Chapter 2
Alaska's Igneous Rocks

Resources

- Alaska Department of Natural Resources, 2010, Division of Geological and Geophysical Surveys, Alaska Geologic Materials Center website, accessed May 27, 2010, at http://www.dggs.dnr.state.ak.us/?link=gmc_overview&menu_link=gmc.
- Alaska Resource Education: Alaska Resource Education website, accessed February 22, 2011, at http://www.akresource.org/.
- Barton, K.E., Howell, D.G., and Vigil, J.F., 2003, The North America tapestry of time and terrain: U.S. Geological Survey Geologic Investigations Series I-2781, 1 sheet. (Also available at http://pubs.usgs.gov/imap/i2781/.)
- Danaher, Hugh, 2006, Mineral identification project website, accessed May 27, 2010, at http://www.fremontica.com/minerals/.
- Digital Library for Earth System Education, [n.d.], Find a resource—Bowens reaction series: Digital Library for Earth System Education website, accessed June 10, 2010, at http://www.dlese.org/library/query.do?q=Bowens%20reaction%20series&s=0.
- Edwards, L.E., and Pojeta, J., Jr., 1997, Fossils, rocks, and time: U.S. Geological Survey website. (Available at http://pubs.usgs.gov/gip/fossils/contents.html.)
- Garden Buildings Direct, 2010, Rocks and minerals: Garden Buildings Direct website, accessed June 4, 2010, at http://www.gardenbuildingsdirect.co.uk/Article/rocks-and-minerals.
- Illinois State Museum, 2003, Geology online–GeoGallery: Illinois State Museum Society database, accessed May 27, 2010 at http://geologyonline.museum.state.il.us/geogallery/.
- Knecht, Elizebeth, designer, Pearson, R.W., and Hermans, Majorie, eds., 1998, Alaska in maps—A thematic atlas: Alaska Geographic Society, 100 p.
  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.
- National Aeronautics and Space Administration, [n.d.], In Situ Resource Utilizaiton (ISRU) element at Marshall Space Flight Center: National Aeronautics and Space Administration web page, accessed June 10, 2010, at http://isru.msfc.nasa.gov/igneous-rocks.html.
- Newman, W.L., 1997, Geologic time—Online edition: U.S. Geological Survey. (Available at http://pubs.usgs.gov/gip/geotime/.)
  Schmincke, H.-U., 2004, Volcanism: New York, Springer-Verlag, 324 p.
  - Chapter 3: Magmas, p. 21–34.
- Smithsonian Institution, [n.d.], The dynamic Earth: Smithsonian National Museum of Natural History website, accessed June 10, 2010, at http://www.mnh.si.edu/earth/main_frames.html.

- Smithsonian Institution, 2010, Minerals, crystals, and gems—Stepping-stones to inquiry—Create a classroom exihibit—Rocks and minerals: Smithsonian Institution website, accessed June 10, 2010, at http://www.smithsonianeducation.org/educators/lesson_plans/minerals/lesson1_main.html.
- U.S. Geological Survey, [n.d.], The living rock—The Earth's continental crust (movie file). This 1-hour video provides a global tour of geologic processes through the eyes of several USGS scientists. (Media file available at mms://video.wr.usgs.gov/movies/living_rock.wmv.)
- U.S. Geological Survey, 2004, Geologic maps: U.S. Geological Survey website. (Available at http://geomaps.wr.usgs.gov/parks/gmap/index.html.)
- U.S. Geological Survey, 2004, Rocks and minerals: U.S. Geological Survey website. (Available at http://geomaps.wr.usgs.gov/parks/rxmin/.)
- U.S. Geological Survey, 2005, Geologic maps and mapping: U.S. Geological Survey website. (Available at http://ngmdb.usgs.gov/ncgmp/ncgmpgeomaps/.)
- U.S. Geological Survey, 2008, Digital geologic map products for Alaska: U.S. Geological Survey web site. (Available at http://minerals.usgs.gov/alaska/prodxdgt.html.)
- U.S. Geological Survey Geologic Names Committee, 2007, Divisions of geologic time—Major chronostratigraphic and geochronologic units: U.S. Geological Survey Fact Sheet 2007-3015, 2 p. (Also available at http://pubs.usgs.gov/fs/2007/3015/; PDF http://pubs.usgs.gov/fs/2007/3015/fs2007-3015.pdf.)
- University of North Carolina, [n.d.], Atlas of igneous and metamorphic rocks, minerals, and textures: University of North Carolina Geology Department website, accessed June 10, 2010, at http://www.geolab.unc.edu/Petunia/IgMetAtlas/mainmenu.html.
- Weathers, Judy, Galloway, John, and Frank, Dave, 2001, Minerals in our environment: U.S. Geological Survey Open-File Report 00-144, 1 sheet. (Also available at http://geopubs.wr.usgs.gov/open-file/of00-144/.)
- Werdon, M.B., Szumigala, D.J., and Davidson, G., 2000, Generalized geologic map of Alaska: Alaska Department of Natural Resources, Division of Geological and Geophysical Surveys, 1 sheet, accessed May 27, 2010, at http://www.dggs.dnr.state.ak.us/download/akgeomap.pdf.

Activities
The activities in this chapter will allow students to become familiar with igneous rocks in terms of identification, location, and association with landscape features including volcanoes. Students will learn about the importance, value, and usage of geological maps with an emphasis on their local region. Students also will become familiar with geochemistry, the various recipes, or compositions of various igneous rock types, and the volcanic forms commonly associated with these compositions in three volcanic regions in the United States, including Alaska. Students will build on their knowledge of plate tectonics and the local plate tectonic boundaries in Alaska.

Activity I. Igneous Rock Identification
Activity II. Igneous Rocks—Coming to a Location Near You!
Activity III. Comparison of Hawaiian, Cascade, and Alaskan Volcanic Rocks

Activity I. Igneous Rock Identification

Grade Level 6–11

Setting Classroom or computer lab

Time 45–90 minutes

Vocabulary (see Glossary)
igneous, mafic, magma, plutonic, silicic, volcanic rock

Correlations to Alaska State Department of Education (2006) Science Performance Standards (Grade Level Expectations)
D1 – Concepts of Earth Science
SD1[6-11] Students develop an understanding of Earth's geochemical cycles.

Overview
In this activity, students will investigate how to identify and classify assorted Alaskan igneous rocks using various properties. These properties also are used to determine the mechanism and location of formation for these igneous rocks including their relations to Alaskan volcanism.

Background
Igneous rocks are formed by solidification of magma, which generally consists of silicate melt (molten rock mainly consisting of silica [Si]), mineral crystals, and dissolved gasses. Magma is generated deep beneath the Earth's surface. As it moves toward the surface, it may be forced out and erupt. Gas-rich magma erupts violently (explosively) as volcanic bombs and ash, whereas gas-poor magma erupts in a less dramatic manner as lava flows. When volcanic bombs, ash, and lavas cool, they form volcanic igneous rocks. Not all magma reaches the surface, however. Sometimes magma remains below the surface and crystallizes completely to form *plutonic* igneous rocks. The cooling history has an important role in the classification of igneous rocks.

One way scientists classify rocks is by determining the origin of the rock (whether it formed above or below the surface). Plutonic rocks cool and crystallize slowly below the Earth's surface allowing crystals more time to develop and results in a rock with large mineral grains typically visible to the unaided eye (known as coarse-grained) with no glass remaining between crystals (the glass represents the solidified melt in the magma). Volcanic rocks cool rapidly at the surface, so magma does not have enough time to crystallize completely. In addition, crystals forming in magma that reached the surface (then called lava) have less time to develop. The result is a rock with fewer and smaller mineral grains (fine-grained), and large amounts of glass between crystals. Another way scientists classify igneous rocks is to determine whether a rock is fine-grained or coarse-grained; this is called texture. The third characteristic that scientists use to classify igneous rocks is chemical composition. Magma that is high in silica (Si) generally forms light-colored rocks, called silicic. Magma that is low in silica generally forms dark-colored rocks, called mafic. These are generalities, however, so keep in mind other factors that affect rock color (for example, bubbles that are left behind by escaped gasses.)

Objectives
The students will be able to classify igneous rocks according to origin, texture, and color.
The students will be able to describe how igneous rocks form.

Materials

- igneous rock samples (samples [number] correspond to samples in Alaska Resource Education kit*****) with as many of the following as possible:
  - Granite (31-8)
  - Pumice (27-7)
  - Scoria
  - Obsidian (28-9)
  - Basalt (29-11)
  - Rhyolite
  - Gabbro (30-10)
  - Andesite
  - Dacite
- magnifiers or hand lenses
- general rock identification book (a few for the class, or one for each group or student)

and (or)

- use the online virtual rock kit of the

School of Ocean and Earth Science, 2006, Igneous rocks: Southampton, U.K., University of Southampton website, accessed June 10, 2010, at http://www.soes.soton.ac.uk/resources/collection/minerals/igne-1/index.htm.

and

- index cards
- *Classification of Igneous Rocks* worksheet

***** Kits are available from the Alaska Resource Education for educators in Alaska. This kit includes a collection of rock and mineral samples. Kits can be requested from the Alaska Resource Education website http://www.akresource.org/.

Procedure

A. Student designed classification system

1. Divide students into small groups. Give each student a tray of igneous rocks (see list of suggested rocks in Materials) or use the recommended virtual rock collection. Ask students to look at the rocks and determine some way to classify their rocks. Once the groups have separated their rocks, ask the class what characteristics they selected to help them classify the rocks. Write these characteristics on the board. Have students classify their rocks again using a different system than they used the first time. When they are finished, ask them again what characteristics they selected and add them to the board.

2. Discuss how scientists classify igneous rocks. Discuss origin (plutonic or volcanic), texture (fine-grained or coarse-grained), and color (mafic or silicic). Relate this vocabulary to the characteristics that the students defined when making their own classifications.

3. Using handbooks and rock identification guides, have students fill out the following list of igneous rock identification information on an index card for each unlabeled rock. Have students use the terms that were used in the discussion concerning how scientists classify igneous rocks.
   - Name: Scientific (likely the last thing to fill in).
   - Grain size/texture: Dominant crystal size: small (need a magnifier), medium (can just make out with unaided eye), large (easily seen with unaided eye) a mix of two or three sizes, somewhere in between, are all the crystals equal in size.
   - Color: Dark, medium, light, black, grey, pink, white, and so on.
   - Composition: Mafic, silicic, also note if this could be due to bubbles left behind in the rock from gases which escaped during cooling.
   - Origin: Extrusive or intrusive, volcanic, or plutonic.
   - Cool Alaska Fact: Associated mineral and rock type, locale, and origin of name, found in Alaska.
   - Picture: Have students draw a picture of their rock on the back of their paper.

B. *Classifying Igneous Rocks* worksheet

1. Have students fill in the chart on the *Classifying Igneous Rocks* worksheet and answer the questions using their note cards for assistance.

Extensions

1. Have students put their note cards together to create an identification booklet. Have them include additional pages that may include a glossary, a figure showing the rock cycle, and so on.

2. Obtain additional specimens of igneous rocks have your students try to identify them using the technique in number 1. Ask students to determine if their system used for classifying igneous rocks works well, or not, and to explain the issues.

3. Have students create a newspaper article of a rock obituary that outlines an igneous rock's life story.

4. Use *Smithsonian Education—Minerals, Crystals, and Gems—Stepping-Stones to Inquiry, Lesson Plan 1: Create a Classroom Exhibit: Rocks and Minerals* website. (Available at http://www.smithsonianeducation.org/educators/lesson_plans/minerals/lesson1_main.html.)

5. Have students also use the *Atlas of Igneous and Metamorphic Rocks, Minerals, and Textures* website to learn more about volcanic and plutonic textures and common minerals in igneous rocks. (Available at http://www.geolab.unc.edu/Petunia/IgMetAtlas/mainmenu.html.)

6. Have the students review the Smithsonian Institution's *The Dynamic Earth* website. (Available at http://www.mnh.si.edu/earth/main_frames.html.)

7. Have students identify the majority of minerals that their igneous rocks are made of. Are there some repeat performers? The most common minerals in igneous rocks may form sequentially as cooling progresses following the Bowens Reaction. Material on the Bowens Reaction Series includes:
   - Digital Library for Earth System Education (DLESE)
     - Bowens reaction series available at http://www.dlese.org/library/query.do?q=Bowens%20reaction%20series&s=0; and
     - Igneous minerals available at http://www.dlese.org/library/query.do?q=igneous%20minerals&s=0.

8. Students can learn about the International Union on Geological Sciences (IGUS) Classification of Igneous Rock.
   - In Situ Resource Utilization (ISRU) Element at Marshall space Flight Center
     Lunar Regolith Simulant Development and Characterization
     NASA Simulant Development: Igneous Rocks website available at http://isru.msfc.nasa.gov/igneous-rocks.html.

Reference 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.

Glossary

Igneous–A rock or mineral that solidified from magma; also applied to processes leading to, related to, or resulting from the formation of such rocks.

Mafic–An igneous rock composed mostly of one or more dark-colored minerals

Magma–Naturally occurring mobile rock material generated within the Earth and capable of intrusion, extrusion, from which igneous rocks are derived through solidification and other processes.

Plutonic–Igneous rocks formed at depth.

Silicic–Silica (Si)-rich igneous rocks or magma, typically two-thirds or 65 percent of the composition is Si.

Volcanic rock–A fine-grained or glassy igneous rock resulting from volcanic action at or near the Earth's surface; either ejected explosively or extruded as lava.

Source of Glossary Definitions

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

Name ______________________________ Date ____________ Period _____

Classifying Igneous Rocks

Igneous Rocks	Rate of Cooling	Texture	Origin
Granite			
Pumice			
Scoria			
Obsidian			
Basalt			
Rhyolite			
Gabbro			
Andesite			
Dacite			

1. What are three ways that scientists use to classify igneous rocks?

2. Describe how cooling rate affects the size of mineral grains in an igneous rock.

3. Compare and contrast volcanic igneous rocks with plutonic igneous rocks.

Classifying Igneous Rocks Answer Key

Igneous Rocks	Rate of Cooling	Texture	Origin	Mineral Composition
Granite	Slow	Coarse-grained	Plutonic	Silicic
Pumice	Very rapid	Fine-grained	Volcanic	Silicic
Scoria	Rapid	Fine-grained	Volcanic	Mafic
Obsidian	Rapid	Fine-grained; glassy	Volcanic	Silicic
Basalt	Rapid	Fine-grained	Volcanic	Mafic
Rhyolite	Rapid	Fine-grained	Volcanic	Silicic
Gabbro	Slow	Coarse-grained	Plutonic	Mafic
Andesite	Rapid	Fine to medium grained	Volcanic	Intermediate
Dacite	Rapid	Fine to medium grained	Volcanic	Intermediate

1. What are three ways that scientists use to classify igneous rocks?

   Scientists use origin, texture, and composition to classify rocks. They look at the texture of the rock to see if it is fine-grained or coarse-grained. The texture of the rock determines its origin—if it cooled below the surface or above the surface. The mineral composition (the types of minerals in the rock and their proportions) tells if it is mafic or silicic (low in silica or high in silica).

2. Describe how the location of magma and its respective cooling rate affects the size of mineral grains in an igneous rock.

   If magma cools below the surface of the earth, it takes longer to solidify. The longer it takes to cool, the more time crystals have to develop and the larger they will become. All of the melt crystallizes, so no glass remains in the rock. If magma cools above the surface, it will solidify faster and melt crystallizes to glass. The mineral crystals will have less time to develop and will be smaller with glass present between crystals.

3. Compare and contrast volcanic igneous rocks with plutonic igneous rocks.

   Extrusive igneous rocks form from lava that has cooled on the surface of the earth. They are volcanic and have small mineral grains. Intrusive igneous rocks form from magma that has cooled below the surface. They are plutonic and have larger mineral grains than extrusive igneous rocks.

   Volcanic igneous rocks form from magma that has cooled on the surface of the earth. Often they have small mineral grains. Plutonic igneous rocks form from magma that has crystallized below the surface. They have larger mineral grains than volcanic igneous rocks.

Activity II. Igneous Rocks—Coming to a Location Near You!

Grade Level 6–11

Setting Classroom

Time 50 minutes

Vocabulary (see Glossary)
bedrock, geologic features, stratigraphic column (geologic column)

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

D1 – Concepts of Earth Science

SD1[6-11]	Students develop an understanding of Earth's geochemical cycles.
SD1.1[8]	The student demonstrates an understanding of geochemical cycles by making connections between components of the locally observable geologic environment and the rock cycle.
SD2[6-11]	Students develop and understanding of the Earth origins, ongoing processes, and forces that shape the structure composition, and physical history of the Earth.
SD2.1[8]	The student demonstrates an understanding of the forces that shape Earth by interpreting topographical maps to identify features (that is, rivers, lakes, mountains, valleys, islands, permafrost, and tundra).

Overview
Students will use a series of maps to identify igneous rock outcrops, young volcanic or plutonic features, and (or) nearby old volcanic features close (or relatively nearby).

Background
Maps of bedrock geology illustrate the types of rocks that exist in a given area. Even if there are no currently active volcanoes outside the classroom, students likely will be able to associate regional features with bedrock types using a geologic map. Students also are likely to identify igneous intrusions or volcanic rocks associated with volcanic activity that may have occurred thousands of years ago.

Objectives
The students will identify local igneous rocks and their associated landforms using an Alaska statewide and (or) regional bedrock geologic map.

Materials
- *Geologic Map of Your Area* worksheet
- string, yarn, or twine, and
- pins with heads, or
- drawing compass, and
- pencil

Geologic Maps—enough copies so that each group has one map. Suggested maps are:

- Werdon, M.B., Szumigala, D.J., and Davidson, G., 2000, Generalized geologic map of Alaska: Alaska Department of Geological and Geophysical Surveys (included in activity)
  PDF http://www.dggs.dnr.state.ak.us/download/akgeomap.pdf and (or)
- A map of your area from
  Alaska Department of Natural Resources, [n.d.], Alaska geologic map index search—Text search interface: Alaska Department of Natural Resources web page, accessed June 10, 2010, at http://maps.akgeology.info/STSE/tsi.jsp.
  Go to the "Geology" section and check "Bedrock geology" and then "Search" (lower left)
  - The purple areas in the completed search have corresponding bedrock geologic maps listed below the map. Click on the Online links (second column from left) for the map of interest. This will bring you to the Alaska Division of Geologic and Geophysical Surveys (ADGGS) website where you can download the PDF of the map, generally by choosing the "Sheet" link(s) and (or)
- Geologic Maps from
  U.S. Geological Survey, 2008, Alaska Mineral Resources—Digital geologic map products for Alaska: U.S. Geological Survey web page. (Available at http://minerals.usgs.gov/alaska/prodxdgt.html.
  - For those titled "Geologic Maps of…" click on the title and on the next screen, the SIM or Plate link to the right is to a PDF file of the map.
  - For those titled "Digital Data for…" click on the title and on the next screen, scroll down to the table of "PDF files of the geologic map and text" the links there go to PDF files of the map and (or)
- Geologic maps accessible from the Alaska Volcano Observatory website http://www.avo.alaska.edu/downloads/classresults.php?pregen=map.

Additional maps of volcanoes in Alaska include:

- Nye, C.J., and others, 1998, Volcanoes of Alaska: Alaska Division of Geological and Geophysical Surveys Information Circular IC 0038, 1 sheet [2 sides], accessed June 1, 2010, at
  - Front PDF (6.4 MB) http://www.dggs.dnr.state.ak.us/webpubs/dggs/ic/oversized/ic038ed1998_sh001.PDF and
  - Back PDF (6.6 MB) http://www.dggs.dnr.state.ak.us/webpubs/dggs/ic/oversized/ic038ed1998_sh002.PDF.
- Smithsonian Institution, [n.d.], Global volcanism program—Volcanoes of Alaska, Map: Smithsonian Institution web page, accessed June 1, 2010, at http://www.volcano.si.edu/world/region.cfm?rnum=11.

Procedure

A. Students read a geologic map of their area

1. Illustrate for the students how to use the map explanation, scale, and other information that is included on the map (such as the stratigraphic column, list of formations, inset maps, and so on).

2. Instruct students to locate their community and place a pin in its exact center. This could be challenging. Students may need to use additional state maps with communities labeled for reference.

3. Direct students to draw in pencil a light circle on the map using a piece of string or a drawing compass to draw an arc around the pin. For large-scale maps, direct students to draw a small circle around their area, for small-scale maps, have students draw a bigger circle.

4. Ask students to figure out and record the scale of their circled region—diameter, radius, and (or) area.

5. Inside the circle, students can identify and record requested information on the *Geologic Map of Your Area* worksheet:
   - All the symbols inside the circle;
   - The age and rock types of the various rocks; and
   - Associate various rock types on the map with surface features (mountains, fjords, mines, gravel pits, volcanoes, valleys, and so on.), using local knowledge of the students.

6. Assign students to answer the questions on the *Geologic Map of Your Area* worksheet. The questions will require the use of a volcanic map of Alaska.

Modified from

Maine Geological Survey, 2005, Activities and resources for Earth Science teachers, Activity #10—Bedrock geologic map of Maine: Maine Department of Conservation website, accessed May 27, 2010, at http://maine.gov/doc/nrimc/mgs/education/lessons/act10.htm.

Reference 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.

Glossary

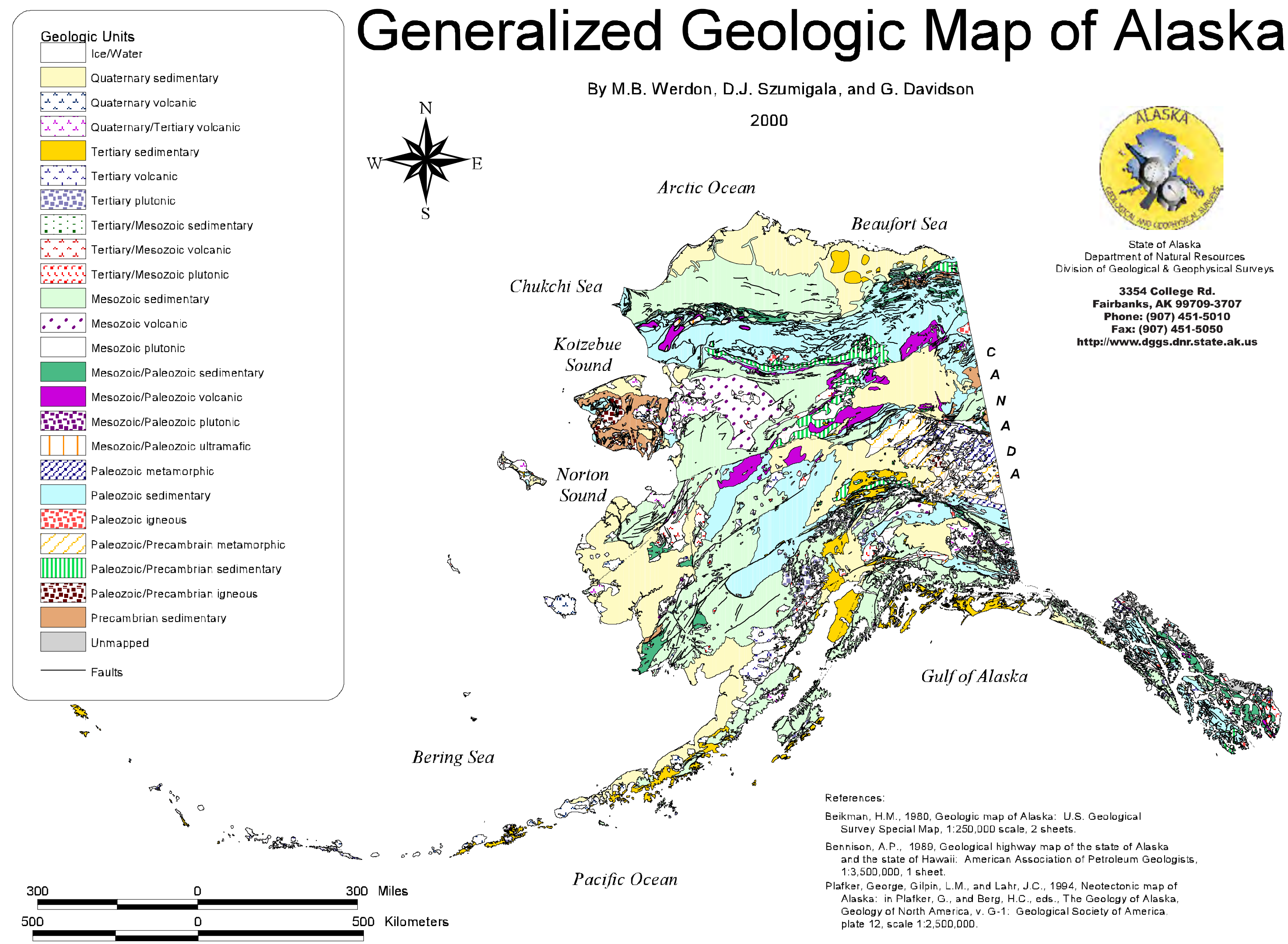
Bedrock – A general term for the rock, solid, that underlies soil or other unconsolidated, superficial material.

Geologic features – The rocks, minerals, and physical structure of a specific area.

Stratigraphic column (geologic column) – A composite diagram that shows in a single column the subdivisions of part or all of geological time or the sequence of stratigraphic units of a given locality or region (with the oldest units at the bottom and the newest at the top) to indicate their relations to the subdivisions of geologic time and their relative positions to each other.

Source of Glossary Definitions

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


Generalized Geologic Map of Alaska
By M.B. Werdon, D.J. Szumigala, and G. Davidson
2000
Geologic Units
Ice/Water
Quaternary sedimentary
Quaternary volcanic
Quaternary/Tertiary volcanic
Tertiary sedimentary
Tertiary volcanic
Tertiary plutonic
Tertiary/Mesozoic sedimentary
Tertiary/Mesozoic volcanic
Tertiary/Mesozoic plutonic
Mesozoic sedimentary
Mesozoic volcanic
Mesozoic plutonic
Mesozoic/Paleozoic sedimentary
Mesozoic/Paleozoic volcanic
Mesozoic/Paleozoic plutonic
Mesozoic/Paleozoic ultramafic
Paleozoic metamorphic
Paleozoic sedimentary
Paleozoic igneous
Paleozoic/Precambrain metamorphic
Paleozoic/Precambrian sedimentary
Paleozoic/Precambrian igneous
Precambrian sedimentary
Unmapped
Faults
N
W
E
S
Arctic Ocean
Beaufort Sea
Chukchi Sea
Kotzebue Sound
Norton Sound
CANADA
Gulf of Alaska
Bering Sea
Pacific Ocean
State of Alaska
Department of Natural Resources
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3354 College Rd.
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Phone: (907) 451-5010
Fax: (907) 451-5050
http://www.dggs.dnr.state.ak.us
300 0 300 Miles
500 0 500 Kilometers
References:
Beikman, H.M., 1980, Geologic map of Alaska: U.S. Geological Survey Special Map, 1:250,000 scale, 2 sheets.
Bennison, A.P., 1989, Geological highway map of the state of Alaska and the state of Hawaii: American Association of Petroleum Geologists, 1:3,500,000, 1 sheet.
Plafker, George, Gilpin, L.M., and Lahr, J.C., 1994, Neotectonic map of Alaska: in Plafker, G., and Berg, H.C., eds., The Geology of Alaska, Geology of North America, v. G-1: Geological Society of America, plate 12, scale 1:2,500,000.

Name ______________________________________ Date _______________ Period _____

Geologic Map of Your Area

1. Familiarize yourself with the explanation, scale, and other information that is included on the map such as the stratigraphic column, list of formations, inset figures, and so on.

2. Locate your community on the map and place a pin in the exact center. This could be challenging! You may need to use additional state maps with communities labeled for reference.

3. Use a piece of string or a drawing compass and pencil to draw an arc around the pin, leaving a circle lightly in pencil on the map. The circle should encompass a familiar region around your community.

4. Figure out and record the scale of your circled region—diameter, radius, and area. Remember to label your units!

   Diameter_______________ Radius _______________ Area _______________

5. In the table below, identify and record the information inside the circle. Continue on the back of this worksheet if you need more room.

Rock Unit Symbol	**Rock Unit Name**	**Rock Unit Age**	**Amount (percent) of Unit in Circle**	**Local Feature Associated With This Unit (mountain, volcano, mine, valley, gravel pit, and so on)**

6. Write a short paragraph describing the major rock types and their likely relations to local features that are inside your circle.

7. Are there igneous, volcanic, and (or) plutonic rocks in your circle? If so, with what local features are they associated?

8. Do your igneous, volcanic, and (or) plutonic rocks correspond with areas of present or past volcanic activity? Look at maps of volcanic regions of Alaska for a comparison.

Activity III. Comparison of Hawaiian, Cascade, and Alaskan Volcanic Rocks

Grade Level 7–11

Setting Classroom

Time 45–90 minutes

Vocabulary (see Glossary)
pyroclastic flow, viscosity, Volcano Explosivity Index (VEI)

Correlations to Alaska State Department of Education (2006) Science Performance Standards (Grade Level Expectations)
D1 – Concepts of Earth Science

SD1[6-11] Students develop an understanding of Earth's geochemical cycles.

SD1.1[8] The student demonstrates an understanding of geochemical cycles by making connections between components of the locally observable geologic environment and the rock cycle.

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
Volcanic rocks from historically active volcanoes in the United States vary in composition—the amounts and relative proportions of minerals that make up the rock. In this activity, students will learn how these compositional variations often are related to the style of eruption and type of volcano seen on the landscape today. It is important to note to students that there are exceptions in almost every case.

Background
Silica (generally referred to as an oxide, SiO_2 – silica dioxide) content determines the thickness of magma, which in turn affects its viscosity: resistance to flow. The higher the amount of SiO_2 (the higher the viscosity) the more resistant to flow. The amount of water, as a dissolved gas, in magma also affects its viscosity. The difficulty with which gas can travel through magma depends in part on the viscosity; the higher the viscosity, the more difficult it is for gases to be released from the magma. Typically, magmas with higher amounts of SiO_2 have volcanic eruptions that are more explosive.

Objectives
The students will be able to describe how composition and tectonic setting of a volcano generally affect the eruptive style and size of a volcanic eruption.

Materials
- *Volcanic Compositions* and *Recent U.S. Volcanic Eruptions* worksheets,
- computer with spreadsheet/graphing computer software program, or
- materials to generate bar graphs by hand (pens, pencils, paper).

Procedure

A. Research assignment

1. Individually, or in groups, have students study the following eruptions of U.S. volcanoes and fill in the *Recent U.S. Volcanic Eruptions* worksheet.
   - Mt. St Helens, Cascade Range, Washington, 1980–86
   - Kilauea, Big Island of Hawai`i, 1983–ongoing
   - Okmok, Alaska Peninsula, 1997
   - Novarupta, Alaska Peninsula, 1912
   - Augustine, Cook Inlet, Alaska, 1986

   Suggested resources include:
   - Alaska Volcano Observatory, [n.d.], Regional map of Alaskan volcanoes: Alaska Volcano Observatory website. (Available at http://www.avo.alaska.edu/volcanoes/.)
   - Miller, T.P., McGimsey, R.G., Richter, D.H., Riehle, J.R., Nye, C.J., Yount, M.E., and Dumoulin, J.A., 1998, Catalog of the historically active volcanoes of Alaska: U.S. Geological Survey Open-File Report 98-0582, 104 p. (Also available at http://www.avo.alaska.edu/downloads/classresults.php?citid=645.)
   - Smithsonian Institution, [n.d.], Global volcanism program: Smithsonian Institution web pages, accessed May 27, 2010, at
     - Volcanoes of the World http://www.volcano.si.edu/world/ and
     - Large Holocene Eruptions http://www.volcano.si.edu/world/largeeruptions.cfm
   - 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.)
   - U.S. Geological Survey, 2010, Cascades Volcano Observatory (CVO): U.S. Geological Survey website. (Available at http://vulcan.wr.usgs.gov/.)
   - U.S. Geological Survey, 2010, Hawaiian Volcano Observatory (HVO): U.S. Geological Survey website. (Available at http://hvo.wr.usgs.gov/.)
   - U.S. Geological Survey, 2010, Volcano Hazards Program: U.S. Geological Survey website. (Available at http://volcanoes.usgs.gov/.)

B. Graphing assignment

1. Have the students use a spreadsheet/graphing computer software program or draw by hand a bar graph (space provided on *Volcanic Compositions* worksheet) of the compositions of five volcanic rocks and answer the *Volcanic Compositions* worksheet using the graph and eruption cards worksheet.

C. Discussion

1. Discuss trends on the graphs and the answers to the *Volcanic Compositions* worksheet with students.

Extensions

1. Have students explore these and other on-line resources for additional research projects comparing and contrasting these volcanoes further.
   - National Park Service, variously dated, Explore nature: National Park Service websites available at
     - Explore Geology—Tour of park geology, search by state, http://www.nature.nps.gov/geology/parks/bystate.cfm.
     - Geology Fieldnotes, Hawaii Volcanoes National Park, Hawaii, http://www.nature.nps.gov/geology/parks/havo/index.cfm.
     - Geology Fieldnotes, Katmai National Park and Preserve, Alaska, http://www.nature.nps.gov/geology/parks/katm/index.cfm.
   - Rozell, Ned, 2001, Okmok Volcano on the rise in the Aleutians, Alaska Science Forum, August 30, 2001: Geophysical Institute, University of Fairbanks, Article No. 1557, accessed May 27, 2010, at http://www.gi.alaska.edu/ScienceForum/ASF15/1557.html.
   - U.S. Forest Service, 2010, Mount St. Helens National Volcano Monument: U.S. Forest Service website. (Available at http://www.fs.fed.us/gpnf/mshnvm/.)
   - U.S. Geological Survey, variously dated, Geology of National Parks—3D and photographic tours featuring park geology and natural history: U.S. Geological Survey websites available at
     - Hawaii Volcanoes National Park—A 3D photographic geology tour. (Available at http://3dparks.wr.usgs.gov/havo/index.html.) and
     - Mount St. Helens National Volcanic Monument—A 3D photographic tour of park geology. (Available at http://3dparks.wr.usgs.gov/sthelens/.)

2. The cooling history and crystallization of plutonic and volcanic rocks can be explored. A comparison of igneous rocks of the same composition and their cooling histories can help students identify that cooling rate associated with cooling location, above or below the ground surface, leads to two different rock types for the same composition magma. Resources include:
   - U.S. Geological Survey, 2009, Volcano Hazards Program, VHP photo glossary—Volcanic rocks—Types of Igneous Rocks: U.S. Geological Survey web page. (Available at http://volcanoes.usgs.gov/images/pglossary/VolRocks.php.)

3. Crystal growing experiments can further illustrate how cooling time relates to crystal size and growth. This may be shown by grown sugar crystals (rock candy) or through laboratory use of salol. Resources include:
   - Digital Library for Earth System Education (DLESE), [n.d.],
   - Crystal growing. (Available at http://www.dlese.org/library/query.do?q=crystal%20growing&s=0.) and
     - Salol. (Available at http://www.dlese.org/library/query.do?q=salol&s=0.)

Modified from

Oregon State University, 2010, VolcanoWorld—Comparing the Chemical Composition of Hawaiian Basalt and Mount Saint Helens Dacite website, accessed May 27, 2010, at http://volcano.oregonstate.edu/vwdocs/vwlessons/activities/r_number8.html.

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.

U.S. Geological Survey, 2009, Volcano Hazards Program, VHP Photo Glossary—Volcanic rocks—Types of Igneous Rocks: U.S. Geological Survey webpage. (Available at http://volcanoes.usgs.gov/images/pglossary/VolRocks.php.)

Glossary

Pyroclastic flow – A pyroclastic flow is 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/h (~62 mi/h) or more. The temperature within a pyroclastic flow may be greater than 500°C (932°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.

Viscosity – Viscosity is the property of a substance to offer internal resistance to flow, specifically the ratio of the shear stress to the rate of shear strain 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.

Source of Glossary Definitions

Bates, R.K., and Jackson, J.A., eds., 1987, Glossary of Geology (3rd 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 _____

Recent U.S. Volcanic Eruptions

Study the following recent volcanic eruptions in the United States and complete the following volcanic eruption cards.

Recent Volcanic Eruptions ~ U.S.

Okmok is an active caldera on the NE end of Umnak Island, about 100 km SW of Dutch Harbor, AK. The caldera is 10 kmdiameter and 500 - 800 m deep. Very large floods and lahars have accompanied past eruptions of this volcano.

Recent Volcanic Eruptions ~ U.S.

Name: Okmok
Location: Alaska Peninsula, Alaska

Recent Eruption: 1997

Eruption Style:

Tectonic Setting:

Eruption Size (VEI):

Eruption Summary:

Cool Fact:

Recent Volcanic Eruptions ~ U.S.

Augustine is the most active and youngest volcano in the Cook Inlet. It erupted five times in the 20th century. This is an island volcano and looks a lot like a pointy witch's hat with a wide, low brim close to shore and a pointy peak near the center.

Recent Volcanic Eruptions ~ U.S.

Name: Augustine
Location: Cook Inlet Region, Alaska

Recent Eruption: 1986

Eruption Style:

Tectonic Setting:

Eruption Size (VEI):

Eruption Summary:

Cool Fact:

Recent Volcanic Eruptions ~ U.S.

Low fountaining from Pu'u 'O'o on Kilauea volcano was common when the still ongoing volcanic volcanic eruption beagn there in 1983. Kilauea reminas one of the most active volcanoes on earth. Scientists have subdivided the multi-decade long eruption of Kilauea into "episodes".

Recent Volcanic Eruptions ~ U.S.

Name: Kilauea
Location: Big Island of Hawai`i

Recent Eruption: 1983-present

Eruption Style:

Tectonic Setting:

Eruption Size (VEI):

Eruption Summary:

Cool Fact:

Recent Volcanic Eruptions ~ U.S.

A 1916 National Geographic expedition into the Katmai valley on the Alaska Peninsula discovered this newly formed lava domethey named Novarupta. This volcanic dome formed during the 1912 eruption that created the Valley of Ten Thousand Smokes.

Recent Volcanic Eruptions ~ U.S.

Name: Novarupta
Location: Alaska Peninsula, Alaska

Recent Eruption: 1912

Eruption Style:

Tectonic Setting:

Eruption Size (VEI):

Eruption Summary:

Cool Fact:

Recent Volcanic Eruptions - U.S.

The 1980 eruption of Mt. St. Helens produced the largest landslide on Earth in recorded history! Rocks, ash, volcanic gas, and steam were blasted upward and outward to the north. The volcano continued to explode and form a summit dome over the next 6 years.

Recent Volcanic Eruptions - U.S.

Name: Mt. St. Helens
Location: Cascade Range, Washington

Recent Eruption: 1980

Eruption Style:

Tectonic Setting:

Eruption Size (VEI):

Eruption Summary:

Cool Fact:

Name ______________________________ Date ____________ Period ____

Volcanic Compositions

Using a spreadsheet/graphing computer software program or drawing by hand in the space provided below, plot the compositions (in weight percent of oxides [wt%]) of the five volcanic rock types given as a bar graph and answer the questions using your graph.

wt% Oxides*	**Kilauea (Hawaii) Basalt 1983**	**Okmok (Alaska) Basalt 1997**	**Augustine (Alaska) Andesite 1986**	**Mt. St. Helens (Washington) Dacite 1980**	**Novarupta (Alaska) Rhyolite 1912**
SiO_2	48.4	52.4	60.1	63.5	77.6
Al_2O_3	13.2	15.8	16.7	17.6	12.4
FeO	11.2	11.5	5.9	4.2	1.2
MgO	9.7	4.9	4.6	2.0	0.1
CaO	10.3	9.8	7.4	5.2	0.9
Na_2O	2.4	3.1	3.7	4.6	4.2
K_2O	0.6	0.8	0.9	1.3	3.3
TiO_2	2.8	1.4	0.6	0.6	0.2
Other	1.4	0.3	0.1	1.0	0.1

*SiO_2 = silica dioxide; Al_2O_3 = aluminum oxide; FeO = total iron oxide; MgO = magnesium oxide; CaO = calcium oxide; Na_2O = sodium oxide; K_2O = potassium oxide; TiO_2 = titanium oxide; Other = other elements. Values are weight percent oxide.

Name ____________________________________ Date ______________ Period _____

Volcanic Compositions Questions

Using your bar graph of the five given volcanic rock compositions and your volcanic eruption cards, answer the following questions.

1. Which rock has the greatest amount (weight percent) of silica?

2. Do you think the amount of silica within the magma, lava, or volcanic rock composition is related to the explosiveness of volcanic eruptions? If so, how?

3. Which rock type has the greatest amount of iron and magnesium?

4. How may the amount of iron and magnesium influence the color of the rock?

5. Of the three Alaskan volcanoes, which one has the greatest weight percent of silica?

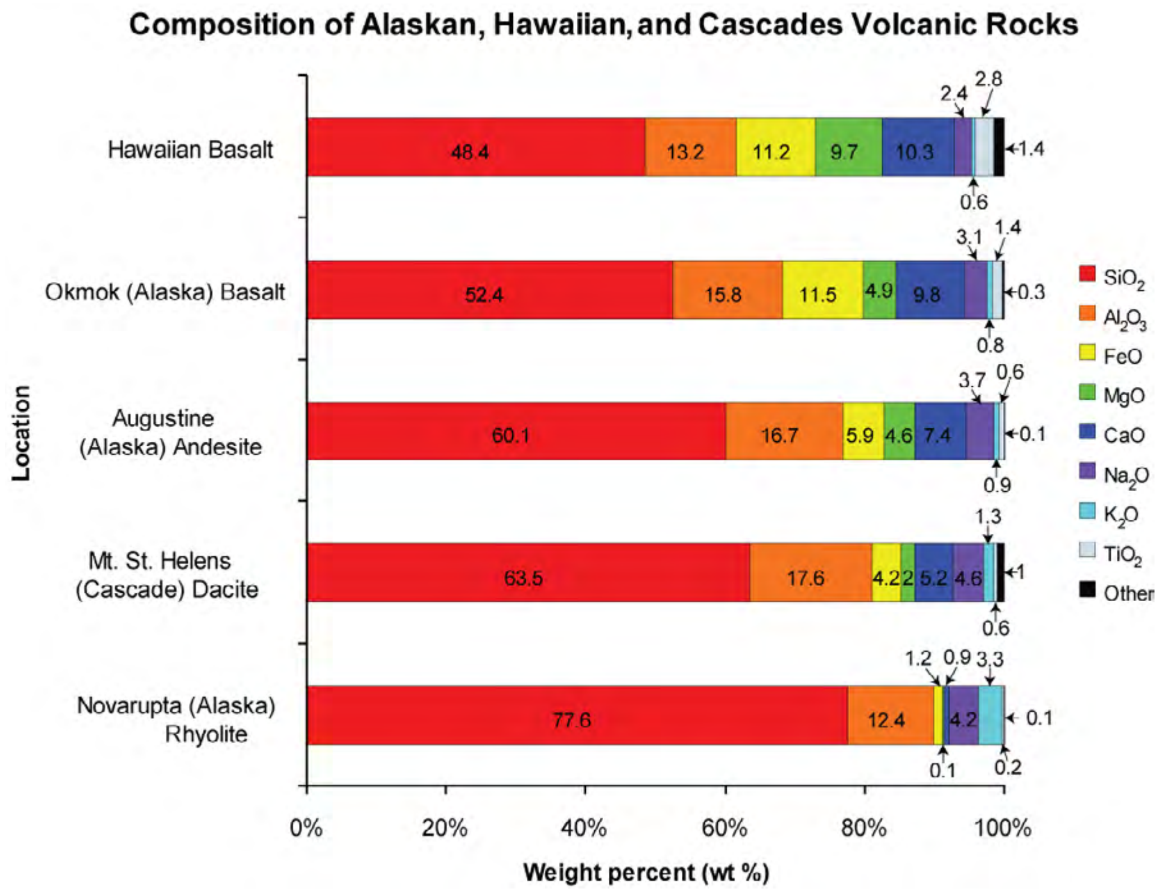
6. Which volcano do you think has the most viscous lava?

7. Which volcano will erupt explosively due to the higher weight percent of silica in its lava?

Recent U.S. Volcanic Eruptions Key

Volcano/year	Eruption Style	Tectonic Setting	Eruption Size (VEI)
Okmok (Alaska) 1997	Explosive with lava flows	Subduction Zone	3
Augustine (Alaska) 1986	Explosive with pyroclastic flows	Subduction Zone	4
Kilauea (Hawaii) 1983-ongoing	Explosive with lava flow	Hot Spot	1
Novarupta (Alaska) 1912	Explosive with pyroclastic flows	Subduction Zone	6
Mt St Helens (Washington) 1980-86	Explosive with pyroclastic flows and flank failure	Subduction Zone	5

Volcanic Compositions Key



SiO_2, silica; Al_2O_3, aluminum oxide; FeO, total iron oxide; MgO, magnesium oxide; CaO, calcium oxide; Na_2O, sodium oxide; K_2O, potassium oxide; TiO_2, titanium oxide; Other, other elements. Values are weight percent oxide.

Volcanic Compositions Questions Key

1. Which rock has the greatest amount of silica?

   The Novarupta (Alaska) rhyolite has the greatest amount of silica with 77.6 weight percent (wt%) SiO_2.

2. Do you think the amount of silica within the magma, lava, or volcanic rock composition is related to the explosiveness of volcanic eruptions? If so, how?

   It may be (it is!). The Novarupta eruption was gigantic!

3. Which rock type has the greatest amount of iron and magnesium?

   The Hawaiian basalt has the greatest amount of iron (FeO at 11.2 wt%) and magnesium (MgO at 9.7 wt%).

4. How may the amount of iron and magnesium influence the color of the rock?

   Iron and magnesium are metallic and dark, in large enough quantities; they may contribute to the dark color of the rock.

5. Of the three Alaskan volcanoes, which one has the greatest percentage of silica?

   The Novarupta (Alaska) rhyolite has the greatest amount of silica with 77.6 wt% SiO_2.

6. Which volcano do you think has the most viscous lava?

   The Novarupta (Alaska) rhyolite has the greatest amount of silica with 77.6 wt% SiO_2 and must be the most viscous.

7. Which volcano will erupt explosively due to the higher percentage of silica in its lava?

   The Novarupta (Alaska) Volcano.