

## Chapter 3 Eruption!

### Resources

- Brantley, S.R., 1999, Volcanoes of the United States: U.S. Geological Survey General Interest Publication, <http://pubs.usgs.gov/gip/volcus/index.html>.
- Hawaii Natural History Association, [n.d.], A teacher's guide to the geology of Hawaii Volcanoes National Park—Kinds of volcanic eruptions: Oregon State University website, accessed June 1, 2010, at <http://volcano.oregonstate.edu/education/vwlessons/kinds/kinds.html>
- Lillie, R.J., 2005, Parks and plates—The geology of our National parks, monuments, and seashores: New York, W.W. Norton and Comdishy, 298 p.
  - Chapter 2: Geologic Features and Processes, p. 34–39.
- Shcmincke, H.-U., 2004, Volcanism: New York, Springer-Verlag, 324 p.
  - Chapter 3: Magmas, p. 21–34.
- Smithsonian Institution, [n.d.], Global volcanism program: Smithsonian Institution web page, accessed June 1, 2010, at
  - Large Holocene Eruptions  
<http://www.volcano.si.edu/world/largeeruptions.cfm>
- Tilling, R.I., 1997, Volcanoes—On-line edition: U.S. Geological Survey General Interest Publication. (Available at <http://pubs.usgs.gov/gip/volc/>.)
- U.S. Geological Survey, 1997 [2007], Volcanoes teacher's guide: U.S. Geological Survey website. (Available at <http://erg.usgs.gov/isb/pubs/teachers-packets/volcanoes/>.)
- WGBH Educational Foundation, 2010, Teacher's domain resource: WGBH Educational Foundation web pages, accessed June 1, 2010, at
  - Volcanic Features  
<http://www.teachersdomain.org/resources/ess05/sci/ess/earthsys/volcanfeatr/index.html> and
  - Volcanism  
<http://www.teachersdomain.org/resources/ess05/sci/ess/earthsys/volcanintro/index.html>.

**Activities**

These activities allow students to build on their knowledge of igneous rocks and magmatic compositions and relate them to features and eruptive products formed at Alaskan volcanoes through multiple eruptions that sometimes occur at the same vent. Students will compare volcanic eruptions that occurred in Alaska to one another and (or) to volcanic eruptions that occurred elsewhere in the United States. Students will learn about a scale used to compare the size of one eruption to another and ultimately will learn about the largest volcanic eruption on Earth in the 20th century, which took place on the Alaska Peninsula in 1912. Specific volcanic products that may pose potential hazards to population locally and far away are presented in Chapter 5. *Alaska's Volcanoes and You*.

Activity I. Eruption 1, 2, 3...

Activity II. Compare and Contrast—Alaska Style

Activity III. Volcanic Explosivity Index, Alaska

## **Activity I Eruption 1, 2, 3...**

**Grade Level** 6–11

**Setting** Classroom

**Time** 50–90 minutes (with homework assignment of varying length at the beginning)

### **Vocabulary (see Glossary)**

caldera, cinder cone, flood or plateau basalt, intracaldera, lava dome, maar, pyroclastic flow, resurgent dome, shield, stratovolcano (or composite cone)

### **Correlations to Alaska State Department of Education (2006) Performance Standards (Grade Level Expectations)**

#### **D1 - Concepts of Earth Science**

**SD[6-11]** Students develop an understanding of the concepts, processes, theories, models, evidence, and systems of earth and space sciences.

**SD2[6-11]** Students develop an understanding of the origins, ongoing processes, and forces that shape the structure, composition, and physical history of the Earth


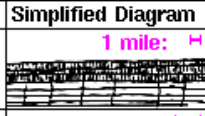

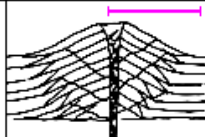

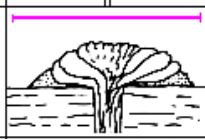

**SD2.3[6]** The student demonstrates an understanding of the forces that shape Earth by describing how the surface can change rapidly as a result of geological activities (i.e., earthquakes, tsunamis, volcanoes, floods, landslides, avalanches).

#### **Overview**

Several types of eruptive processes can occur at a single volcano over its long lifespan. Many of Alaska's volcanoes have had multiple eruptions of varying types over the course of their lengthy and active history. This variance in eruption style is reflected in the types of volcanic features and deposits that may still be visible at the volcano. By using common, everyday materials available in the classroom and at home, students will construct a volcano model. Using at least two different methods students will generate at least two consecutive and varying volcanic eruptions of their model volcano and recreate various eruptive types and products, which then can be related to those seen at Alaskan volcanoes.

## Background

Several types of eruptive processes generate various volcanic deposits and features. In many cases, a dominant eruption process leads a particular volcano to be labeled as a shield, caldera, stratovolcano or composite cone, cinder cone or dome. In many cases, however, individual volcanoes have had variation in eruption processes and products over time. A single volcano can produce a wide variety of features throughout its multi-eruption history. Resources concerning the various volcanic eruption processes include:

<b>Types of Volcanoes</b>				
	<b>Volcano Type</b>	<b>Characteristics</b>	<b>Examples</b>	<b>Simplified Diagram</b>
Increasing Violence Increasing Viscosity 	<b>Flood or Plateau Basalt</b>	Very liquid lava; flows very widespread; emitted from fractures	Columbia River Plateau	
	<b>Shield Volcano</b>	Liquid lava emitted from a central vent; large; sometimes has a collapse caldera	Larch Mountain, Mount Sylvania, Highland Butte, Hawaiian volcanoes	
	<b>Cinder Cone</b>	Explosive liquid lava; small; emitted from a central vent; if continued long enough, may build up a shield volcano	Mount Tabor, Mount Zion, Chamberlain Hill, Pilot Butte, Lava Butte, Craters of the Moon	
	<b>Composite or Stratovolcano</b>	More viscous lavas, much explosive (pyroclastic) debris; large, emitted from a central vent	Mount Baker, Mount Rainier, Mount St. Helens, Mount Hood, Mount Shasta	
	<b>Volcanic Dome</b>	Very viscous lava; relatively small; can be explosive; commonly occurs adjacent to craters of composite volcanoes	Novarupta, Mount St. Helens Lava Dome, Mount Lassen, Shastina, Mono Craters	
	<b>Caldera</b>	Very large composite volcano collapsed after an explosive period; frequently associated with plug domes	Crater Lake, Newberry, Kilauea, Long Valley, Medicine Lake, Yellowstone	



Topinka, USGS/CVID, 1997, Modified from: Allen, 1975, *Volcanoes of the Portland Area, Oregon, Ore-Bir*, v.37, no.9

- [http://vulcan.wr.usgs.gov/Glossary/VolcanoTypes/volcano\\_types.html](http://vulcan.wr.usgs.gov/Glossary/VolcanoTypes/volcano_types.html) and
- U.S. Geological Survey, 2008, Volcano types "Quick reference guide": U.S. Geological Survey web page. (Available at [http://vulcan.wr.usgs.gov/Glossary/VolcanoTypes/volcano\\_types\\_quick\\_reference.html](http://vulcan.wr.usgs.gov/Glossary/VolcanoTypes/volcano_types_quick_reference.html).)

Some salient points that can provide a general view of Alaskan-style volcanism and dispel misperceptions about the nature of volcanic eruptions are:

- A wide range of activity can take place during volcanic eruptions, including explosive and non-explosive events that may occur during the entire period of eruption.
- Volcanoes can produce what may initially appear as processes leading up to an eruption ending without an eruption; in many cases this is due to magma moving underground but not erupting.
- Eruptions can be long or short; they may culminate in a single event or progress for months to years in several events.
- Eruptions are multifaceted—they consist of multiple processes occurring simultaneously, or one following the other, and this dynamic may change throughout the entire timeframe of an eruption.
- Volcanoes can erupt in different ways through time with varying degrees and timing of constructive and destructive processes shaping the volcanoes.

Over the long lifespan of many of Alaska's calderas, consecutive eruptions have generated complexes of closely spaced domes, cinder cones, and lava flows, sometimes piled on top of one another. In some instances, an eruption leading to the formation of a caldera can happen before and after the formation of other significant volcanic products over millions of years. Example Alaskan calderas with intracaldera features include Aniakchak, Okmok, Kaguyak, and Veniaminof. For descriptions, see the AVO website <http://www.avo.alaska.edu/volcanoes/>.

Additionally, some volcanoes exhibit an eruptive type not classically recognized based solely on the type of igneous rocks ejected. For example, Wrangell, an andesitic volcano is a shield volcano, which is more commonly associated with basaltic compositions. Scientists believe this is because of the massive amount of lava ejected by Wrangell volcano, with lava flows as long as 58 km (36 mi), which occurred over a very short amount of time. Many stratovolcano or composite cones in Alaska also feature summit domes and craters, and cinder cones on their flanks. Each volcanic feature is connected to a particular, varying eruptive process, and magmatic composition.

### **Objectives**

Students will learn about how one volcano can display different eruption styles and products through time. Students will understand different eruption processes at Alaskan volcanoes.

### **Materials**

Students will need to combine several volcanic models and eruption processes using different household and classroom materials for this activity. Students can create their volcano model as a homework assignment and then conduct two or more eruptions (using different processes) of that model in the classroom.

Suggestions for volcano models, eruption processes, and materials needed are available at these web sites:

- Hawai'i Space Grant College, 1996, Teacher pages: University of Hawaii, Hawai'i Institute of Geophysics and Planetology, accessed June 1, 2010, at
  - Gelatin Volcanoes  
[http://www.spacegrant.hawaii.edu/class\\_acts/GelVolTe.html](http://www.spacegrant.hawaii.edu/class_acts/GelVolTe.html) and
  - Cake Batter Lava  
[http://www.spacegrant.hawaii.edu/class\\_acts/CakeLavaTe.html](http://www.spacegrant.hawaii.edu/class_acts/CakeLavaTe.html).
- Montana Bureau of Mines and Geology, [n.d.], Let's make a volcano: Montana Bureau of Mines and Geology web page, accessed June 1, 2010, at [http://www.mbmng.mtech.edu/kids/make\\_a\\_volcano.htm](http://www.mbmng.mtech.edu/kids/make_a_volcano.htm).
- Oregon State University, [n.d.], VolcanoWorld—Volcano models: Oregon State University website, accessed June 1, 2010, at <http://volcano.oregonstate.edu/education/models/index.html>.
- Reeko's Mad Scientist Lab, 2005, Build a real working volcano: Reeko's Mad Scientist Lab web page, accessed June 1, 2010, at <http://www.spartechsoftware.com/reeko/Experiments/volcano.htm>.
- Rockhounding Arkansas, 1998, Make a volcano: Rockhounding Arkansas web page, accessed June 1, 2010, at <http://rockhoundingar.com/pebblepups/volcano.html>.
- U.S. Geological Survey, 1997, The mountain blows its top, Lesson 2, Activity 1, *in* Volcanoes! Creators and destroyers: U.S. Geological Survey web pages (Available at <http://edc2.usgs.gov/pubslists/teachers-packets/volcanoes/pdf/Lesson2-all.pdf>.)
- Wolff-Michael Roth, [n.d.], How to build your own volcano—Paper mâché volcano: University of Victoria, Lansdowne Professor, Applied Cognitive Science, Faculty of Education, accessed June 1, 2010, at [http://www.educ.uvic.ca/faculty/mroth/438/VOLCANO/PAPER\\_MACHE.html](http://www.educ.uvic.ca/faculty/mroth/438/VOLCANO/PAPER_MACHE.html).

The materials required will vary based on the eruption styles selected.

**Procedure** (see part E for an example)

**A. Review or introduce materials on types of volcanoes**

1. Using the background figure and resources, and additional materials available through your science curriculum, review the main types of volcanoes with your class. *Note* Activity I in Chapter 4 of this guidebook also covers this material.

**B. Planning and student homework assignment**

1. Divide your class into small groups who will work together on this homework assignment and follow-up classroom activity.
2. Have each group of students select an Alaskan volcano to model. In addition to other on-line, classroom, and library resources, students may use the AVO website (<http://www.avo.alaska.edu/>) or other source(s) of information on eruptive features and types of Alaskan volcanoes. Students can learn about the most recent and (or) most dominant (still visible) eruptive processes and products at their selected volcano.

3. Assign students the task of building a model of their selected volcano as homework. It may be best to give students a weekend or multiple evenings to work on the model. Students may generate an initial, first eruption in the process of making their volcano. Students will then conduct two subsequent eruptions of their volcano in the classroom using two different processes and record their observations.

### **C. Subsequent eruptions in the classroom**

1. Students may or may not have conducted an initial, first, eruption in the construction of their volcano model. Either way, direct students to bring their homework volcano models into the classroom and have them conduct at least two eruptions in the classroom using different processes to generate different volcanic products on top any existing erupted material they may have generated at home.
2. Students can record their observations and identify any preexisting and newly formed land features (cone, vent, dome, explosion, lava flow) on the *Successive Volcanic Eruptions: Record Sheet* worksheet.
3. If time allows, students may follow the same procedures, using yet another eruption mechanism. They record their observations and identify any preexisting and newly formed land features (cone, vent, dome, explosion, lava flow) on the *Successive Volcanic Eruptions: Record Sheet* worksheet.

### **D. Sketches, investigations, and class discussion**

1. At the completion of all of the eruptions, students can draw a sketch illustrating and labeling all deposits and features that formed, were altered, or destroyed by all of their eruptions. Students can do this on the *Successive Volcanic Eruption Sketch* worksheet. If a digital camera is available, photographs of each eruption can be used for comparison purposes as well.
2. Make enough copies of each completed *Successive Volcanic Eruption Sketch* worksheet so that every group receives a sketch from every other group.
3. Students can try to determine the sequence of eruptive processes that produced the features illustrated in each group's sketch (or photograph), and then write down the eruptive order (using additional copies of the *Successive Eruptions: Record Sheet* worksheet) they suspect lead to the outcome volcano and its features. You may also do this as a class exercise and write their conclusions on the board. If available, students may also want to look at each other's post-eruptions models.
4. Students will then learn from the groups who generated each volcano model the order of eruption processes and product generation and (or) destruction.

## E. Example

1. Students may select Aniakchak volcano, a large caldera on the Alaska Peninsula that has several cinder cones, lava flows, and domes inside.  
(<http://www.avo.alaska.edu/volcanoes/volcinfo.php?volcname=Aniakchak>). Also see this example used in the *Example Successive Volcanic Eruptions Record Sheet*.
  - For their homework assignment, students may generate the caldera using a balloon and flour or sand model (one eruption) or paper mache.
  - For their classroom eruption, students may inject jelly or warm wax into the caldera using a plastic tube and pastry bag (a second eruption).
  - Also in the classroom, students may follow up with a tube and air compressor or pressurized air from a canister to generate an ash explosion leading to cone formation elsewhere in their caldera (a third eruption).

## Extensions

1. Some volcanoes in Alaska are thought to be connected through an underground network of pipes, dikes, and (or) sills. One such connection is suspected in the eruption and formation of the Novarupta dome and the collapse of Mt Katmai on the Alaska Peninsula in 1912. Students can be challenged to construct two (or more) connected volcanic vents and to observe the consequences when each vent erupts separately or when a single vent erupts repeatedly.
2. Alaska Museum of Natural History, 2006, Volcano simulator: Alaska Museum of Natural History website, accessed June 1, 2010, at <http://www.alaskamuseum.org/features/volcano/>.
3. Camp, Vic, [n.d.], How volcanoes work—The eruption model—Dynamics of a Plinian eruption: San Diego State University, animation, accessed June 1, 2010, at [http://www.geology.sdsu.edu/how\\_volcanoes\\_work/Eruption\\_model.html](http://www.geology.sdsu.edu/how_volcanoes_work/Eruption_model.html).
4. Driedger, C.L., Doherty, Anne, and Dixon, Cheryll, 2005, Living with a volcano in your backyard—An educator's guide with emphasis on Mount Rainier: U.S. Geological Survey General Interest Product 19; produced in cooperation with the National Park Service. (Available at <http://vulcan.wr.usgs.gov/Outreach/Publications/GIP19/>.)
  - PlayDough Topo  
[http://vulcan.wr.usgs.gov/Outreach/Publications/GIP19/chapter\\_three\\_play-dough\\_topo.pdf](http://vulcan.wr.usgs.gov/Outreach/Publications/GIP19/chapter_three_play-dough_topo.pdf).
  - Lava Building Blocks  
[http://vulcan.wr.usgs.gov/Outreach/Publications/GIP19/chapter\\_two\\_lava\\_blocks.pdf](http://vulcan.wr.usgs.gov/Outreach/Publications/GIP19/chapter_two_lava_blocks.pdf).
  - Riding the Magma Elevator  
[http://vulcan.wr.usgs.gov/Outreach/Publications/GIP19/chapter\\_one\\_magma\\_elevator.pdf](http://vulcan.wr.usgs.gov/Outreach/Publications/GIP19/chapter_one_magma_elevator.pdf).
  - Soda Bottle Volcano  
[http://vulcan.wr.usgs.gov/Outreach/Publications/GIP19/chapter\\_one\\_soda\\_bottle\\_volcano.pdf](http://vulcan.wr.usgs.gov/Outreach/Publications/GIP19/chapter_one_soda_bottle_volcano.pdf).



## References Cited

- Alaska State Department of Education and Early Development, 2006, Standards and grade level expectations, March 2006: State of Alaska website, accessed October 2009 at <http://www.eed.state.ak.us/tls/assessment/GLEHome.html>.
- Smithsonian Institution, [n.d.], Global volcanism program—Wrangell: Smithsonian Institution web page, accessed June 1, 2010, at <http://www.volcano.si.edu/world/volcano.cfm?vnum=1105-02->.

## Glossary

**Caldera** – A caldera is a large, usually circular depression at the summit of a volcano formed when magma is withdrawn or erupted from a shallow underground magma reservoir. The removal of large volumes of magma may result in loss of structural support for the overlying rock, thereby leading to collapse of the ground, and formation of a large depression. Calderas are different from craters, which are smaller, circular depressions created primarily by explosive excavation of rock during eruptions.

**Cinder cone** – A steep, conical hill of volcanic fragments that accumulate around and downwind from a vent. The rock fragments, often called cinders or scoria, are glassy and contain numerous gas bubbles “frozen” into place as magma exploded into the air and then cooled quickly. Cinder cones range in size from tens to hundreds of meters tall.

**Flood or plateau basalt** – Very liquid basaltic lava pours from long fissures and floods the surrounding countryside with lava flows forming broad plateaus.

**Intracaldera** – Within a caldera.

**Lava dome** – A roughly circular mound-shaped protrusion resulting from the slow eruption of felsic lava (usually rhyolite or dacite) from a volcano, or from multiple lava episodes of different magma types.

**Maar** – A low-relief broad volcanic crater formed by shallow explosive eruptions. The explosions are usually caused by the heating and boiling of groundwater when magma invades the groundwater table. Often fill with water to form a lake.

**Pyroclastic flow** –A ground-hugging avalanche of hot ash, pumice, rock fragments, and volcanic gas that rushes down the side of a volcano as fast as 100 km/hour (~60 mi/hour) or more. The temperature within a pyroclastic flow may be greater than 500°C (900°F), sufficient to burn and carbonize wood. Once deposited, the ash, pumice, and rock fragments may deform (flatten) and weld together because of the intense heat and the weight of the overlying material. The emplaced flow is called a deposit.

**Resurgent dome** – Volcanic domes are rounded, steep-sided mounds built by very viscous magma, usually either dacite or rhyolite, if they are resurgent then they have appeared again after a previous growth or eruption.

**Shield volcano** – A volcano characterized by low angle slopes.

**Stratovolcano** – A type of volcano (also called a composite cone), characterized by slope angles of as much as 35 degrees.

**Sources of Glossary Definitions**

Bates, R.K., and Jackson, J.A., eds., 1987, Glossary of Geology (3<sup>rd</sup> ed.): Falls Church, Va., American Geological Institute, 571 p.

U.S. Geological Survey, 2008, Cascades Volcano Observatory—Volcano Types : U.S. Geological Survey web page. (Available at [http://vulcan.wr.usgs.gov/Glossary/VolcanoTypes/volcano\\_types.html](http://vulcan.wr.usgs.gov/Glossary/VolcanoTypes/volcano_types.html).)

U.S. Geological Survey, 2010, Volcano Hazards Program—USGS photo glossary of volcanic terms: U.S. Geological Survey website. (Available at <http://volcanoes.usgs.gov/images/pglossary/index.php>.)

Name \_\_\_\_\_ Date \_\_\_\_\_ Period \_\_\_\_\_

### Successive Volcanic Eruptions: Record Sheet

<b>Eruption Mechanism</b>	<b>Pre-eruption Features</b>	<b>Hypothesis</b>	<b>Post-eruption Features</b>	<b>Post-eruption Observations</b>
1.				
2.				
3.				

Name \_\_\_\_\_ Date \_\_\_\_\_ Period \_\_\_\_\_

## Successive Volcanic Eruption Sketch

**Map View**

**Cross Section View**

## Example Successive Volcanic Eruptions: Record Sheet Key

For example, students may choose Aniakchak volcano, a large caldera on the Alaska Peninsula that has several cinder cones, lava flows, and domes inside. Also, see this example used in the *Example Successive Volcanic Eruptions Record Sheet*

- For their homework assignment, students may generate the caldera using a balloon and flour or sand model (one eruption) or paper mache.
- For their classroom eruption, students may inject jelly or warm wax into the caldera using a plastic tube and pastry bag (a second eruption).
- Also in the classroom, students may follow up with a tube and air compressor or pressurized air from a canister to generate an ash explosion leading to cone formation elsewhere in their caldera (a third eruption).

<b>Eruption Mechanism</b>	<b>Pre-eruption Features</b>	<b>Hypothesis</b>	<b>Post-eruption Features</b>	<b>Post-eruption Observations</b>
<b>1.</b> stratovolcano or composite cone collapse	stratovolcano or composite cone	generation of a caldera	caldera	left behind a spherical ridge of almost uniform height defining the caldera walls
<b>2.</b> eruption of viscous lava	caldera	dome generation through the caldera floor	caldera and dome	caldera rim stayed the same, dome feature dominates caldera floor. May have some lava flows or spreading of the dome.
<b>3.</b> high pressure explosion	caldera and dome	dome and (or) rim of caldera could break apart, vent or cone could form on caldera floor	caldera, dome and vent or cone	dome and (or) rim of caldera could break apart, vent or cone could form on caldera floor

## **Activity II. Compare and Contrast: Alaska Style**

**Grade Level** 6–11

**Setting** Classroom

**Time** 50–90 minutes (may best be done as a homework assignment with class discussion)

### **Correlations to Alaska State Department of Education (2006) Performance Standards (Grade Level Expectations)**

**D1**—Concepts of Earth Science

**SD[6-11]** Students develop an understanding of the concepts, processes, theories, models, evidence, and systems of earth and space sciences.

**SD2[6-11]** Students develop an understanding of the origins, ongoing processes, and forces that shape the structure, composition, and physical history of the Earth

### **Vocabulary (see Glossary)**

tectonic setting, vent, viscosity, Volcanic Eruption Index (VEI)

### **Overview**

Students can select two volcanic eruptions, and compare and contrast their occurrences. Students may select two eruptions at the same volcano in Alaska, or eruptions from one volcano in Alaska and another one elsewhere.

### **Background**

Alaska is home to so many volcanoes that just about every eruption type is represented there. With so many Alaskan volcanoes to choose from, each student can research one that is unique. Several resources are available that describe many of the more popular Alaskan volcanoes and volcanic eruptions. Students may also choose to compare and Alaskan eruption with one outside of Alaska.

### **Objectives**

By comparing and contrasting two volcanic eruptions, at least one of which took place in Alaska, students will gain an appreciation for the variances in eruption types, products, and hazards throughout the state and elsewhere. Student presentations on their research may be best suited for a poster, paper, oral presentation, or *Compare and Contrast Volcanic Eruptions* worksheet.

### **Materials**

Students will need on-line access, and time to also use library and (or) textbook resources. Presentation materials will be dependent on the presentation type and can be limited to materials available on hand. The *Compare and Contrast Volcanic Eruptions* worksheet provided may act in place or to aid in the organization of a presentation.

## Procedure

### A. Research and Present

1. Students can select two volcanoes, or two volcanic eruptions from a single volcano in Alaska, to compare and contrast in a poster, paper, oral presentation and (or) by completing the *Compare and Contrast Volcanic Eruptions* worksheet.
2. There are many obscure volcanoes and eruptions in Alaska with few resources available to complete this activity. Students can select from a list specific volcanoes and volcanic eruptions based on the amount of available materials for research. One suggested list includes:
  - Akutan
  - Aniakchak
  - Augustine
  - Bogoslof
  - Cleveland
  - Katmai: 1912
  - Novarupta: 1912
  - Okmok: 1997
  - Pavlof
  - Redoubt: 1989-1990, 2009
  - Shishaldin
  - Spurr: 1992 (Crater Peak), 1953
  - Trident

### Extensions

1. As a class, students can make a key of different kinds of volcanic features found through their research. Students can develop an identifying mark for each feature and draw them on a map of Alaska at the volcanoes where each feature is found. Depending on the volcanoes studied, students may see a large cluster of calderas on the Alaska Peninsula, stratovolcanoes (or composite cones) in the Cook Inlet region and Aleutians, and the large shield volcano, Wrangell, in the southeastern area of the state. Students could conduct further investigations to find out if their observations have relevance to tectonic regions, local faults or other structures, or if there is not a systematic occurrence of volcano features throughout the state.
2. Students may incorporate or focus on the use of the VEI in their comparisons. Some resources for this comparison are:
  - Smithsonian Institution, [n.d.], Global volcanism program: Smithsonian Institution web pages, accessed June 1, 2010, at
    - Large Holocene Eruptions  
<http://www.volcano.si.edu/world/largeeruptions.cfm> and
    - Volcanic Explosivity Index (VEI)  
<http://www.volcano.si.edu/world/eruptioncriteria.cfm#VEI>

- U.S. Geological Survey, 2009, Volcano Hazards Program—VHP photo glossary—VEI: U.S. Geological Survey website. (Available at <http://volcanoes.usgs.gov/images/pglossary/vei.php>.)

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Alaska State Department of Education and Early Development, 2006, Standards and grade level expectations, March 2006: State of Alaska website, accessed October 2009 at <http://www.eed.state.ak.us/tls/assessment/GLEHome.html>.

Oregon State University, [n.d.], VolcanoWorld—Kinds of volcano eruptions: Oregon State University website, accessed June 1, 2010, at <http://volcano.oregonstate.edu/education/vwlessons/kinds/kinds.html>.

### Glossary

**Tectonic setting** – The way in which plates move at their margins defines the tectonic setting or type of dynamic movement of tectonic plates, for a given region. Examples include divergence, convergence, and transform.

**Vent** – Vents are openings in the Earth's crust from which molten rock and volcanic gases escape onto the ground or into the atmosphere. Vents may consist of a single circular-shaped structure, a large elongate fissure and fracture, or a tiny ground crack. The release of volcanic gases and the eruption of molten rock will result in an assortment of constructional features ranging from enormous shield volcanoes and calderas to fumaroles and small rootless hornitos.

**Viscosity** – The property of a substance to offer internal resistance to flow; specifically the ratio of the shear stress to the rate of shear strain, which is known as the coefficient of friction.

**Volcano Explosivity Index (VEI)** - Proposed in 1982 as a way to describe the relative size or magnitude of explosive volcanic eruptions. It is a 0-to-8 index of increasing explosivity. Each increase in number represents an increase around a factor of ten. The VEI uses several factors to assign a number, including volume of erupted pyroclastic material (for example, ash fall, pyroclastic flows, and other ejecta), height of eruption column, duration in hours, and qualitative descriptive terms.

### Sources of Glossary Definitions

Bates, R.K., and Jackson, J.A., eds., 1987, Glossary of Geology (3<sup>rd</sup> ed.): Falls Church, Va., American Geological Institute, 571 p.

U.S. Geological Survey, 2010, Volcano Hazards Program—USGS photo glossary of volcanic terms: U.S. Geological Survey website. (Available at <http://volcanoes.usgs.gov/images/pglossary/index.php>)



Name \_\_\_\_\_ Date \_\_\_\_\_ Period \_\_\_\_\_

### Compare and Contrast Volcanic Eruptions

Fill in two different volcanic eruptions (they may be from the same volcano) and compare and contrast the various volcanic features. You may add more features in the space available in the table on the second page.

<b>Feature</b>	<b>Volcanic Eruption I name, location &amp; eruption date:</b>  _____	<b>Volcanic Eruption II name, location &amp; eruption date:</b>  _____
<b>Vent type</b>		
<b>Volcanic features</b>		
<b>Eruption length</b>		
<b>Placement of vent</b>		
<b>Hazards</b>		
<b>Destruction</b>		
<b>Rock type</b>		
<b>Gas type(s)</b>		
<b>Earthquake size and frequency, measured</b>		
<b>Volume of material erupted</b>		

<b>Feature</b>	<b>Volcanic Eruption I name, location &amp; eruption date:</b> _____	<b>Volcanic Eruption II name, location &amp; eruption date:</b> _____
<b>Lava viscosity, if applicable</b>		
<b>Often visited by scientists, tourists</b>		
<b>Tectonic setting</b>		

## Activity III. Volcanic Explosivity Index, Alaska

Grade Level 6–11

Setting Classroom

Time 50 minutes

### Correlations to Alaska State Department of Education (2006) Performance Standards (Grade Level Expectations)

**D1**—Concepts of Earth Science

**SD[6-11]** Students develop an understanding of the concepts, processes, theories, models, evidence, and systems of earth and space sciences.

**SD2[6-11]** Students develop an understanding of the origins, ongoing processes, and forces that shape the structure, composition, and physical history of the Earth

### Overview

According to the Volcano Hazards Program USGS photo glossary of volcanic terms, in 1982, volcanologists proposed a scale from which to assign values associated to the “size” of a volcano eruption. This logarithmic scale is called the Volcanic Explosivity Index, or VEI, and has been applied to known volcanic eruptions worldwide. After students are introduced to this scale, they will apply it to a significant, recent volcanic eruption in Alaska—the June 6–9, 1912, eruption of Novarupta volcano, the associated collapse event, which formed the Katmai caldera and the Valley of Ten Thousand Smokes in what is now Katmai National Park on the Alaska Peninsula.

### Background

- Alaska Volcano Observatory, [n.d.], Statistics, description and links to images, maps, bibliography, reported activity, and webrecorders and webcams where available: Alaska Volcano Observatory web pages available at:
  - Novarupta description and statistics  
<http://www.avo.alaska.edu/volcanoes/volcinfo.php?volcname=Novarupta>
  - Katmai description and statistics  
<http://www.avo.alaska.edu/volcanoes/volcinfo.php?volcname=Katmai>Regional map and volcano list
  - Alaska Peninsula  
[http://www.avo.alaska.edu/volcanoes/alaska\\_peninsula.php](http://www.avo.alaska.edu/volcanoes/alaska_peninsula.php)
- U.S. Geological Survey
  - Fierstein, Judy, and Hildreth, Wes, 2001, Preliminary volcano-hazard assessment for the Katmai volcanic cluster, Alaska: U.S. Geological Survey Open-File Report 00-0489, 50 p., 1 plate. (Also available at <http://geopubs.wr.usgs.gov/open-file/of00-489/of00-489.pdf>.)
  - Fierstein, Judy, Hildreth, Wes, Hendley, J.W., II, and Stauffer, P.H., 1998, Can another great volcanic eruption happen in Alaska?: U.S. Geological Survey Fact Sheet 0075-98, 2 p. (Also available at <http://pubs.usgs.gov/fs/fs075-98/> and <http://pubs.usgs.gov/fs/fs075-98/fs075-98.pdf>.)

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- U.S. Geological Survey, 2008, Annotated NASA image Katmai vicinity, Alaska—Katmai vicinity including the Valley of Ten Thousand Smokes, Alaska, August 1989: U.S. Geological Survey web page. (Available at [http://vulcan.wr.usgs.gov/Photo/NASA/AnnotatedImages/nasa\\_katmai\\_vicinity\\_8908.html](http://vulcan.wr.usgs.gov/Photo/NASA/AnnotatedImages/nasa_katmai_vicinity_8908.html).)
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- Annenberg Media Multimedia Collection, 2010, Interactives—Volcanoes, judging hazards—Katmai Video Clip (1:02 minutes; 6,272 KB), accessed June 1, 2010, at <http://www.learner.org/interactives/volcanoes/movies/movies4.html>.
- Smithsonian Institution, [n.d.], Global volcanism program: Smithsonian Institution web pages, accessed June 1, 2010, at
  - Novarupta <http://www.volcano.si.edu/world/volcano.cfm?vnum=1102-18-> and
  - Katmai <http://www.volcano.si.edu/world/volcano.cfm?vnum=1102-17->.
- National Park Service
  - Adleman, J.N., 2002 The great eruption of 1912, *in* Alaska Park Science—Connections to natural and cultural resources in Alaska's National parks: U.S. Department of the Interior, National Park Service, Alaska Support Office, 39 p., accessed July 2, 2010, at <http://www.arlis.org/docs/vol1/52558645/52558645v1no1.pdf>.
  - Clemens, Janet, and Norris, Frank, 1999, Building in an Ashen Land—Historic Resource Study of Katmai National Park and Preserve: Anchorage, Alaska, National Park Service, Alaska Support Office, accessed June 1, 2010, at [http://www.nps.gov/history/history/online\\_books/katm/hrs/hrs.htm](http://www.nps.gov/history/history/online_books/katm/hrs/hrs.htm).
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  - National Aeronautics and Space Administration, 2006, Goddard Space Flight Center—Historic volcanic eruption shrunk the mighty Nile River: NASA News and Media Releases, Feature November 21, 2006, accessed June 1, 2010 at [http://www.nasa.gov/centers/goddard/news/topstory/2006/volcano\\_nile.html](http://www.nasa.gov/centers/goddard/news/topstory/2006/volcano_nile.html).
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- Lillie, R.J., 2005, Parks and plates—The geology of our National parks, monuments, and seashores: New York, W.W. Norton and Comdishy, 298 p.
  - Chapter 5: Southern Alaska Subduction Zone, p. 120-121.
- Riehle, Jim, 2002, The geology of Katmai National Park and Preserve, Alaska: Publication Consultants, p. 112.

### **Objectives**

Students will understand the Volcano Explosivity Index (VEI) scale used to determine the relative size of volcanic eruptions worldwide. By applying this scale to a significant volcanic eruption in Alaska students will be introduced to the largest volcanic eruption in the world in the Twentieth century and the significance Alaska's volcanism plays in global tectonics, economy, and hazards.

### **Materials**

— *Eruption Data: Novarupta 1912* worksheet

## Procedure

### I. Class brainstorming exercise and introduction to VEI

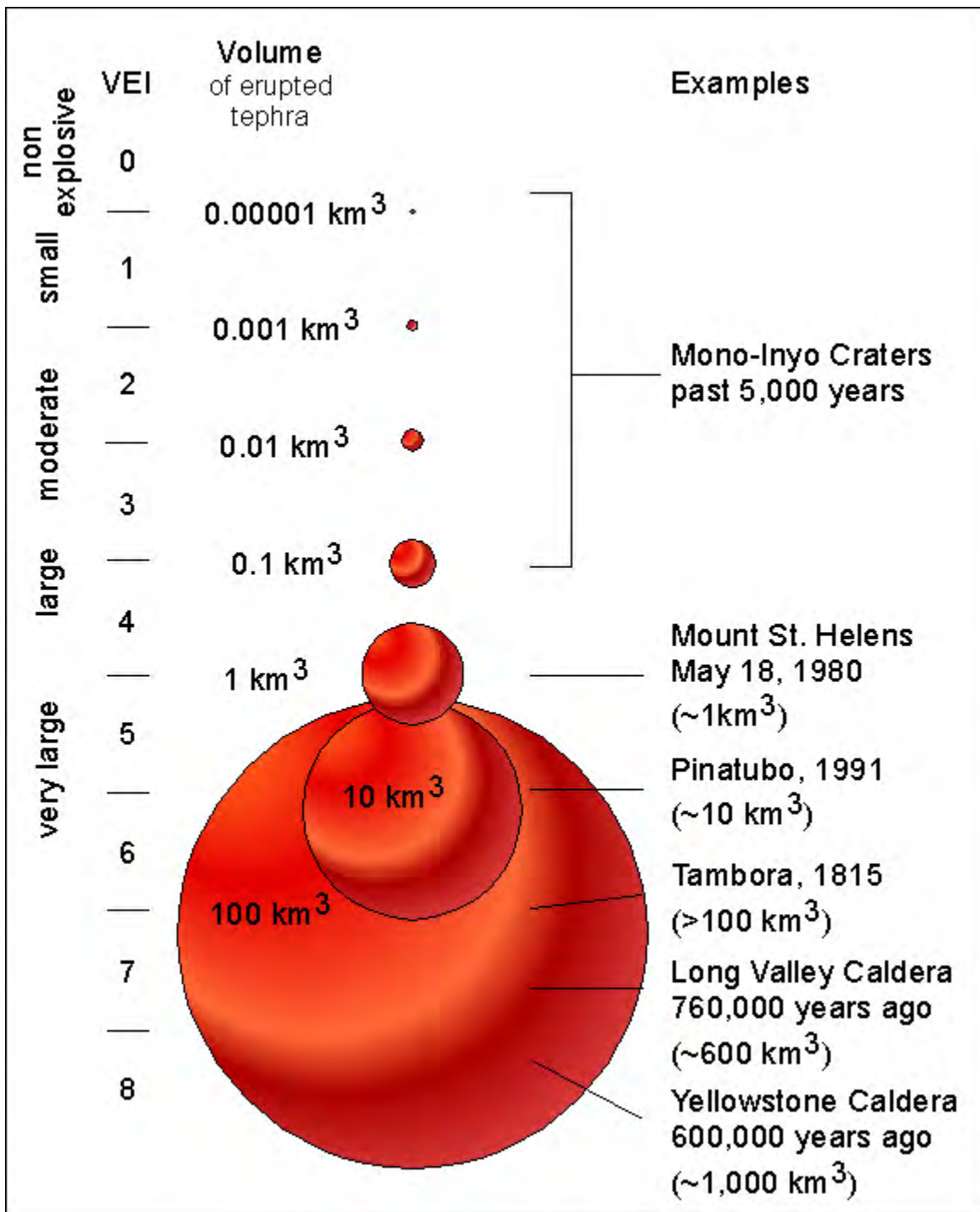
1. Ask students to brainstorm about the various ways one could measure the “size” of a volcanic eruption. Record student answers. You may contribute key measurement techniques if students do not generate these answers. A robust list will include:

- Magma volume
- Tephra volume
- Amount of energy released
- Plume height
- Temperature of deposits
- Area covered by deposits
- “Reach” of deposits – as far as they got
- Amount of time materials was airborne
- Type of eruption
- Composition (rock type) of deposits
- Length, in time, of eruption
- Size and or number of associated earthquakes
- Number of people displaced, effected, harmed or killed

2. Introduce students to the Volcano Explosivity Index (VEI).

Several resources/examples are available to cover this materials:

- Lowenstern, J.B., and others, 2005, Steam explosions, earthquakes, and volcanic eruptions—What's in Yellowstone's future?: U.S. Geological Survey Fact Sheet 2005-3024, 6 p. (Also available at <http://pubs.usgs.gov/fs/2005/3024/> and <http://pubs.usgs.gov/fs/2005/3024/fs2005-3024.pdf>.)
- Mattox, S.R., 1994, A teachers' guide to the geology of Hawaii Volcanoes National Park: Hawaii Natural History Association, 391 p.
- Activity 9.5: The Volcanic Explosivity Index (Grades 9–12) p. 159; 162.
- Newhall, C.G., and Self, Stephen, 1982, The Volcanic Explosivity Index (VEI)—An estimate of explosive magnitude for historical volcanism: *Journal of Geophysical Research*, v. 87, no. C2, p. 1231-1238. (Also available at <http://www.agu.org/journals/jc/v087/iC02/JC087iC02p01231/JC087iC02p01231.pdf>.)
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- U.S. Geological Survey, 2009, Volcano Hazards Program, VHP photo glossary—VEI : U.S. Geological Survey web page. (Available at <http://volcanoes.usgs.gov/images/pglossary/vei.php>.)





3. If needed, explain the principle of the logarithmic scale (as opposed to a linear scale). A logarithmic scale is a unit of measurement in which an increase or decrease of one unit represents a ten-fold change in the quantity measured. Several resources focus on earthquakes that can be used to illustrate a logarithmic scale.
  - Braile, L.W., 2002 [2006], The AS-1 Seismograph—Magnitude determination: Explorations in Earth Science web page, accessed June 1, 2010, at <http://web.ics.purdue.edu/~braile/edumod/as1mag/as1mag3.htm>.
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  - Wald, Lisa, and Shindle, Wendy, 2001 [2004], Magnitude vs intensity—4-12: U.S. Geological Survey Earthquake Hazards Program web page. (Available at [http://earthquake.usgs.gov/learning/teachers/Mag\\_vs\\_Int\\_Pkg.pdf](http://earthquake.usgs.gov/learning/teachers/Mag_vs_Int_Pkg.pdf).)
4. Ask students to identify very large volcanic eruptions—start worldwide. Students will likely come up with Vesuvius and additional volcanoes featured in documentaries they have seen. Some may come up with recent eruptions of Alaskan volcanoes such as Redoubt, Spurr, and Augustine. Tell your students that they will learn about the largest volcanic eruption of the 20th century—and that it occurred in Alaska. Ask if any students can name this volcano and the year of this eruption. Although students may name the volcano as Katmai, let students know that the largest volcanic eruption of the 20th century was the 1912 eruption of Novarupta on the Alaska Peninsula.
5. Students will work individually or in small groups to learn about the 1912 eruption of Novarupta. Using the resources listed in the Background section in Chapter 3 and other resources, students will complete a data table (*Eruption Data: Novarupta 1912* worksheet provided). Using this data, students will assign a VEI to this eruption.

### **Extensions**

1. Students can investigate how the Novarupta eruption affected Alaska and parts of western Canada and the lower-48 states in 1912 and for several subsequent years.
2. Students can make circle diagrams that illustrate the relative sizes of each VEI levels. Students could also collect, label and discuss containers that show the relative sizes of different eruptions (pill jar or pickle jar or soda bottle or bucket, and so on)

3. Driedger, C.L., Doherty, Anne, and Dixon, Cheryll, 2005, Living with a volcano in your backyard—An educator’s guide with emphasis on Mount Rainier: U.S. Geological Survey General Interest Product 19; produced in cooperation with the National Park service. (Available at [http://vulcan.wr.usgs.gov/Outreach/Publications/GIP19/.](http://vulcan.wr.usgs.gov/Outreach/Publications/GIP19/))
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[http://vulcan.wr.usgs.gov/Outreach/Publications/GIP19/chapter\\_two\\_tephra\\_popcorn.pdf](http://vulcan.wr.usgs.gov/Outreach/Publications/GIP19/chapter_two_tephra_popcorn.pdf).
4. NOVA Online, 2000, Deadly shadow of Vesuvius—Volcanic Explosivity Index (VEI) and activity <http://www.pbs.org/wgbh/nova/vesuvius/deadliest3.html>.
5. U.S. Geological Survey, 2008, Predict an eruption: U.S. Geological Survey web-based program. (Available at [http://volcanoes.usgs.gov/edu/predict/.](http://volcanoes.usgs.gov/edu/predict/))
6. University Corporation for Atmospheric Research, 2005, Windows to the Universe—Student Worksheet—Lesson: Reading graphs with a logarithmic scale: University Corporation for Atmospheric Research website, accessed June 1, 2010, at [http://www.windows.ucar.edu/tour/link=/teacher\\_resources/graphs/worksheet\\_logarithmic\\_scale.html](http://www.windows.ucar.edu/tour/link=/teacher_resources/graphs/worksheet_logarithmic_scale.html).
7. Explore different types of natural disaster scales: Modified Mercalli Scale: DLESE Teaching Boxes Living in Earthquake Country (6-12) Lesson 5: A Whole Lot of Shakin’ Goin’ On! Activity 2—Determining the Intensity  
[http://www.teachingboxes.org/earthquakes/lessons/lesson5\\_activity2.jsp](http://www.teachingboxes.org/earthquakes/lessons/lesson5_activity2.jsp).

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Name \_\_\_\_\_ Date \_\_\_\_\_ Period \_\_\_\_\_

### Eruption Data: Novarupta 1912

<b>Feature</b>	<b>Value</b>
<b>Plume height</b>	
<b>Ash fall (where and how much)</b>	
<b>Length of eruption (duration in time)</b>	
<b>Geomorphic observations (cones, domes, flows...)</b>	
<b>Earthquakes (size, frequency, number...)</b>	
<b>Airborne ash (volumes, coverage, distance traveled...)</b>	
<b>Total volume (of features, total...)</b>	
<b>Phenomena reported (human and animal behaviors...)</b>	
<b>Volcanic deposit temperatures</b>	

**VEI** \_\_\_\_\_

## Eruption Data: Novarupta 1912 Key

<b>Feature</b>	<b>Value</b>
<b>Plume height</b>	100,000 ft
<b>Ash fall</b>	1,000 km east and 100 km west in 24 hours after onset of eruption
<b>Length of eruption (time)</b>	~60 hours
<b>Geomorphic observations</b>	11 hours after onset, a 2.5 km-wide caldera formed from summit collapse due to the absence of roughly 5 km <sup>3</sup> of magma had erupted thus far
<b>Earthquakes</b>	The caldera formation generated 14 earthquakes of magnitudes 6 and 7, and up to 100 greater than magnitude 5, some felt as far as 200 miles away
<b>Airborne ash</b>	Traveled ~ 4,000 miles southeast reaching Virginia 4 days after onset and more than 25,000 miles southeast reaching Algeria 11 days after onset
<b>Total volume of new magma erupted</b>	13 km <sup>3</sup> total : 17 km <sup>3</sup> of fall deposit and 11 km <sup>3</sup> of ash-flow tuff (ignimbrite)
<b>Phenomena reported</b>	lightening, areas within 200 mi including Kodiak and Afognak Islands, were engulfed in dark, opaque ash fall, explosions were heard as far as 600 mi away in Juneau, the average temperature of the Northern hemisphere was lowered by ~ 1°C (2°F) for more than 1 year
<b>Volcanic deposit temperatures</b>	The ash flow deposit temperatures were 800 – 1,000°C (1,400 – 2,000°F)

VEI         6

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