.wikipedia.org) and how countless volunteers around the world contribute, so it is especially important to verify information found there with other sources, such as the references listed at the bottom of articles. The site's reliability has improved considerably through the years through their crowd-sourced approach, but what they learn there—like what they learn through most Internet sites and other sources—should not be assumed to be true. Tell students that is why you want them to use at least 3 (or a number of your choice) reliable sources, which will be listed at the end of the presentation or throughout it, like footnotes.

    - Suggest ideas for notetaking strategies, an area in which many students struggle. Good strategies include:

        - Creating notecards, with one card for each idea; sources should be given numbers, with the number and page or paragraph written on each card so students can remember where they found information

        - Using software that allows notes to be easily moved around, such as concept mapping software and presentation tools with a slide sorter, such as PowerPoint

        - Using reference management software, such as the free tool ZoteroBib (zbib.org); the full-featured Zotero is "your personal research assistant" (for advanced students): zotero.org



    Demonstrate for students how each of these strategies allows them to easily organize their ideas by similar topics before or after trying to create an outline. Then they can finish preparing a well-organized presentation plan or research paper.

    - Provide students with options for how they might create the visual components of their presentation. They could use PowerPoint or another program to present their key points and engaging visuals, or they might create a large poster or use another method that you approve. Their goal is to help other students understand the STEM leaders and their discoveries. Stress the importance of this being a persuasive presentation in which they seek to convince the audience why the person and their contributions were visionary and/or revolutionary. Ask them to try to include only the key concepts in the visuals that will be presented, so those key details can be clarified and reinforced without distracting the audience with too much reading while the students are presenting orally.

Explain

3. **Explain how students will need to be ready to answer questions and talk about the person's legacy.** (1–2 min.)
    - After students have had time to work on their projects, tell them that they will need to try to become experts about the person they research, their contributions, and why they were visionary and/or revolutionary. Clarify the meanings of those terms, as well as the concept of a legacy. Discuss how it is what a person or organization creates and/or leaves behind long-term as a result of their actions.
    - Explain that the students should also be ready to discuss any obstacles their STEM visionaries had to overcome, such as discrimination, poverty, cultural biases about accepted roles for women or minority groups, or lack of educational opportunities.
    - Provide students with a deadline for when all the projects will need to be completed. Tell them they should let you know when they are ready so the presentations can be staggered to provide you with time to view them all. You might provide students with an incentive of an extra ten points (or some other number) to those who give the first four superb, persuasive presentations. (It would be ideal if the whole group of the first students to present had a chance to receive the bonus).
4. **Students present to a group as they finish their projects**. (will vary)
    - Ask students to turn in their completed rubric when they are ready to present. Ask their group members to join you in listening to the presentation and asking questions about it.
    - You can also invite students from other groups to listen to the presentation, but we suggest you allow students who have not yet presented to have more time to finish their projects, if needed.
    - Ask the students listening to take notes about the presentations in science notebooks. They should especially focus on the speakers' points about why they think the person was/is visionary and/or revolutionary.
    - After each presentation, the presenter should try to answer any/all questions from you and the other listeners. They should then lead a discussion about whether members of the group agree that the scientist was/is visionary or revolutionary and why.
5. **Discuss diversity, equity, and inclusion (DEI), gender discrimination, and intellectual freedom in STEM.** (5–7 min.)
    - Discuss the ways in which many of the STEM visionaries had to overcome obstacles or even persecution, as well as the missed opportunities for people and nations when people are denied opportunities to achieve their full

potential. This can be done as a think-pair-share activity and/or as a class. Include a discussion of how even white revolutionaries, such as Galileo Galilei and many people of Jewish descent, faced incredible challenges during different periods of history.

- Discuss student ideas about the concepts of diversity, equity, and inclusion. The Ford Foundation provides good definitions: fordfoundation.org/about/people/diversity-equity-and-inclusion
- Discuss how research has revealed that more diverse organizations are more successful and why that might be the case. (Reasons include: a greater variety of ideas, challenges to faulty assumptions, ability to better serve the needs of more people, a more satisfied workforce where everyone feels included and listened to, etc.; see this article for details: weforum.org/agenda/2019/04/business-case-for-diversity-in-the-workplace/.) You might relate the discussion to the benefits of biodiversity in ecosystems.
- Discuss student ideas for how to make STEM opportunities, work places, and professional organizations more inclusive for everyone who wants to pursue them. This can be done as a think-pair-share activity and/or as a class.
- You might ask about a DEI expert in your community who could help facilitate the discussion and provide additional training for your students and/or your staff about these critical issues.

Extend / Enrich

- **Students can create 3-D models, visual diagrams, videos, or other tools to help explain the scientists' ideas and why they were visionary and/or revolutionary.**
- **Students can write persuasive essays or research papers, in addition to sharing oral presentations.**

  Completed essays/papers can be exchanged with one or more students who have an interest in the subject. Then the students can discuss the subject and ideas for improving the paper. Students can revise papers based on peers' feedback before they are submitted to you.
- **Students can plan (and possibly also conduct) their own investigations.** (30 min. or more)

  Challenge students to think about how they might design their own investigation to prove how and/or why an observed phenomenon occurs. The lesson "Science in Action! Exploring Scientists' Connections to the Three Dimensions of NGSS Standards" from Shape of Life provides more ideas in the Enrich / Extend section and graphic organizers at the end to help support students in this process: shapeoflife.org/lesson-plan/sol/science-action.
- **Encourage students to connect with mentors who may be able to support their interests in STEM fields.**

  Organizations that can help support students in this way include:

  - Regional STEM hubs, such as the Portland Metro STEM Partnership: pdxstem.org

    - Organizations listed at girlswhostem.com/best-stem-organizations-for-girls-and-women
    - Local universities and community colleges
    - Local Small Business Development Center (SBDC) offices; search GoogleMaps or another resource such as the main SBDC website at sba.gov/sbdc for local offices

- **Invite one or more visionary STEM professionals to speak to your class about their work or do a field study to observe them at work.**
- **Show a video of one or more influential scientists at work.**

  "Science in Action! Exploring Scientists' Connections to the Three Dimensions of NGSS Standards" from Shape of Life provides videos and lesson plans that meet NGSS standards: shapeoflife.org/lesson-plan/sol/science-action.

Evaluate

6. **Evaluate presentations/projects using the rubric.**
7. **Record levels of oral participation and group participation throughout the project.**
8. **Review any other projects** to celebrate student work and teach others about influential scientists.

Expand Knowledge + Skills

- "Beyond Curie." beyondcurie.com
- Holm, J. "Everything you need to know about Grace Hopper in six books.": opensource.com/article/19/10/grace-hopper-books
- "The Nobel Prize"—Women Who Changed Science: nobelprize.org/womenwhochangedscience/stories
- "Science in Action! Exploring Scientists' Connections to the Three Dimensions of NGSS Standards." Shape of Life: shapeoflife.org/lesson-plan/sol/science-action
- Wallmark, L. *Grace Hopper: Queen of Computer Code* for young readers: sterlingpublishing.com/9781454920007

Screenshot from "Beyond Curie"; learn more about revolutionary geologist Florence Bascom: beyondcurie.com/florence-bascom

Name: ________________________________ Period: ____ Date: ____________________

Visionary Scientists + Their Discoveries

The scientists, inventors, engineers, and mathematicians below helped change the world and/or our understanding of it. **Step 1:** Check off the people you would like to learn more about. **Step 2:** Rank your choices from 1–5 with numbers to the left of the check boxes. You will be creating a persuasive presentation about one of your top choices and how their contributions were visionary or revolutionary.

Earth + Space Science

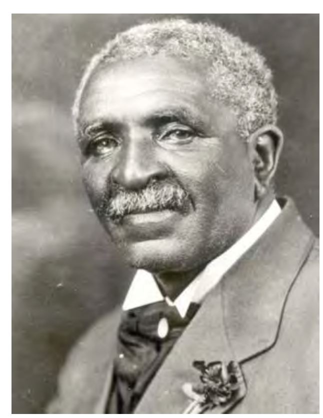
- ☐ **Mary Anning**—self-taught paleontologist; important fossils finds
- ☐ **Aristotle**—spherical Earth; contributed to all scientific fields + philosophy
- ☐ **Florence Bascom**—volcanoes / volcanic rocks; cycles of erosion
- ☐ **Sophia Brahe**—accurate data supported heliocentrism; horticulture
- ☐ **J. Harlan Bretz**—catastrophic Ice Age Floods in Northwest
- ☐ **Georges Cuvier**—catastrophism; "father of paleontology"
- ☐ **Subrahmanyan Chandra**—black holes; structure and evolution of stars
- ☐ **Ernst Chladni**—meteoritics; acoustics
- ☐ **Nicholas Copernicus**—heliocentrism (Sun-centered universe)
- ☐ **Robert L. Folk**—sedimentary rocks; nanoparticles
- ☐ **Galileo Galilei**—observational astronomy; scientific method
- ☐ **Caroline Herschel**—discovered 8 comets and 14 nebulae
- ☐ **Stephen Hawking**—origin of universe; black holes
- ☐ **Johannes Kepler**—elliptical orbits; mathematics
- ☐ **Charles David Keeling**—Keeling Curve; anthropomorphic climate change
- ☐ **Maria Mitchell**—astronomer who discovered comet; sunspots
- ☐ **Pythagoras**—spherical Earth; mathematics
- ☐ **Adam Reiss**—dark energy; expanding universe
- ☐ **Charles Richter**—earthquake prediction / Richter scale
- ☐ **Vera Rubin**—galaxy rotation; data to support theory of dark matter
- ☐ **Neil deGrasse Tyson**—cosmology, science education
- ☐ **Charles D. Walcott**—stratigraphy (study of rock layers); ancient species
- ☐ **Alfred Wegener**—plate tectonics / continental drift

Stephen Hawking experiences zero gravity
en.wikipedia.org/wiki/File:Physicist_Stephen_Hawking_in_Zero_Gravity_NASA.jpg

Alfred Wegener (left) + **Rasmus Villumsen in Greenland**
commons.wikimedia.org/wiki/File:Wegener_Expedition-1930_026.jpg

Life Science

- ☐ **Frances Arnold**—bioengineering / directed evolution
- ☐ **Elizabeth Blackwell**—first female M.D. in U.S.; hospital for women + children
- ☐ **Elizabeth Blackburn**—telomeres, molecular biologist
- ☐ **George Washington Carver**—agricultural scientist / inventor
- ☐ **Charles Darwin**—natural selection / theory of evolution
- ☐ **Leonardo da Vinci**—described systems like capillary action in detail; inventions
- ☐ **A.E. Douglass**—dendrochronology (tree-ring dating)
- ☐ **Gertrude Belle Elion**—drugs to treat cancer, malaria, and other diseases
- ☐ **Alexander Fleming**—penicillin antibiotics
- ☐ **Jane Goodall**—chimpanzee behavior
- ☐ **Dorothy Crowfoot Hodgkin**—X-ray crystallography
- ☐ **Percy Julian**—chemical synthesis of medicinal drugs
- ☐ **Mae C. Jemison**—first African American female astronaut; weightlessness
- ☐ **Nicole King**—multicellularity; choanoflagellates
- ☐ **Hans Adolf Krebs**—cellular respiration



George Washington Carver
flickr.com/photos/tradingcardsnpsyahoocom/7222899028

- ☐ **Rita Levi-Montalcini**—neurobiology; cellular reproduction
- ☐ **Gregor Mendel**—founded modern genetics
- ☐ **Barbara McClintock**—genetics / “jumping genes”
- ☐ **May-Britt Moser**—neuroscience
- ☐ **Florence Nightingale**—founder of modern nursing; statistician; social reformer
- ☐ **Louis Pasteur**—pasteurization; microbiology; epidemiology
- ☐ **Ignaz Semmelweis**—antiseptics; “hand hygiene”
- ☐ **Tu Youyou**—discovered artemisinin that treats millions for malaria

Florence Nightingale
en.wikipedia.org/wiki/File:Florence_Nightingale._Coloured_lithograph._Wellcome_V0006579.jpg

Physical Science / Engineering

- ☐ **Luis Alvarez**—sub-atomic particles; co-discover of asteroid-impact theory
- ☐ **Walter Alvarez**—theory that dinosaurs went extinct after impact from asteroid
- ☐ **Katey Walter Anthony**—methane + climate change
- ☐ **Amedeo Avogadro**—molecular theory
- ☐ **John L. Baird**—an inventor of television
- ☐ **Gerd Binnig / Heinrich Rohrer**—scanning tunneling microscope
- ☐ **Niels Bohr**—structure of atoms
- ☐ **Marie Curie**—polonium and radium, radiation in medicine; radioactivity
- ☐ **Thomas Edison**—inventor of reliable light bulb, phonography, movie camera, etc.
- ☐ **Albert Einstein**—revolutionary theories in modern physics, including relativity
- ☐ **Robert Goddard**—invented liquid-fuel rocket propulsion
- ☐ **Grace Hopper**—computer programming pioneer; invented first compiler

Admiral Grace Hopper leads programming team
flickr.com/photos/8212496@N06/493885707

- ☐ **Rosalind Franklin**—behavior of X-rays through DNA
- ☐ **Mary Jackson**—aerodynamics; NASA’s first African American female engineer
- ☐ **Hedy Lamarr**—invented frequency “hopping” that led to other important technologies; influential actress
- ☐ **Ada Lovelace**—wrote code to program first mechanical computer; saw uses beyond math
- ☐ **Raye Montague**—naval engineer; first person to design ship with computer
- ☐ **Maria Goeppert Mayer**—nuclear physics
- ☐ **Dmitri Mendeleev**—periodic table of the elements
- ☐ **Isaac Newton**—foundation of modern physics + mathematics; laws of motion, gravity, etc.
- ☐ **Konstantin Novoselov**—graphene
- ☐ **Joseph Priestly**—discovered 10 gases, including oxygen; combined it with hydrogen to make water
- ☐ **Donna Strickland**—lasers
- ☐ **Chien-Shiung Wu**—nuclear physics
- ☐ **Nicola Tesla**—alternating current (AC) system of electricity supply
- ☐ **Granville Woods**—inventor with 60 patents for safer, better transportation
- ☐ **Ahmed Zewail**—mapping chemical reactions

Mathematics

- ☐ **Euclid**—“father of geometry”
- ☐ **Christian Doppler** —Doppler effect
- ☐ **Karl F. Gauss**—non-Euclidean geometry
- ☐ **Katherine Johnson**—use of electronic computers in U.S. space program
- ☐ **Gladys West**—mathematical model of the Earth that was a foundation for GPS

Chien-Shiung Wu
commons.wikimedia.org/wiki/File:Chien-Shiung_Wu_(1912-1997)_in_1963_-_Restoration.jpg

More female Nobel Prize winners: nobelprize.org/womenwhochangedscience/stories

- ☐ **Another visionary/revolutionary scientist you would like to study:** ____________________________

Name(s): ____ Date: ______________________

Visionary Scientist Presentation

Title: ____

Part 1: Content	**Maximum Points Possible**	**Self-Score** (fill out before presentation)	**Teacher Score**
Subject clearly introduced; persuasively explained why person was visionary or revolutionary, as well as any obstacles they had to overcome	10		
Contributions to STEM (science, technology, engineering, and mathematic) and legacy (how they changed world and/or our understanding of it)	10		
Ideas supported by examples and/or data, graphs, etc.; All information accurate and obtained from reliable sources	10		
Conclusion summarizes key points; Questions answered thoroughly and accurately	10		
Part 2: Delivery / Audience Engagement			
Speech delivered clearly at appropriate volume and speed (not too fast, slow, loud, or soft)	10		
Speed, volume, and voice inflection are varied to engage audience and emphasize key points	10		
Speaker connects with audience through eye contact and does not spend too much time looking at notes or screen	10		
Speaker demonstrates enthusiasm for topic throughout presentation; audience is persuaded by speaker	10		
Part 3: Visuals			
Visuals help to clearly explain concepts	10		
Part 4: Writing Conventions			
Grammatical and spelling conventions followed	10		
TOTALS:	**100**		

Comments:

Ice Age Floods Glossary

abrasion	the mechanical wearing, grinding, scraping, and rubbing down of the land surface by friction and impact of solid rock particles transported by wind, water, or ice
adaptation	Characteristic an organism possesses that evolved over time in response to its habitat or other environmental conditions
alcove	a deep, horseshoe-shaped inner canyon that forms below a recessional **cataract**
anastomosis	a braided, interlacing network of branching and reuniting flood channels
anticline	the upwarped portion of a fold in the Earth's crust, like the upward rounded linear ridges of a rumpled carpet
arête	thin crest of rock left after two glaciers have worn a steep ridge into the rock between them
argillite	a metamorphic rock, originally mudstone or shale, that has been transformed into an extremely hard, compact, dark-colored rock tightly cemented with silica; found in northern Washington, Idaho, and Montana
basalt	a dark, igneous volcanic rock composed primarily of the minerals plagioclase and pyroxene Over a period of 11 million years (17 to 6 million years ago), hundreds of flows of Columbia River basalt were extruded from long, linear vents in southeastern Washington, northeastern Oregon, and west-central Idaho and traveled for hundreds of miles before cooling and solidifying to form the Columbia Plateau
basalt member	a grouping of individual basalt lava flows with similar characteristics, erupted around the same time
bedrock	a general term for the rock that underlies the soil or other unconsolidated. surficial material
beds	discrete layers of sediment or rock of varying thickness and character Individual beds are laid down sequentially, so that beds at the bottom of a sequence are older than those on top.
bergmound	an accumulation of ice-rafted debris that melted out of large grounded icebergs; The pile of debris forms low, cone-shaped mounds. In the Pasco Basin, most bergmounds are found in slack water areas, generally between 650 and 850 feet in elevation.
borrow pit	man-made excavation to remove loose sand and gravel for use in road building or other construction
boulder	a large rock, generally worn smooth by erosion

butte a conspicuous, isolated, generally flat-topped hill with relatively steep-sided slopes; often capped by a more resistant layer of rock and bordered by **talus**; often represents an erosional remnant, smaller in extent than that of a **mesa**; carved from flat-lying rocks

caliche rock consisting of sediment cemented together into a hard mass with calcium carbonate; forms only after many thousands of years of near-surface soil development in arid to semi-arid climates

cataract a tall, now-dry cliff formed during Ice Age Floods

During flooding, vertical cataracts, sometimes in stair-step fashion, would recede many miles upstream; these are called recessional cataracts.

catastrophism the theory that sudden, violent, short-lived events outside our present experience or knowledge of nature have greatly modified the surface of the Earth

calving process in which ice breaks off into a large water body, such as the ocean or a lake

Channeled Scablands

eroded, interconnected network of streamlined **loess** islands, flood channels, **coulees**, **cataracts**, and **plunge pools** scoured into **basalt** by cataclysmic floods in eastern Washington State

These features are unique to this region of the Earth, although they are similar to channel networks observed on Mars.

chatter marks gauges chipped out of bedrock by rocks dragged on the bottom of glaciers

cirques "concave, circular basins carved by the base of a glacier as it erodes the landscape." NSIDC: nsidc.org/cryosphere/glaciers/gallery/aretes.html

clast an individual particle or fragment of a sediment or rock produced by the mechanical weathering of a larger rock mass

clastic dike a feature that cuts across bedding structures and is composed of the **sedimentary** material it transects

It is believed to be the result of fracturing and sediment movement due to earthquake shaking during or soon after cataclysmic flooding.

clay extremely small **sedimentary** particles that are less than 0.004 mm in diameter

climate average weather conditions of a place, such as temperature and rainfall levels, over a long period of time

colonnade columnar basalt that forms the lower, interior portions of basalt lava flows that contain larger, more massive columns, most of which are bounded by vertically oriented cooling fractures; found alongside entablature

Polygonal columns up to several feet in diameter are common to some flows.

Columbia River Gorge
steep-sided valley separating Oregon and Washington; formed by erosion from the Ice Age Floods and Columbia River

columnar basalt thick lava flows commonly appear to be comprised of vertical honeycomb-like columns of basalt; linear joints form in rock as it cools

They define the columns and generally form perpendicular to the cooler bounding surfaces above and below. In cross section, the resulting joints are often six-sided (an optimum packing geometry), but may be anywhere from 3-sided to nearly round. Because of the through-going joining, columns are relatively easily broken out of a rock face by hydraulic plucking and ice-wedging.

compass instrument with a magnetic pointer used for navigation

confluence where streams or rivers join together to form a larger water body

Cordilleran Ice Sheet
large sheet of glacial ice that covered much of present-day Western Canada and the northwestern U.S.

coulee a mostly dry, box-shaped canyon with a broad, flat bottom and steep sides
In south central Washington, the term coulee is mostly used for an abandoned Ice Age Flood channel.

data evidence, facts, and statistics, often numerical, collected for analysis or reference

data analysis process of evaluating data using statistics, graphs, etc. to determine trends

density amount of matter in a defined area, or mass per unit volume; calculated by mass divided by volume

deposition process by which material that is picked up by **glaciers** can be moved hundreds or thousands of kilometers before it is deposited on the land

depressions lower areas of land to which water flows

drumlin an elongated, teardrop-shaped hill comprised of previously-deposited glacial drift (or solid rock) up to 2 kilometers (1.25 miles) long; shaped by subsequent glaciation of rock, sand, and gravel that formed under moving glacier ice

ecosystem plants, animals, and other living organisms interacting together and with their environment which includes nonliving things like water, air, and sunlight; often thought of as a functioning unit

elevation height above a point, usually sea level

environment surroundings of an organism; includes all the other living and nonliving things

eolian pertaining to the wind; includes deposits of **loess** and dune **sand**

expansion bar broad, laterally-spread flood sediment deposits in wider portions of a channel immediately downstream from a more confined channel section

These deposits are thought to result from the slackening of debris-charged floodwaters as they spill out of the more confined channel into the broader channel sections where the rate of flow slackens.

foreset bedding primary sedimentary structure in flood gravels where a pronounced dip occurs in bedding planes in the direction of sediment transport

erosion process of moving rock, soil, or minerals by water, wind, or other natural processes; can reduce water clarity and quality in freshwater ecosystems

erratic a piece of rock that differs from the size and type of rock native to the area in which it rests, implying it has been transported and deposited at some distance from the outcrop from which it was derived and generally associated with transport by glacial ice or icebergs

feature distinguishing trait or characteristic of a place, organism, etc.

field area in which a scientific study is conducted

field journal place to record observations, illustrations, data, and ideas

field sketch drawing made in the area where a study is conducted; a way of recording observations

fjords long, **U-shaped valleys** that are open to the ocean with submerged floors

flood bar an accumulation of sediment, most often composed of **sand** and/or **gravel**, that occurs along flood routes where the currents move slower for various reasons
Different types of flood bars include eddy bars, **expansion bars**, shoulder bars, and **pendant bars**

flow rate unit of fluid moving per unit of time

geomagnetic relating to Earth's magnetic properties

giant current ripples (GCRs)

active channel topographic forms up to 20 m (66 ft.) high, which develop within central flow areas of the main outflow valleys created by glacial lake outburst floods

Giant current ripple marks are extremely large analogs of small current ripples formed in sandy stream sediments. They are important diagnostic depositional features in plains and scablands associated with massive floods.

GIS geographic information system; way to organize and analyze data rooted in geography

glacial budget describes the balance between accumulation and ablation of snow and ice—how much the glacier is growing or shrinking

Glacial Lake Missoula

source for most or all of the floodwater that created the **Channeled Scablands** of eastern Washington

The lake formed behind an ice dam in the Idaho Panhandle that periodically failed; sending torrents of water downstream. At its maximum, Lake Missoula contained 600 cu. mi. of water, was 2,000 ft deep, 200 miles long, and covered an area of 3,000 sq. mi. It took up to 125 years to fill, but only 2 to 3 days to completely empty.

glacial landforms are those created by the powerful erosional force of glaciers, which act like bulldozers on the land, as well as glacial deposition

glacier areas of snow and ice that build up via **precipitation** of **snow** over hundreds or thousands of years. All glaciers **flow** downhill due to the force of **gravity**.

gorge narrow canyon, typically with rocky walls and a stream or river running through it

gravity force that acts on substances to move them toward those with more mass, such as how water flows downhill toward the center of the Earth

granodiorite a type of **granitic** rock consisting of mostly crystalline quartz and plagioclase feldspar

granitic pertaining to granite; a general term for any light-colored **igneous** rock that formed deep underground within a cooling body of liquid magma

gravel large sedimentary particles that are greater than 2.0 mm in diameter; gravel **clasts** include, in increasing size, granules, pebbles, cobbles, and boulders

grooves and striations

long lines carved into bedrock by boulders and rocks dragged along by glaciers

groundwater underground water in soil or permeable rock, often feeding springs and wells

habitat place or type of site where an organism lives

hanging valley a tributary valley whose floor is notably higher than the valley it joins; characteristic of flood

headwaters source of a river or stream

histogram / bar chart / bar graph

graphic representation of data using rectangles to show distribution of numerical or categorical data

Holocene epoch period of geologic time since the last Ice Age (11,000 years ago to the present)

hydraulic constriction

where a large volume of water is confined to a narrow opening, if more water enters the opening than can drain through

The constriction will cause water to back up, creating a type of hydraulic dam.

hydrologist scientist that studies the properties, distribution, circulation, and management of water

hypothesis a tentative explanation for an observation based on limited evidence; what scientists use to guide their explorations

Ice Age The **Last Glacial Period** is commonly referred to as the Ice Age, and was the most recent glacial period within the Quaternary glaciation occurring during the last 100,000 years of the Pleistocene, from approximately 110,000 to 11,700 years ago. Scientists consider this "ice age" to be merely the latest glaciation event in a much larger ice age, one that dates back over two million years and has seen multiple glaciations. During this period, there were several changes between glacier advance and retreat. The Last Glacial Maximum, the maximum extent of glaciation within the last glacial period, was approximately 22,000 years ago.

igneous rock that solidified from molten or partly molten material (i.e. magma); one of the three principal rock types, along with **sedimentary** and **metamorphic**

kolk an underwater vortex created when a rapidly rushing current of water passes an underwater obstacle in boundary areas of high shear

High velocity gradients produce a violently rotating column of water, essentially a high energy whirlpool. That can pluck multi-ton rocks from the underlying bed of the current. A Kolk is usually relatively stationary due to the factors that create it; and is the mechanism that created Kolk ponds during the Floods.

lithology the physical character of a rock, including its color, mineralogic composition, and grain size.

Lake Bonneville an Ice Age lake that formed in central Utah from melting mountain glaciers Today's Great Salt Lake is a much smaller remnant of Lake Bonneville

The lake drained catastrophically only once, toward the end of the Ice Age about 15,000 years ago when the lake overtopped a drainage divide and partially drained northward into the Snake River.

Lake Lewis a temporary lake that formed behind the hydraulic constriction at Wallula Gap; Within 5 days or less the lake grew to an elevation of 1,250 ft (381 m) above sea level before completely draining through the gap over a period of several days.

loess windblown **silt** and fine **sand** that collects on the lee sides of ridges at higher elevations; abundant within the Pasco Basin, adding to the soil's fertility

maar a broad, low-relief volcanic crater caused by an eruption when groundwater comes into contact with hot lava or magma

Maars are shallow, flat-floored craters that scientists interpret as having formed above a volcanic pipe as a result of a violent expansion of magmatic gas or steam. Most maars have low rims composed of a mixture of loose fragments of volcanic rocks and rocks torn from the walls of the diatreme.

mass measurement of amount of matter something contains; measured by using a balance to compare a known amount of matter (e.g., freshwater or weights) to an unknown amount of matter

magnetic polarity shift

a change in a planet's magnetic field, such that the positions of magnetic north and magnetic south are reversed

The Earth's field has alternated between periods of *normal* polarity, in which the direction of the field was the same as the present direction, and *reverse* polarity, in which the field was the opposite. The time spans are randomly distributed, with most being between 0.1 and 1 million years with an average of 450,000 years. Most reversals are estimated to take between 1,000 and 10,000 years.

mesa	an isolated, nearly level land mass standing distinctly above the surrounding country; bounded by abrupt steep-sided slopes on all sides and capped by layers of more-resistant rock
metamorphic	any rock derived from pre-existing rocks by mineralogical, chemical, and/or structural changes; one of the three principal rock types, along with **sedimentary** and **igneous**
Miocene epoch	period of geologic time between 23 and 5.3 million years before the present, when Columbia River **basalt** was extruded into the Pasco Basin
microscopic	so small as to be invisible without a microscope
mineral	any natural, inorganic material that can be extracted from the earth
mitigation	steps taken to avoid or minimize negative environmental impacts
model	representation of something that explains / shows how it works
moraines	rocks and dirt that have been moved and deposited in an elevated by a glacier
NGSS	Next Generation Science Standards: nextgenscience.org
paleomagnetism	the fossil magnetism in rocks, used to determine the past configurations of the continents and to investigate the past shape and magnitude of the Earth's magnetic field The record of geomagnetic reversals preserved in volcanic and sedimentary rock sequences (magnetostratigraphy) provides a time-scale that is used as a geochronologic tool. Certain minerals in rocks lock-in a record of the direction and intensity of the magnetic field when they form. This record provides information on the past behavior of Earth's magnetic field and the past location of tectonic plates.
paleosol	very old, buried soil
patterned ground	well-defined, more or less symmetrical forms in the ground, such as circles, polygons, nets, steps, and stripes that are characteristic of, but not necessarily confined to, surficial material subject to intense frost action, especially in polar, subpolar, and arctic regions; Patterned ground in the Pasco Basin, however, appears to be related to **seismicity** that occurred during or soon after cataclysmic flooding.
pedogenic	relating to the processes that produce soil
pendant bar	a type of flood bar that forms immediately downstream of an obstruction in the flow of the flood current
Pleistocene epoch	period of geologic time between 2.6 million and 11,700 years ago The Pleistocene spans the period of repeated glaciations known as the Ice Ages.
Pliocene epoch	period of geologic time of the Tertiary period, from 5.3 million years ago to 2.6 million years ago, after the Miocene and before the Pleistocene epochs
plucking	process in which glaciers pick up rocks as large as houses as they flow
plunge pool	a deep pool or basin formed at the foot of a waterfall

pluvial lake a lake formed in the **Pleistocene epoch** during a time of glacial advance. and now either extinct or existing as a remnant

point bar an arcuate (curved or bow-shaped) ridge of **sand** and **gravel** developed on the inside of a growing meander (loop) in the course of a stream

rhythmite a graded **sedimentary** layer several inches to several feet thick, deposited under slack water conditions, especially in back-flooded valleys during cataclysmic floods

Some believe that each rhythmite represents a separate cataclysmic flood from **Glacial Lake Missoula**.

Ringold formation sediments stratigraphically overlying Columbia River **basalt** and underlying cataclysmic flood deposits in southeastern Washington; mostly derived from ancient river and lake deposits that accumulated within the ancestral Columbia River basin between about 8 million and 3.4 million years ago

sand sedimentary particles that are between 0.06 and 2.0 mm in diameter

sedimentary rock composed of sediment; one of the three principal rock types, along with **igneous** and **metamorphic**

slack water areas with slower-moving flood waters associated with cataclysmic flooding where fine-grained sediment was deposited

silt small, sedimentary particles 0.06 to 0.004 mm in diameter

sublimation when ice turns directly into the gas water vapor

Sangamon Interglacial – time period between glacial stages roughly 130,000 – 80,000 years ago, when climatic conditions were similar to those of today

Wisconsinan also called the **Wisconsin Glacial Episode**, it refers to the fourth and last glacial stage of the **Pleistocene epoch** in North America, following the **Sangamon Interglacial** and preceding the **Holocene Epoch**

The late Pleistocene Wisconsinan glacial stage occurred between about 80,000 and 15,000 years before the present.

pools deeper, slower-moving sections of stream or river with a smooth surface and silty bottom

precipitation water in all of its forms that falls from clouds to the ground; e.g. rain, sleet, snow

predator animal that hunts and eats other animals

predict make an educated guess about why or how something will occur

prey animal that is hunted and eaten by other animals

radiometric refers to methods of age determination based on the nuclear decay of radioactive isotopes

reverse grading refers to **sedimentary** beds that show an increase in particle size upward within the bed, as opposed to normal grading which shows a decrease upward
Most flood rhythmites display normal grading.

reverse or **thrust fault**
a fault, usually with a dip of >45 degrees, in which the hanging wall has moved up relative to the footwall of the fault

ridge Long, narrow elevated piece of land

ridgeline Line formed by the highest points along a mountain ridge

riffles Shallow, swift-moving areas of stream or river with broken surfaces and rocky bottoms

riparian area / riparian zone
area bordering a river or stream

riparian area important strip of habitat along rivers and streams where water is abundant

rubric document that explains expectations for an assignment and the components that are included in the evaluation of the assignment

runoff draining away of water and possibly other substances in it from surfaces when those surfaces are either fully saturated with water or do not absorb water, such as pavement, concrete and metal siding

rip-up clast **sedimentary** material that has been eroded and transported only a short distance in a semi-consolidated (e.g. frozen) state

sediment loose sand, clay, silt and other soil particles that settle on the bottom of a body of water

sedimentation process in which particles settle out of a fluid to form a layer

silt mineral material the size between sand and clay; may occur as a soil or as sediment mixed in with water and soil in a body of water such as a river

sketch rough drawing

soft-sediment deformation
deformation that occurs during or soon after sediment deposition while sediment is still partially or fully saturated with water

Examples of soft-sediment deformation include flame structures, load structures, and clastic dikes.

soil horizon a distinct interface (surface or thin layer) in a stratigraphic sequence

streamflow (flow rate)
amount of water flowing in a river or stream per unit of time; varies based on amount of precipitation, runoff, and snow melt

subglacial formed or accumulated in or by the bottom parts of a glacier or ice sheet

substrate material on the bottom of a water body

survey	to observe and record the features of an area to produce a map or other representation of it; term used for the product of those observations / measurements
system	set of things in which every part relates to others
syncline	the down-warped portion of a fold in the Earth's crust, like the downward rounded linear valleys of a rumpled carpet
talus	broken rock accumulated at the base or against the lower part of a steep slope or cliff
tectonic	relating to the structure of the Earth's crust and the large-scale processes that take place within it
temperature	Amount of heat energy contained in a substance (such as water or air); more oxygen dissolves in cooler water which is then available for animals to breathe
tephra	airfall deposit from a volcanic eruption; usually consists of distinctive, light-colored, well-sorted, gritty particles of ash
terminus	End of a river or stream
topography	Earth surface features of a region, such as mountains, plains, or hills
transport	Movement of sediment downriver
troughs	long valleys with steep sides carved by glaciers that are not open to the sea
turbidity	measure of amount of solids in water; provides good measure of water quality
U-shaped valleys	landforms with steep walls and flat bottoms (as opposed to **V-shaped valleys**) The erosive action of glaciers works along the entire valley, which widens it and steepens the walls.
uniformitarianism	the theory that landscapes were shaped through slow, continuous, uniform processes and that these processes are/were mostly the same in the past, present, and future. It argues that we can observe processes like vulcanism (volcanoes) and erosion by water, wind, and glaciers and know that they have happened before and will happen again. This theory is used to explain many dramatic landforms throughout the world, such as the Grand Canyon and the Cascade and Rocky Mountains.
V-shaped valley	**valley** with gradually sloping sides formed by the erosional power of rivers
valley	area of land that lies between hills or mountains; often contains a stream or river
velocity	speed of an object in a given direction
Venturi effect	the principle that fluid moving through a smaller area will move at a higher velocity than the same amount of water moving through a larger area For example, floodwater moving through a narrow opening such as **Wallula Gap** was moving much faster, with significantly more erosive power, than the water above or below the gap.

vertebrate animal with a backbone; includes mammals, reptiles, birds, fish, and amphibians; their fossil records help us determine which were present in the areas of the Ice Age Floods, although much of the evidence was literally washed away

volume amount of space that a substance or shape occupies or contains

Wallula Gap the narrow constriction, only a few miles wide, through which all floodwaters from **Glacial Lake Missoula** passed on their way to the Pacific Ocean

During the largest floods, the water within Wallula Gap was over 1,200 ft (381 m) deep.

water Liquid that forms rain, lakes, rivers, and seas; when pure is colorless, transparent, and odorless; is necessary to sustain living organisms; chemical composition is two hydrogen atoms and one oxygen atom

watershed Land area that drains into a river, stream, or other body of water

weathering Breaking down of a substance, such as rocks and wood, through the action of water, wind, and/or sun

weight Measurement of the pull of gravity on an object; measured on a **scale**

X axis Horizontal axis of a system of coordinates or graph that runs through zero

Y axis Vertical axis of a system of coordinates or graph that runs through zero

Youth Permission and Waiver Form

Project: ______________________ Site Location: ______________________ Date: ______________________

ALL PARTICIPANTS UNDER THE AGE OF 18 WHO ARE UNESCORTED BY AN ADULT MUST HAVE A PARENT OR GUARDIAN SIGN THIS PERMISSION AND WAIVER FORM. Escorted youth may be included by their parent, guardian or authorized adult on the adult registration and waiver form.

This is a waiver and release. Please read it carefully before signing. I am the parent or legal guardian of Participant named below and I, the undersigned, enter this Release and Waiver of liability and Assumption of Risk Agreement ("Agreement") on behalf of myself, the Participant, my personal representatives, next of kin, heirs, successors, and assigns and anyone else who may make any claim for or on behalf of the Participant.

- I will **cause the Participant to agree and comply** with the terms of the Agreement and not to take any actions that would assist or cause the Participant to invalidate, renounce, negate, revoke, or disclaim any part of the Agreement.
- I make this Agreement for the benefit of partner organizations, other individual volunteers, project coordinators, sponsors, suppliers, supporters, and all private and public land owners on whose property the project described above may be located (collectively the "Released Parties), including, without limitation, the Released Parties' employees, agents, personal representatives, next of kin, heirs, successors and assigns.
- I make this Agreement in consideration of the Released Parties providing Participant with the opportunity to **participate as a volunteer** in this project.
- I understand that the Project may include **dangerous or hazardous** activities and that the Project may take place on a location or under conditions that may be dangerous to Participant.
- Participant and I **accept full personal responsibility** for all risks arising from or relating to this Project.
- Participant's involvement in this Project is **completely voluntary** and neither participant nor I have received nor expect to receive any compensation for participation in it.
- Participant will read, listen to and follow all **safety instructions and procedures** presented in conjunction with this Project and **use best judgment** based upon physical and mental abilities at all times, and to immediately terminate participation in this Project if activities become too strenuous, difficult or hazardous.
- I agree to **waive all liability** of the Released Parties, **discharge them, and covenant not to sue them** for any liability, claims, sums, costs, or other expenses on my account that may be caused in whole or in part by Participant's involvement in the Project.
- I agree that this Agreement shall act as a **complete bar against all actions or claims** that I might otherwise bring against the Released Parties, including negligence claims, arising from or related to this project.
- I have read this Agreement, fully understand its terms, understand that I have **given up substantial rights** by signing it, and have **signed it freely** and without any inducement or assurance of any nature. I intend this Agreement to be a **complete and unconditional release of all liability** to the greatest extent allowed by law, and I further agree that if any portion of this Agreement is held invalid, then the balance of the Agreement shall continue in full force and effect.
- I understand that a photographer may be present to photograph the activities at the Project and that Participant may be photographed while participating in the Project. I agree that Participant will contact the photographer if he or she does not wish to be photographed.
- I hereby grant the irrevocable and unrestricted right to **use and publish photographs of Participant**, or in which Participant may be included. I hereby release Photographer and his/her legal representatives and assigns and partner organizations from all claims and liability relating to any such photographs.

Thank you for filling out the form below and signing to give permission for your student to participate in field work. Please print clearly. We would never sell or trade your information.

Name of Participant						☐ **Male** ☐ **Female**
Name of Parent/Guardian						
Relationship to Participant		**Phone**	-	-		☐ **Home** ☐ **Business**
Address						☐ **Home** ☐ **Business**
City				**State**		**Zip**
Age of Participant						
	Signature of Parent or Guardian					**Date**

Are you able to chaperone? ☐ YES ☐ No ☐ Maybe

If so, please indicate your preferred method(s) of contact.

☐ **Email, using address below** (please write your email address in the boxes below)	☐ **Mail, using address above**	☐ **Phone**
		☐ **Home** ☐ **Business**

Ice Age Floods Trivia!

1. What scientific phenomenon created most of the rocks in the Pacific Northwest? (Circle one)
   a. Floods
   b. Glaciers
   c. Erosion
   d. Deposits of sediment over millions of years
   e. Volcanoes

2. This phenomenon created dramatic Northwest landforms during the Ice Age Floods, such as the Channeled Scablands and Grand Coulee. (Circle one)
   a. Downpours of rain
   b. Glaciers
   c. Erosion
   d. Deposits of sediment over millions of years
   e. Volcanoes

3. What is an “erratic”? (as a geology term—circle one or more)
   a. Another name for a supervolcano
   b. A huge glacial lake
   c. An unexplained mountain
   d. A huge storm
   e. A piece of rock that differs from the size and type of rock native to the area in which it rests

4. What do scientists think was the source of most of the flood waters during the Ice Age Floods?
   a. An asteroid that landed in the Pacific Ocean
   b. A sudden melting of all the glaciers at the same moment
   c. Glacial Lake Missoula
   d. The Snake River
   e. Torrential rains that lasted for months

5. Do glaciers move? Circle one:

   Yes No Sometimes

6. What happened during the Ice Age Floods and what scientific evidence do we have to prove it?

Ice Age Floods Program
Student Feedback

We want your opinion about your experience! Help us find out what was good and bad about the program, and what difference it made for you. There are no right or wrong answers and no one will know your responses.

Please read each statement below and decide if you agree or disagree with the statement.
Put an X in one box in each row.

Statement	Strongly NO	Sort of No	I'm Not Sure	Sort of Yes	Strongly YES
What I did in this program was interesting.					
I think I will remember the things I learned in this program about the Ice Age Floods, etc..					
I see some things differently because of this program.					
I care more about Northwest landforms and what created them than I did before.					
I can see the connection between this program and the other things I am learning in school.					
I might volunteer to help teach others about the Ice Age Floods.					
I might like to enter a career dealing with science, natural resources, and/or conservation because of what I have been doing.					

Do you have any suggestions or comments about this program?

THANK YOU—Your input helps a lot!