



SUPERVOLCANOES

EDUCATORS GUIDE



DENVER MUSEUM OF
NATURE & SCIENCE



SUPERVOLCANOES

Volcanism is one of the most creative and destructive processes on our planet. It can build huge mountain ranges, create islands rising from the ocean, and produce some of the most fertile soil on the planet. It can also destroy forests, obliterate buildings, and cause mass extinctions on a global scale.

To understand volcanoes one must first understand the theory of plate tectonics. Plate tectonics, while generally accepted by the geologic community, is a relatively new theory devised in the late 1960's. Plate tectonics and seafloor spreading are what geologists use to interpret the features and movements of Earth's surface. According to plate tectonics, Earth's surface, or crust, is made up of a patchwork of about a dozen large plates and many smaller plates that move relative to one another at speeds ranging from less than one to ten centimeters per year. These plates can move away from each other, collide into each other, slide past each other, or even be forced beneath each other. These "subduction zones" are generally where the most earthquakes and volcanoes occur.

Yellowstone Magma Plume (left) and Toba Eruption (cover page) from Supervolcanoes.



National Next Generation Science Standards

Content Standards - Middle School

MS-ESS2-a.

Use plate tectonic models to support the explanation that, due to convection, matter cycles between Earth's surface and deep mantle.

MS-ESS2-e

Develop and use models of past plate motions to support explanations of existing patterns in the fossil record, rock record, continental shapes, and seafloor structures.

MS-ESS2-d

Construct explanations from evidence for how different geoscience processes, over widely varying scales of space and time, have shaped Earth's history.

MS-ESS2-o

Use arguments supported by evidence from the rock and fossil records to explain how past changes in Earth's conditions have caused major extinctions of some life forms and allowed others to flourish.

Excerpted from <http://www.nextgenscience.org>.

Content Standards - High School

HS-ESS2-a

Use Earth system models to support explanations of how Earth's internal and surface processes operate concurrently at different spatial and temporal scales to form landscapes and seafloor features.

HS-ESS2-d

Use a model of Earth's interior, including the mechanisms of thermal convection, to support the explanation for the cycling of matter within the Earth.

HS-ESS2-e

Construct a scientific explanation based on evidence from the geoscience record that changes to any Earth and Solar System processes can affect global and regional climates over a wide range of time scales.

Key Questions

- What drives plate tectonics?
- What is the Ring of Fire?
- What makes a volcano a supervolcano?
- What are some examples of supervolcanoes?
 - The eruption of Mount Toba
 - The volcanoes of Io
 - Ice volcanoes
- Have there been any supervolcanoes in recorded human history?
- What was the Great Dying?
- Can we predict when volcanoes will erupt?

Island of Sumatra (left) from Supervolcanoes

What drives plate tectonics?

The answer, in short, is water and heat.

In some areas, erosion from a continent deposits a thick layer of sediment into the ocean. Over a period of tens to hundreds of millions of years, this sediment pushes down on the plate. This stress is eventually so great that the ocean crust literally breaks and begins to dive, or subduct beneath the continental crust. This is the driving force that causes the plate boundaries to form.

Deep beneath the surface of our planet, decaying radioactive isotopes radiate the heat which, along with other heat generators, drives the movement of the plates. Most of this heat is stored in the mantle. The upper mantle is cooler than the lower mantle, creating convection currents in the mantle that cause the mantle to flow, albeit very slowly, much like a soft plastic, with the plates riding on top.

Water also plays a major role in the formation of volcanoes and earthquakes. When an oceanic plate subducts, below a continental plate, it pulls huge volumes of sea water down into the Earth. The rock in the plate is then metamorphosized, or changed, by the integration of the water along with intense heat and pressure. As the rock travels deeper, it changes again, this time releasing the water in the form of water vapor. This water vapor rises up to hotter rock where it lowers the melting point of the rock and is absorbed. The rock eventually rises higher and the pressure is reduced, allowing the water vapor, and other volcanic gases to form bubbles, which reduces the density of the rock. Over time, it transforms into liquid hot magma. The magma eventually gathers in a chamber near the Earth's surface, and when the build up of gases creates enough pressure, the magma will rise and erupt.

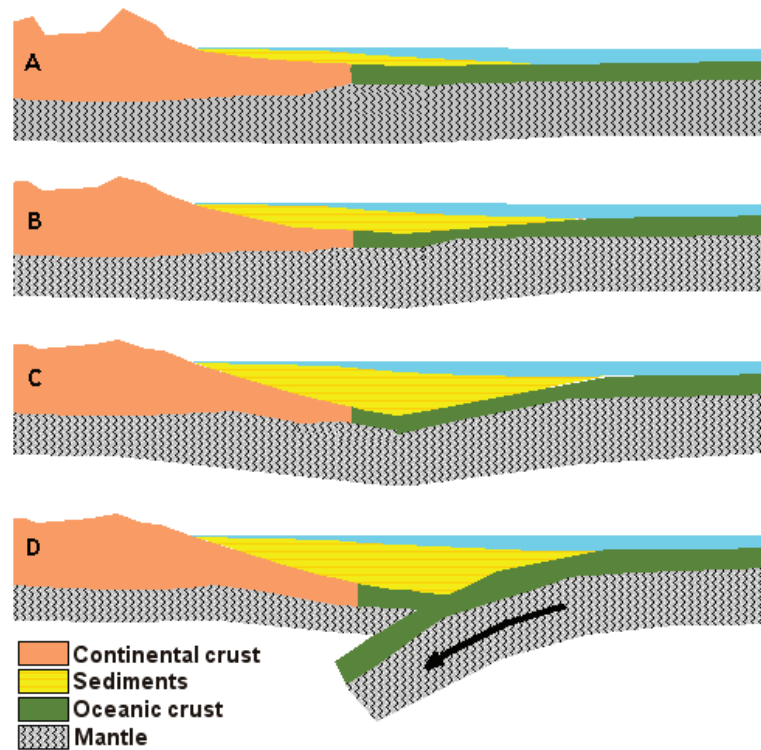
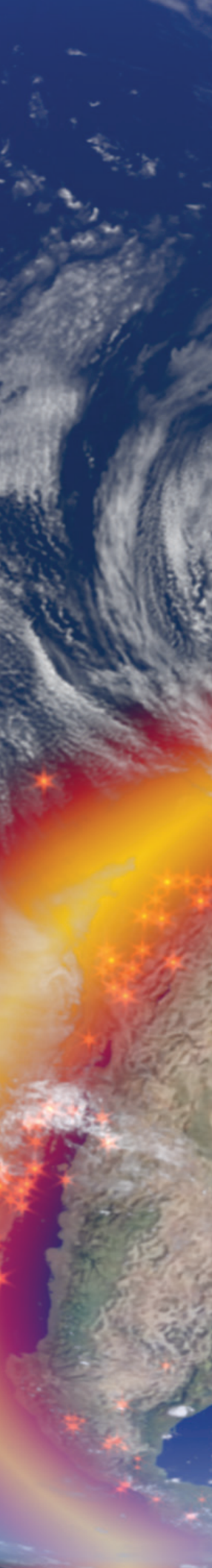


Plate Tectonics graphic (above) from Vancouver Island University



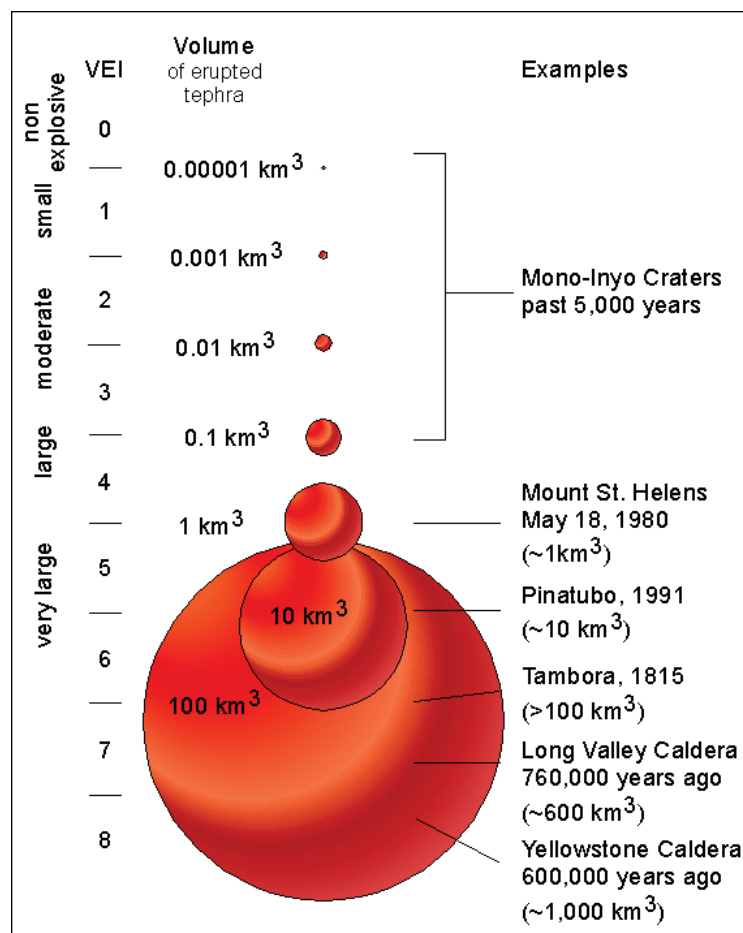
What is the Ring of Fire?

The Ring of Fire, also called the Circum-Pacific seismic belt, is a series of volcanic arcs and oceanic trenches that go up the western coasts of South, Central, and North America. These regions highlight the edges of the Pacific plate. The ring loops up along the Aleutian Islands off the coast of Alaska, then goes down along the Korean Peninsula, the islands of Japan, the Philippines, through Indonesia, and down to New Zealand.

This is where a large percentage of the world's earthquakes and volcanoes occur.

What makes a volcano a supervolcano?

In 1982 the Volcanic Explosivity Index, or VEI, was proposed as a way to describe the size and magnitude of volcanic eruptions. The scale is a logarithmic scale similar to the Richter scale but goes from 0-8 and is based on the amount of erupted fragments and ash from the volcano in kilometers cubed. A supervolcano erupts with a VEI of 8, which is defined as having an amount of erupted volcanic rock and ash, known as tephra, in excess of 1,000 cubic kilometers.



VEI graph (above) from USGS and The Ring of Fire (left) from Supervolcanoes



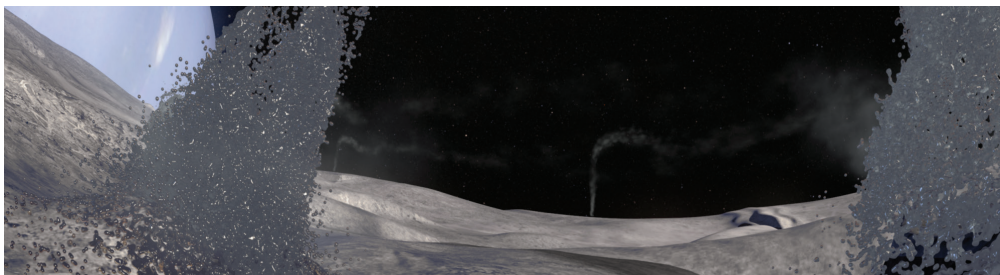
The eruption of Mount Toba

Mount Toba, located in today's Indonesia on the island of Sumatra, erupted around 74,000 years ago. It was the most recent true "supervolcano". The best approximations hold that Toba ejected 2,800 Km³ of ash and lava over a period of about two weeks. This dwarfs the eruption of Mount St. Helens, which released only about 1Km³ of material. In the aftermath of Toba, global temperatures dropped by as much as 10 degrees Celsius. Enormous quantities of soot and volcanic ash suspended in the atmosphere blotted out the sun for years after, reflecting its rays and cooling the Earth — a phenomenon known as a "volcanic winter".

The original size of the mountain is unknown but we can see the remains of it in Lake Toba. The approximate size of the caldera is 30 km wide by 100 km long. The island in the middle of the lake, known as Samosir, has an elevation of 1633 m.

What causes an ice volcano?

Ice volcanoes, also known as cryovolcanoes, are similar to lava volcanoes found on Earth, except they eject water, water ice, methane, or ammonia instead of hot molten rock. Methane and ammonia melt at much lower temperatures, methane at -295.6 F (-182 C) and ammonia at 107.9 F (-77.73 C). This means that in the colder parts of our solar system, they flow much like lava and magma here on Earth.



What is the Io Supervolcano?

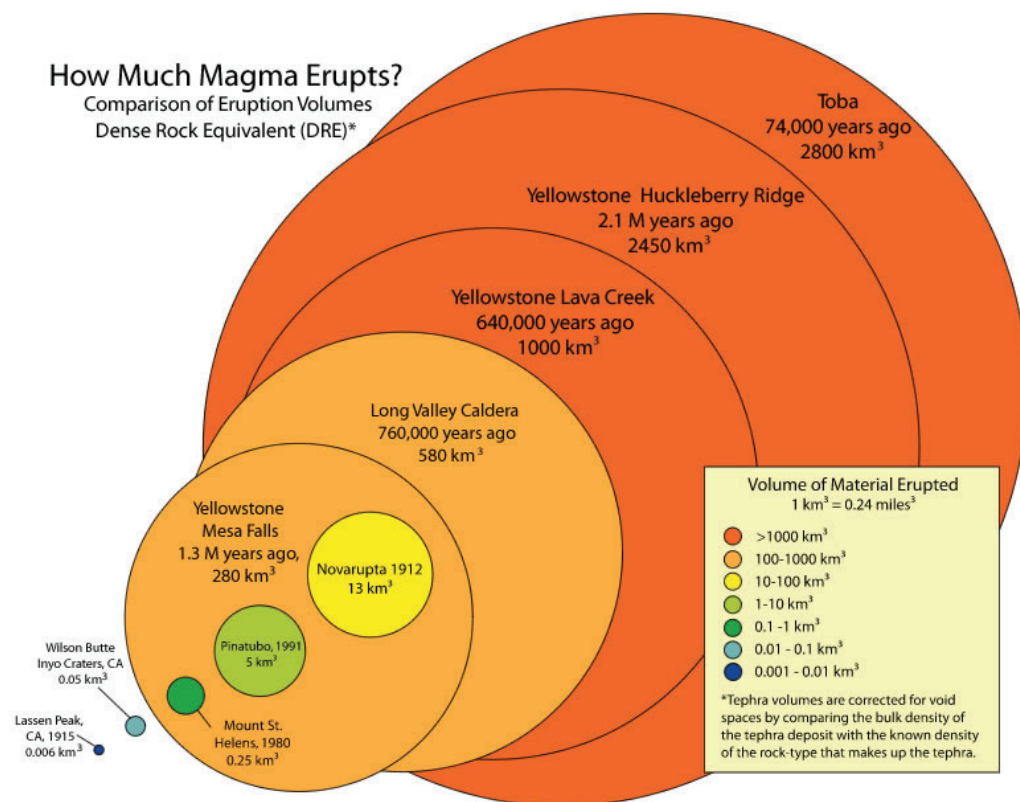
The largest volcano on Jupiter's moon Io, called Loki Patera, can be classified as a supervolcano with eruptions of material, thought to be molten sulfur or silicate rock, from 3,300 Km³ - 16,500 Km³. Unlike Earth, the volcanoes on the small moon Io are caused by the tugging gravity, known as tidal forces, from Jupiter and the larger moons Europa, Callisto, and Ganymede.

*Toba Eruption (top) and the Triton Ice Volcano (above)
from Supervolcanoes*

Have there been any supervolcanoes in recorded human history?

There are numerous records of devastating volcanic eruptions going back roughly 5,000 years. None of these, however, can be classified as supervolcanoes. Mount Vesuvius was responsible for the destruction of Pompeii in AD79. That eruption ejected around 4 Km³ of volcanic tephra, making it a VEI 6. In 1883, Krakatoa ejected a total of 18 Km³, making it a VEI 6 as well. Pinatubo, in 1991, ejected 10 Km³, making it a VEI 6; and Mount St. Helens, in 1980, only ejected around 1 Km³.

The largest eruption ever recorded was Mount Tambora on the Indonesian island of Sumbawa in 1815. The Tambora eruption resulted in 10,000 immediate deaths. Secondary effects, including famine and drought, claimed upwards of 80,000 more lives in a 600 km radius around the eruption. Tambora threw so much soot, ash, and smoke into the upper atmosphere that it reduced the amount of sunlight reaching Earth's surface. The eruption was followed by a "Year without Summer" that included crop failures in Europe and the United States. As dramatic and devastating as Tambora was with 150 Km³ of tephra, it ranks as only a 7 on the VEI scale.



Magma Eruption graph (above) from USGS



What was the Great Dying?

The Great Dying was an event on Earth that occurred 250 million years ago and caused the end of the Permian Period and Paleozoic Era. It involved a mass extinction in which 9 out of every 10 marine species and 7 out of every 10 land species vanished from the fossil record. It took almost 30 million years for life on Earth to eventually recover. Scientists suspect that it was caused by volcanic eruptions that spread over a large portion of today's Russia, called the "Siberian Traps". There are other possible causes for the Great Dying: an asteroid impact, coal fires ignited by volcanic activity, and even biological causes, such as accelerated bacteria growth in the ocean that emitted great amounts of methane.

Can we predict when volcanoes will erupt?

Sometimes geologists can predict volcanic eruptions. Geologists classify a volcano as active, dormant, or extinct. An active volcano is one that has erupted in recent history; a dormant volcano is one that has not erupted in recent history; an extinct volcano is one that is highly eroded and doesn't show any signs volcanic activity at all.

Geologists look into the past eruptions of the volcano to determine how dangerous it might be. Kilauea in Hawai'i, for example, is relatively low risk for human casualties. The lava flows easily from the vents but not explosively. Mount Vesuvius, however, erupted suddenly and violently in the year AD79, killing more than 29,000 people in the cities of Pompeii and Herculaneum.

Today, geologists monitor active volcanoes using a variety of instruments. They place seismic instruments on the sides of the volcano, and they also monitor the temperature of nearby lakes, well water, and hot springs. They may also look for changes in the amount of or composition of the gases emitted from vents, and changes to the shape or size of volcanic domes formed by magma swelling underneath.

Could a supervolcano happen today?

The answer is a secret in plain sight. Visitors come by the millions to Yellowstone National Park in Wyoming to view its geysers, hot springs, and other thermal features. They may never suspect that they are atop one of the world's largest active volcanoes.

Like Toba, Yellowstone is a resurgent volcano. It has erupted time and again over the last 18 million years in supervolcano proportions. Though it may not blow again for hundreds or thousands of years, scientists who have been charting Yellowstone's explosive history believe it's now overdue.

Permian Sea (left) from Supervolcanoes

Definitions

ash

Fragments erupted into the air during a volcanic eruption measuring less than 2 mm in diameter.

caldera

Large depression produced following an eruption by the collapse of the roof of a magma chamber; usually circular or horseshoe shaped when viewed from above.

core

The center of Earth comprised of the outer and inner layers which are between 5,000°C and 7,000°C. The outer layer is about 2,240 km (1,400 miles) thick and is liquid. The inner core is 2,440 km (1,540 miles) in diameter and is solid due to the extreme pressure that prevents it from being liquid.

crater (volcanic)

Bowl-shaped depression or hollow, usually with steep sides, at the summit of a volcano or on its flanks, produced by explosive activity.

crust

Outermost, rocky, and rigid surface layer of Earth made up of two types, continental (averaging 45 km, or 30 miles in thickness) and oceanic (averaging 8 km, or 5 miles in thickness).

earthquake

The sudden movement of strained blocks of Earth's crust.

eruption

The outflow of ash, gas, lava, water or other material from the surface of planet or moon.

fault

A fracture zone in the crust of Earth.

geyser

Intermittent vertical jet of water produced by the heating of underground water.

genetic bottleneck

A chance event that greatly limits the genetic variation of population.

lava

Molten rock that has reached the surface of the Earth.

magma

Molten rock within Earth.

mantle

Intermediate and most prominent layer of Earth. Composed of dense rock over 1,000°C (1,800°F) and over 2,900 km (1,800 miles) thick. Split into the upper and lower mantle which are physically different, the upper being plastic and the lower being rigid.

metamorphic rock

Rock altered by pressure and heat

mid-oceanic ridge

A submarine mountain chain that is created where two plates diverge, or move away from each other, and magma rises to plug the gap created.

plates

Large sections of the crust separated by plate boundaries such as fault, subduction zones, or mid-oceanic ridges.

plume

Mantle plumes, or plumes, are areas of the mantle that are anomalously hot.

subduction zone

Area where two leading edges of plates collide and one plate goes underneath another plate. Often where volcanoes form.

tephra

The fragments of volcanic rock and lava, regardless of size, that are blasted into the air by volcanic explosions. From the Greek word for ash.

thermal convection

The movement of heat from one location in an object to another location.

tidal force

The difference in gravitational force applied on an object by another object's gravity.

volcanic winter

A global reduction in temperature caused by the blocking on the sun's radiation due to the amount of volcanic ash in the atmosphere.

volcano

An opening in Earth's crust (also known as a vent) through which lava, rock debris, and gases are erupted. Named after the Roman god of fire, Vulcan.



VOLCAN 🔍 DETECTIVES

THE STORIES ROCKS CAN TELL

Educators Guide



Purpose: Students will examine mineral composition of volcanic rocks in order to better understand what makes a volcano a supervolcano.

Overview: Students will examine the mineral composition of rhyolite, andesite, and basalt to better understand the relationship between the rocks and the type of volcano in which they were formed. Students will then use latitude and longitude coordinates to locate each volcano on their world map and label them as rhyolite, andesite, and basalt. Observing plate boundaries and their newly acquired knowledge of volcanic rocks, students will make observations about which volcanoes are potential supervolcanoes.

Student Outcomes:

- Compare and contrast the types of volcanic features on our planet
- Gain knowledge of the types of igneous rocks that make up volcanoes around the world
- Gain knowledge of the Volcanic Explosivity Index (VEI), which determines if a volcano is a supervolcano
- Identify what makes a volcano a supervolcano
- Identify the Ring of Fire on their world map
- Use mathematical skills to compare the mineral composition of each sample
- Infer difficulties scientists may come across when attempting to predict volcanoes

Time: One 45-minute class period (abbreviated activity: one 30-minute class period)

Levels: Middle school and high school

Materials: Colored pencils, protractor, calculator, student worksheets

Next Generation Science Standards

ESS1.C

Local, regional, and global patterns of rock formations reveal changes over time due to earth forces, such as earthquakes. The presence and location of certain fossil types indicate the order in which rock layers were formed.

ESS2-2

Analyze and interpret data from maps to describe patterns of Earth's features. [Clarification Statement: Maps can include topographic maps of Earth's land and ocean floor, as well as maps of the locations of mountains, continental boundaries, volcanoes, and earthquakes.]

ESS2.B

The locations of mountain ranges, deep ocean trenches, ocean floor structures, earthquakes, and volcanoes occur in patterns. Most earthquakes and volcanoes occur in bands that are often along the boundaries between continents and oceans. Major mountain chains form inside continents or near their edges. Maps can help locate the different land and water features areas of Earth.

Excerpted from www.nextgenscience.org.



Prerequisites

To understand volcanoes one must first understand the theory of plate tectonics. Plate tectonics, while generally accepted by the geologic community, is a relatively new theory devised in the late 1960s. Plate tectonics and seafloor spreading are what geologists use to interpret the features and movements of Earth's surface. According to plate tectonics, Earth's surface, or crust, is made up of a patchwork of about a dozen large plates and many smaller plates that move relative to one another at speeds ranging from less than one to ten centimeters per year (about the rate your fingernails grow). These plates can move away from each other, collide into each other, slide past each other, or even be forced beneath each other. These "subduction zones" are generally where the most earthquakes and volcanoes occur.

TEACHERS: WHAT TO DO AND HOW TO DO IT

Engage

Distribute student worksheets. To set the stage, teachers should share the main purpose for the activity. Read the first two overview sections of the student worksheet to your students.

Explore

Follow the directions in "What to Do and How to Do It." Challenge students to think critically about their findings. For an abbreviated activity, or if your class does not have the required protractors, skip Steps 1 and 2 and provide students with the Percent Silica for each volcano from your Teacher Information Sheet.

Explain

After students have completed their Volcano Data chart and located each of the volcanoes on their world map, ask them to answer each question on the Analysis and Conclusions worksheet. Lead a short class discussion about their results. Note: The VEI scale is logarithmic, with each interval on the scale representing a tenfold increase in observed ejected material. The largest volcanoes in history (supervolcanoes) are given a magnitude of 8 on the scale where smaller less explosive volcanoes such as the ones found in the Hawaiian Islands are given a very low VEI such as 1 or 2.

Elaborate

Feel free to add your own specific questions during your class discussion. For further research opportunities, see Explore Further below.

Evaluate

After completion of the investigation, students should come back together as an entire class, and participate in a brief class discussion. Review students Analysis and Conclusions answers and use the Key Questions below to challenge students to think about concepts covered in this learning activity.

Key Questions

- Can you locate the Ring of Fire?
- What makes a volcano a supervolcano?
- Have there been any supervolcanoes in recorded human history?
- What did you notice about the volcanoes on other planets?

Explore Further

Try the NASA learning activity "Making and Mapping a Volcano" at http://solarsystem.nasa.gov/docs/Map_Volcano.pdf. The activity explores the sequence of lava flows produced by multiple eruptions. Baking soda, vinegar, and play dough are used to model fluid lava flows. Various colors of play dough identify different eruption events. Students will be asked to observe where the flows travel, make a model, and interpret the stratigraphy.



VOLCANO DETECTIVES: THE STORIES ROCKS CAN TELL

Student Worksheet

Name: _____

The Story

All rocks have a story to tell, even the ones you kick with your shoe on a hike without giving it a second thought. These rocks have a history that range from the ordinary to the extraordinary, such as being created from one of the most creative and destructive forces on our planet, a supervolcano.

The location of a volcano tends to determine the composition of the volcanic rock it produces. Three of these types of volcanic rocks are rhyolite, andesite, and basalt, and all three tell us something about the type of volcano in which they formed.

In this lab, you will analyze the mineral composition of rocks from volcanoes around the world. You will determine the type of rock, use latitude and longitude coordinates to plot its location on a world map, then relate each rock to the type of volcano and the plate boundary at which it may have formed.

The Rocks

- **Silica** is the major material present in volcanic rock.
- **Basalt** is the volcanic rock considered low in silica content (less than 52%). It is usually black. This material is generally found at divergent plate boundaries or at hot spots, which are areas under the crust where there is a lot of activity, such as the Hawaiian Islands.
- **Andesite** is the rock with medium silica content (52%–66%). It is usually dark gray. This material typically appears at subduction zones as well, without rising toward the surface.
- **Rhyolite** is high in silica content (more than 66%). It is usually gray or pink. This type of material is usually found at convergent boundaries where some crustal material is subducted and rises to the surface.

WHAT TO DO AND HOW TO DO IT

1. The attached worksheets contain the mineral composition of rocks from 16 different volcanoes. Using a protractor, measure the amount of silica in degrees for each circle graph. (Note: You might find it helpful to extend the line between silica and aluminum on each graph to assist with the measurement.) Record the “Degrees Silica” under each circle graph.
2. Using the recorded data, calculate the “Percent Silica” in each sample. Record your answer under each circle graph and on your Volcano Data Sheet. For example, a measurement of 180 degrees on the protractor would be equal to 50% of the volcanic rock because 50% (.50) of 360 degrees equals 180 divided by 360. In this way, determine the percent of silica in each sample.
3. Next, using the Percent Silica, determine if each volcano produces basalt, andesite, or rhyolite rocks. Remember: basalt (less than 52% silica content), andesite (52%–66% silica content), and rhyolite (more than 66% silica content).
4. Referencing your Volcano Data Sheet, use the given latitude and longitude coordinates and colored pencils to label the rhyolite, andesite, and basalt volcanoes on your map. Make sure to use different colors for each type of volcano. Color in the key at the top of the map to help identify each.



5. Complete the following questions by referring to your completed map, the completed Volcano Data Sheet, and your circle graphs from each volcano. Pay particular attention to the VEI Index for each volcano.

VEI: The Volcanic Explosivity Index (VEI) was devised by the U.S. Geological Survey in 1982 to provide a relative measure of the explosiveness of volcanic eruptions. The largest volcanoes in history (supervolcanoes) are given a magnitude of 8 on the scale, and smaller, less-explosive volcanoes such as the ones found in the Hawaiian Islands, are given a very low VEI, such as 1 or 2.

Analysis and Conclusions

1) Along what outlines do most volcanos fall?

2) Are all volcanos located along this outline? Where are the others?

3) At what type of plate boundaries do the following volcanic materials appear?

Rhyolite? _____ Andesite? _____ Basalt? _____

4) Smooth-flowing lavas are high in iron and typically low in silica. Based on your circle graphs, which volcanos are most likely to have formed smooth-flowing lava?

5) Explosive eruptions produce lava high in silica composition. Based on your circle graphs, which volcanos are most likely to have experienced an explosive eruption?

6) What type of relationship do you notice between the VEI Index and rock type?

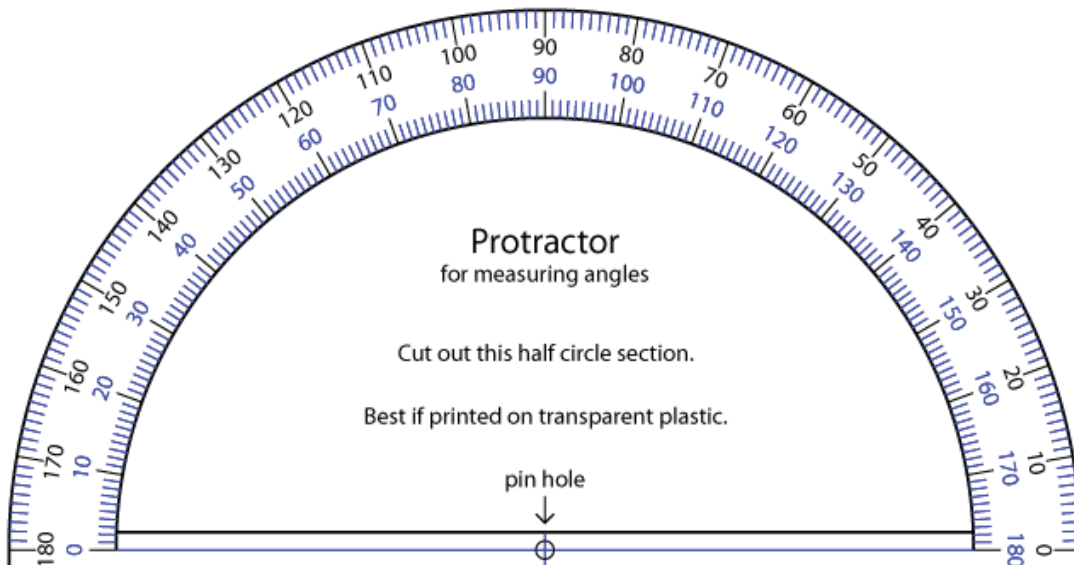
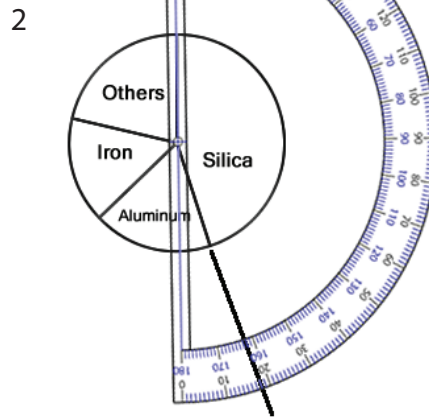
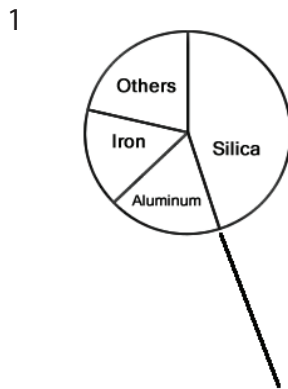
7) What type of rock is created from a Supervolcano (VEI 8)?

8) What do you notice about the border of the Pacific Plate? What would be a good nickname for this region?

Using a Protractor

If you can't find a protractor, print this page and cut out the protractor below. It might work best if printed or copied on transparent plastic. Follow the steps below to measure angles of the pie charts in this activity.

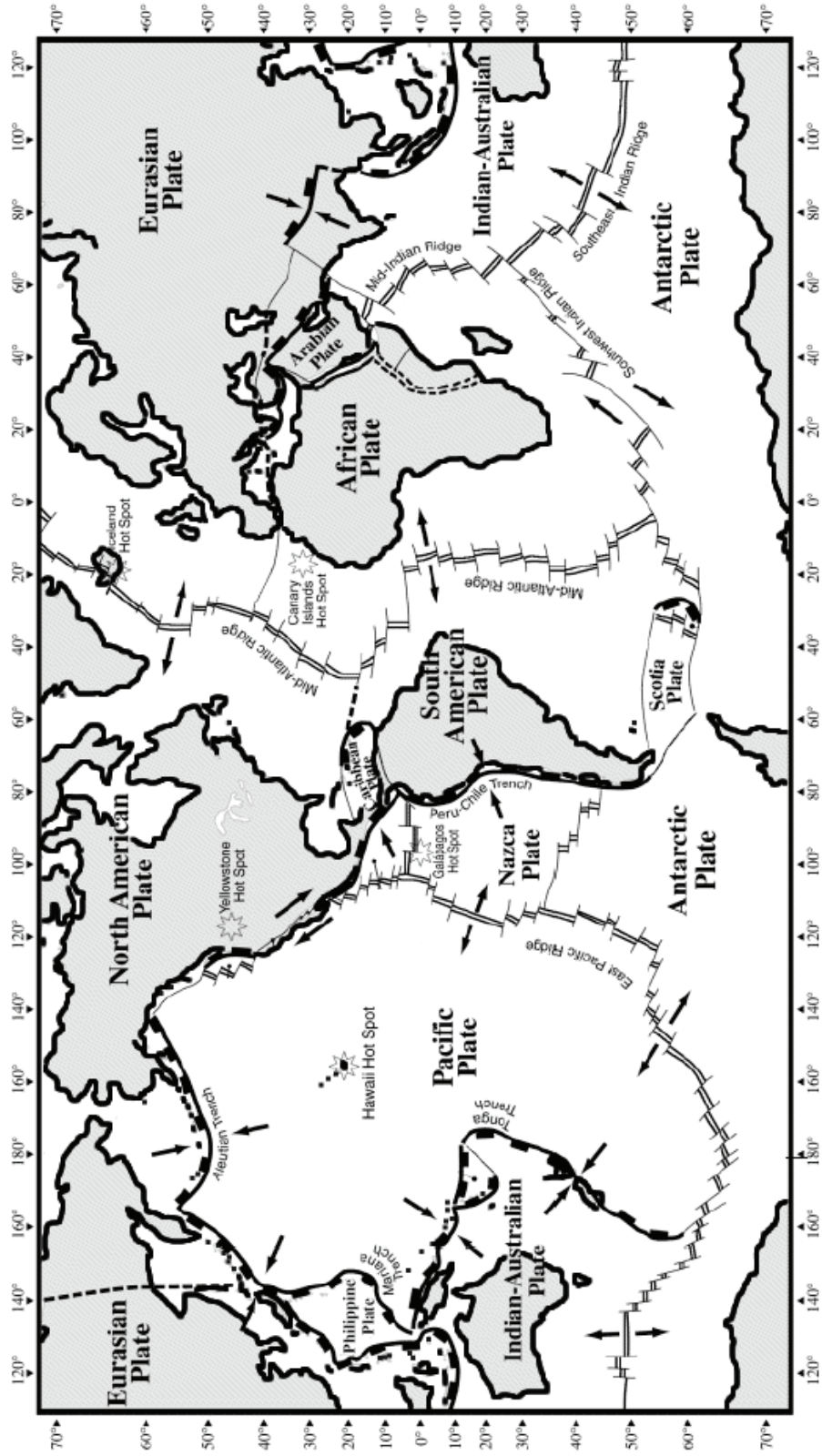
- 1) It helps if you extend the line that you would like to measure as seen in Image 1 below.
- 2) Place your protractor over your pie chart aligning the pin hole over the center point.
- 3) Make sure that one of the lines you are measuring is aligned with the 0 degree line and read the number in degrees of the opposite line. In Image 2 below the angle is 162 degrees
- 4) Convert 162 degrees to percent by dividing 162 by 360
- 5) The percent of silica in the pie chart below is 45% (.45)



Volcano Defective Tectonic Plates Map

Name: _____

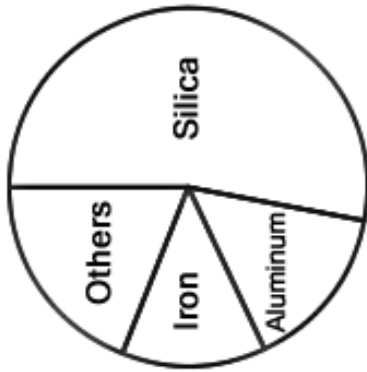
- Rhyolite
- Andesite
- Basalt



KEY:

- Mid-Ocean Ridge
- Divergent Plate Boundary (usually broken by transform faults along mid-ocean ridges)
- Transform Plate Boundary (Transform Fault)
- Convergent Plate Boundary (Subduction Zone)
 - overriding plate
 - subducting plate
- Complex or Uncertain Plate Boundary
- Relative Motion at Plate Boundary
- Mantle Hot Spot
- Hot Spot

NOTE: Not all plates and boundaries are shown.

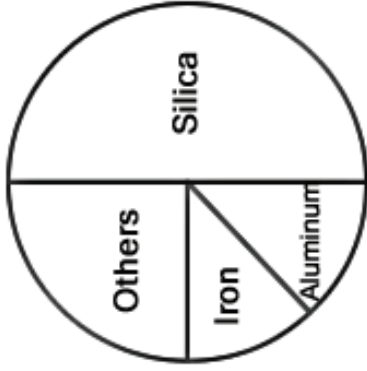


Kasatochi

Degrees Silica:

Percent Silica:

Rock Type:

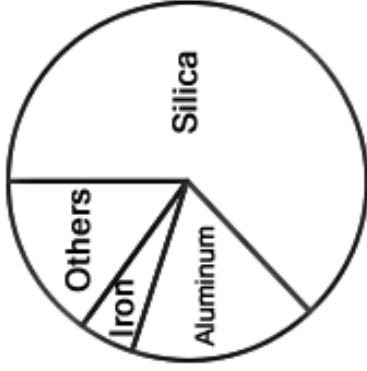


Kilauea

Degrees Silica:

Percent Silica:

Rock Type:

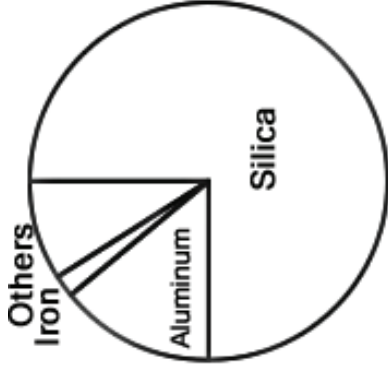


Mt. St. Helens

Degrees Silica:

Percent Silica:

Rock Type:

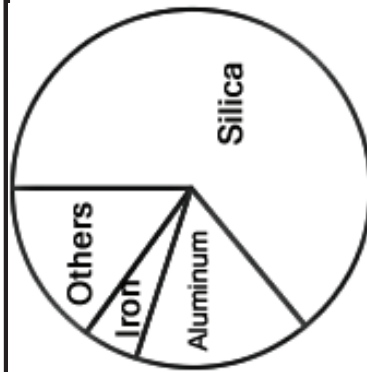


Yellowstone

Degrees Silica:

Percent Silica:

Rock Type:

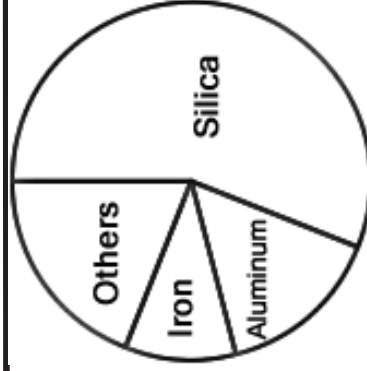


Popocatepetl

Degrees Silica:

Percent Silica:

Rock Type:

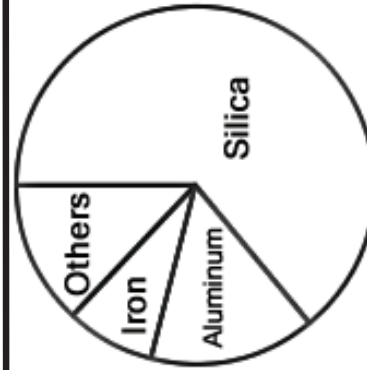


Llaima

Degrees Silica:

Percent Silica:

Rock Type:



Mt. Vesuvius

Degrees Silica:

Percent Silica:

Rock Type:

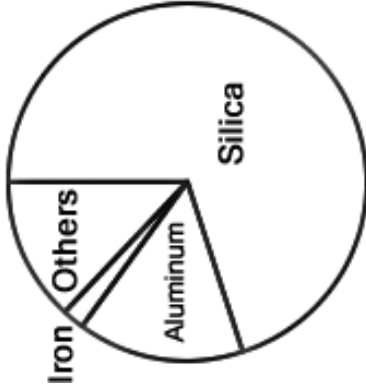


Mt. Kilimanjaro

Degrees Silica:

Percent Silica:

Rock Type:

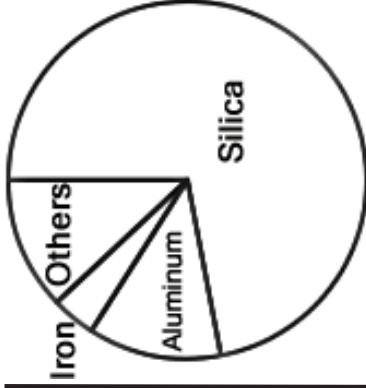


Siberian Traps

Degrees Silica:

Percent Silica:

Rock Type:

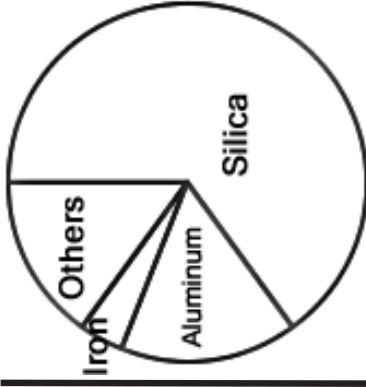


Toba

Degrees Silica:

Percent Silica:

Rock Type:

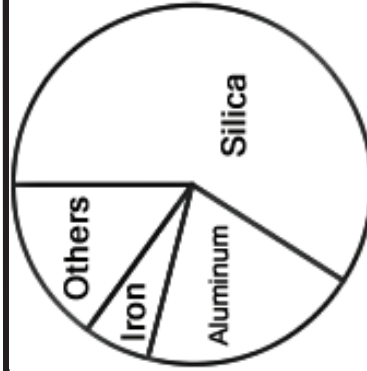


Krakatoa

Degrees Silica:

Percent Silica:

Rock Type:

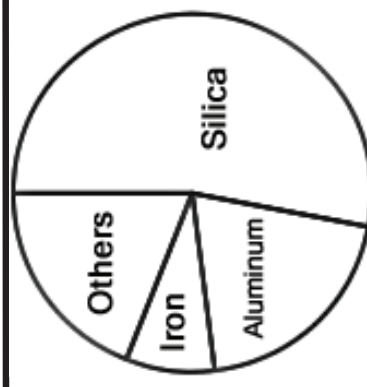


Mt. Tambora

Degrees Silica:

Percent Silica:

Rock Type:

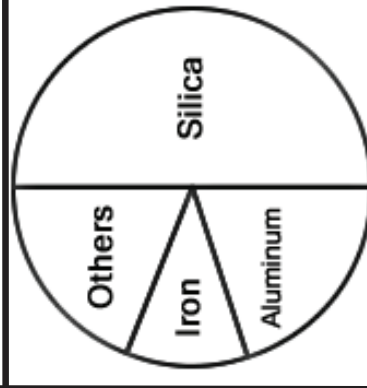


Mt. Pinatubo

Degrees Silica:

Percent Silica:

Rock Type:

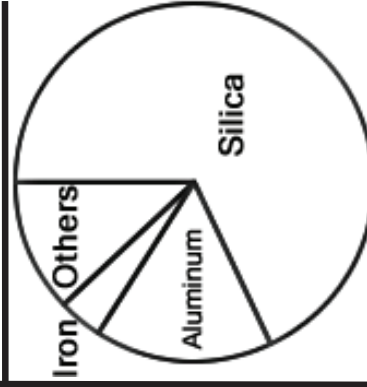


Mt. Fuji

Degrees Silica:

Percent Silica:

Rock Type:



Lake Taupo

Degrees Silica:

Percent Silica:

Rock Type:

Volcano Detective
The Stories Rocks Can Tell

Name: _____

Volcano Data

Volcano	Latitude	Longitude	Last Major Eruption	VEI	% Silica	Rock Type
Kasatochi	52 N	175 W	2008	4		
Kilauea	19 N	155 W	2010	1		
Krakatoa	6 S	105 E	1883	6		
Lake Taupo	38 S	176 E	26,000 years ago	8		
Llaima	39 S	72 W	2008	3		
Mount Fuji	35 N	138 E	1707	5		
Mt Kilimanjaro	3 S	37 E	150,000 years ago	4		
Mt Pinatubo	15 N	120 E	1991	6		
Mt St. Helens	46 N	122 W	1980	5		
Mt Tambora	8 S	118 E	1812	7		
Mt Vesuvius	41 N	14 E	79	5		
Nevado del Ruiz	5 N	75 W	1985	3		
Popocatepetl	19 N	98 W	2005	3		
Siberian Traps	64 N	102 E	500 million years ago	8		
Toba	3 N	98 E	74,000 years ago	8		
Yellowstone	44 N	110 W	600,000 years ago	8		

**Volcano Detective
The Stories Rocks Can Tell**

Teacher Answer Sheet

Volcano Data

Volcano	Latitude	Longitude	Last Major Eruption	VEI	Degrees Silica	% Silica	Rock Type
Kasatochi	52 N	175 W	2008	4	190.8	53	Andesite
Kilauea	19 N	155 W	2010	1	180	50	Basalt
Krakatoa	6 S	105 E	1883	6	234	65	Andesite
Lake Taupo	38 S	176 E	26,000 years ago	8	244.8	68	Rhyolite
Llaima	39 S	72 W	2008	3	201.6	56	Andesite
Mount Fuji	35 N	138 E	1707	5	180	50	Basalt
Mt Kilimanjaro	3 S	37 E	150,000 years ago	4	162	45	Basalt
Mt Pinatubo	15 N	120 E	1991	6	190.8	53	Andesite
Mt St. Helens	46 N	122 W	1980	5	226.8	63	Andesite
Mt Tambora	8 S	118 E	1812	7	212.4	59	Andesite
Mt Vesuvius	41 N	14 E	79	5	230.4	64	Andesite
Nevado del Ruiz	5 N	75 W	1985	3	208.8	58	Andesite
Popocatepetl	19 N	98 W	2005	3	230.4	64	Andesite
Siberian Traps	64 N	102 E	500 million years ago	8	252	70	Rhyolite
Toba	3 N	98 E	74,000 years ago	8	259.2	72	Rhyolite
Yellowstone	44 N	110 W	600,000 years ago	8	270	75	Rhyolite



VOLCAN DETECTIVES

IDENTIFYING SUPERVOLCANOES

Educators Guide



VOLCANO DETECTIVES: IDENTIFYING SUPERVOLCANOES

Purpose: Students will examine the volume of erupted volcanic material in order to better understand what makes a volcano a supervolcano.

Overview: Students will examine the VEI, Volcanic Explosivity Index, to better understand the scale of volcanic eruptions and what makes a volcano a supervolcano. Students will then locate a series of volcanoes on the solar system map and make observations about their location and VEI scale. Using their maps, students will compare each volcano by size and location, and use their newly acquired knowledge of volcanoes to make observations about which ones are potential supervolcanoes.

Student Outcomes:

- Compare and contrast the types of volcanic features on our planet and on other planets in our solar system
- Gain knowledge of the Volcanic Explosivity Index (VEI), which determines whether a volcano is a supervolcano
- Identify the Ring of Fire on their world map
- Use mathematical skills to compare the scale of each volcano
- Infer whether there have been any supervolcanoes in recorded human history

Time: One 45-minute class period

Level: Elementary

Materials: Colored pencils or markers, student worksheets

NEXT GENERATION SCIENCE STANDARDS

MS-ESS2-d

Construct explanations from evidence for how different geoscience processes, over widely varying scales of space and time, have shaped Earth's history.

MS-ESS2-o

Use arguments supported by evidence from the rock and fossil records to explain how past changes in Earth's conditions have caused major extinctions of some life forms and allowed others to flourish.

MS-ESS2-2

Analyze and interpret data from maps to describe patterns of Earth's features. [Clarification: Maps can include topographic maps of Earth's land and ocean floor, as well as maps of the locations of mountains, continental boundaries, volcanoes, and earthquakes.]

MS-ESS2.A

Earth's Materials and Systems: The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.

Excerpted from www.nextgenscience.org.



Prerequisites

To understand volcanoes one must first understand the theory of plate tectonics. Plate tectonics, while generally accepted by the geologic community, is a relatively new theory devised in the late 1960s. Plate tectonics and seafloor spreading are what geologists use to interpret the features and movements of Earth's surface. According to plate tectonics, Earth's surface, or crust, is made up of a patchwork of about a dozen large plates and many smaller plates that move relative to one another at speeds ranging from less than one to ten centimeters per year (about the rate your fingernails grow). These plates can move away from each other, collide into each other, slide past each other, or even be forced beneath each other. These "subduction zones" are generally where the most earthquakes and volcanoes occur.

TEACHERS: WHAT TO DO AND HOW TO DO IT

Engage

Distribute the student worksheets for this investigation. To set the stage, tell the students the main purpose for the activity. Read "The Mystery" and "Your Task" sections of the student worksheet to your students.

Explore

Follow the directions for the investigation found in What to Do and How to Do It. Challenge students to think critically and outside of the box about their findings.

Explain

After students have completed their VEI graphs and located each of the volcanoes on their world map, lead a short class discussion about their results.

- The VEI scale is logarithmic, with each interval on the scale representing a tenfold increase in observed ejected material.
- The largest volcanoes in history (supervolcanoes) receive a magnitude of 8 on the scale, and smaller, less-explosive volcanoes, such as the ones found in the Hawaiian Islands, receive a very low VEI, such as 1 or 2.
- For this activity, a simple scale has been created ("Volcano Detective VEI Index") to help students compare the size of volcanoes and more easily identify a supervolcano.

Elaborate

You have the opportunity to ask your students specific questions in Step 6 of What to Do and How to Do It. You may also add to what you would like for your students to include in their Investigation Reports to Professor Mapleton in Step 5. For more research opportunities, refer to Explore Further.

Evaluate

After completing the investigation, students regroup as an entire class and participate in a brief class discussion. Ask questions to challenge students to think about concepts covered in this learning activity. Use the Key Questions to start, and feel free to devise your own.

Key Questions

- Can you locate the Ring of Fire?
- What makes a volcano a supervolcano?
- Have there been any supervolcanoes in recorded human history?
- What did you notice about the volcanoes on other planets?

Explore Further

Try the NASA learning activity Making and Mapping a Volcano at http://solarsystem.nasa.gov/docs/Map_Volcano.pdf. The activity explores the sequence of lava flows produced by multiple eruptions. Baking soda, vinegar, and play dough are used to model fluid lava flows. Various colors of play dough identify different eruption events. Students will be asked to observe where the flows travel, make a model, and interpret the stratigraphy.



VOLCANO DETECTIVES: IDENTIFYING SUPERVOLCANOES

Student Worksheet

Name: _____

The Mystery

Volcanism is one of the most creative and destructive processes on our planet. It can build huge mountain ranges, create islands rising from the ocean, and produce some of the most fertile soil on the planet. It can also destroy forests, obliterate buildings, and cause mass extinctions on a global scale.

Your Task

To better understand what makes a volcano a supervolcano, we have been asked to assist Professor Mapleton, who is a volcanologist, or a scientist who studies volcanoes. Today the professor needs our help determining which volcanoes in our solar system are supervolcanoes. For this activity you and your classmates are official Volcano Detectives and are tasked with using clues to help better understand the most creative and destructive forces in our solar system.

WHAT TO DO AND HOW TO DO IT

1. Set the stage by becoming familiar with the map of the solar system. Explore the planets, identifying which planets have volcanoes. Next, take a closer look at our own planet. Label the map of Earth using the word bank below

Pacific Ocean	Atlantic Ocean	Indian Ocean	Africa	Asia
North America	South America	Australia	Europe	

2. Using the Volcanoes in Our Solar System chart, label the VEI of each volcano on your worksheet.

VEI: The Volcanic Explosivity Index (VEI) was devised by the U.S. Geological Survey in 1982 to provide a relative measure of the explosiveness of volcanic eruptions. The largest volcanoes in history (supervolcanoes) are given a magnitude of 8 on the scale, and smaller, less-explosive volcanoes such as the ones found in the Hawaiian Islands, are given a very low VEI, such as 1 or 2.

3. Once you have identified each volcano's VEI, use a colored pencil or marker to color in the appropriate number of blocks to represent the eruptible magma in each volcano.

Use this example as a reference:

Volcano VEI: 4 (Using the VEI Index below, 10 blocks are colored in to represent a VEI of 4.)



4. After you complete each of the 20 volcanoes in our solar system, make observations about each on your worksheet, such as location, year of last major eruption, etc.

5. Look over your observations and write a short Investigation Report to Professor Mapleton about the connections you notice between the eruptible magma in a volcano and the VEI Index. Also list where you located supervolcanoes in our solar system.

6. Finally, use your various worksheets to answer questions provided by your teacher.



Volcano Detective VEI Index

VEI	1	2	3	4	5	6	7	8
# of blocks	1 block	3 blocks	5 blocks	10 blocks	20 blocks	30 blocks	40 blocks	50 blocks

Volcanos in our Solar System

#	Volcano	Last Major Eruption	VEI
1	Kasatochi Island	2008	4
2	Kilauea - Hawaii	2010	1
3	Mount St. Helens	1980	5
4	Yellowstone Caldera	600,000 years ago	8
5	Popocatepetl	2005	3
6	Nevado del Ruiz	1985	3
7	Galeras	1993	2
8	Llaima	2008	3
9	Mount Vesuvius	79	5
10	Mount Kilimanjaro	150,000 years ago	4
11	Siberian Traps	500 million years ago	8
12	Toba	74,000 years ago	8
13	Krakatoa	1883	6
14	Mount Tambora	1812	7
15	Mount Pinatubo	1991	6
16	Mount Fuji	1707	5
17	Lake Taupo	26,000 years ago	8
18	Olympus Mons - Mars	25 million years ago	8
19	Loki Patera – Jupiter’s moon	Unknown	8
20	Triton Ice Volcano – Neptune’s moon	Unknown	8

Data from the USGS



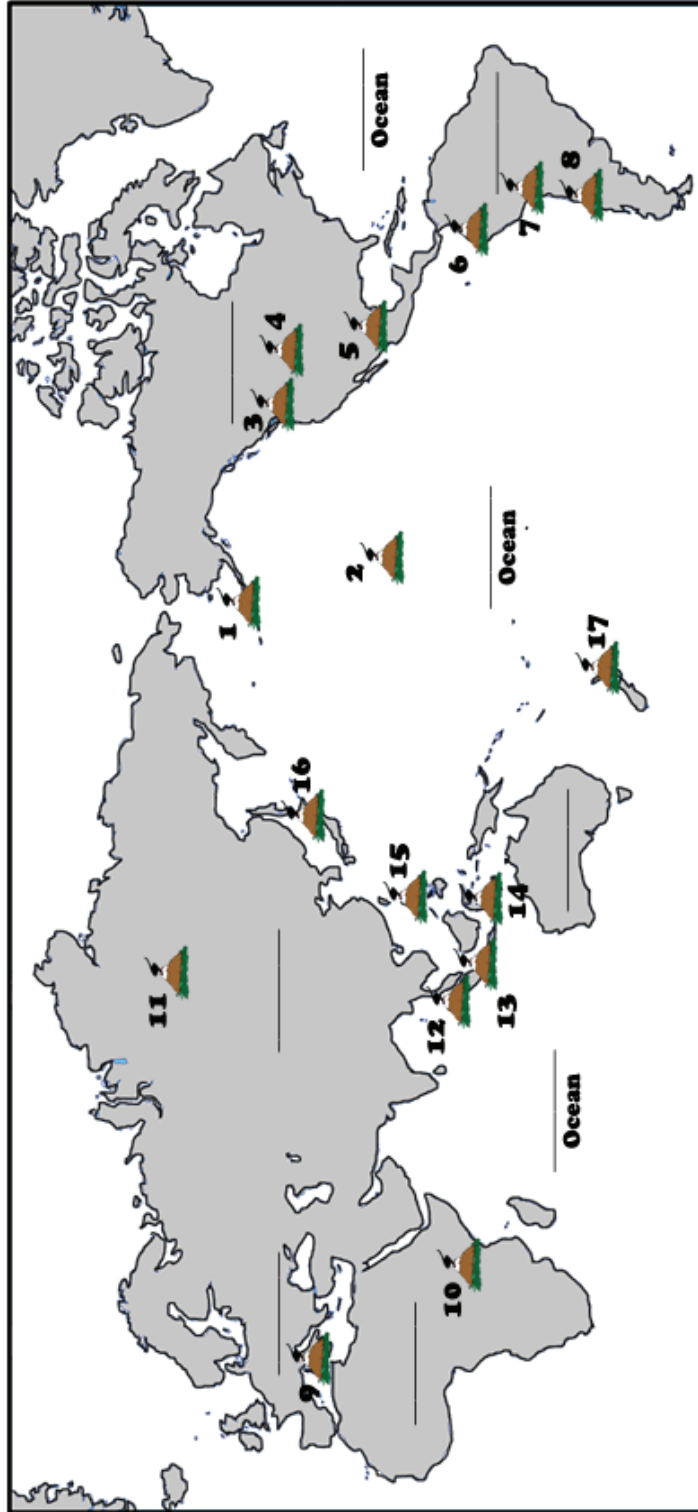
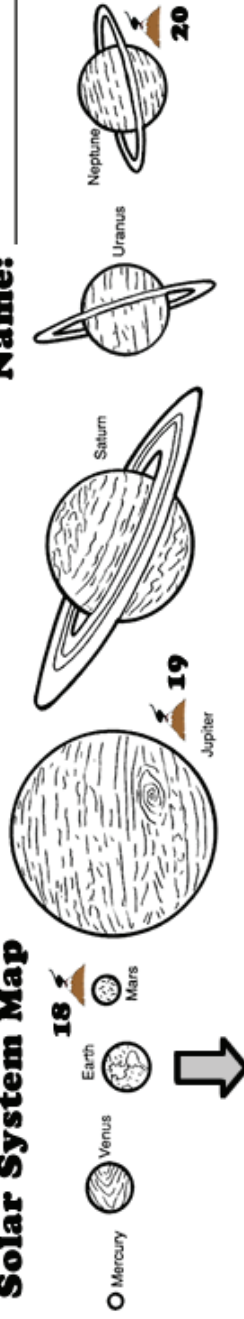
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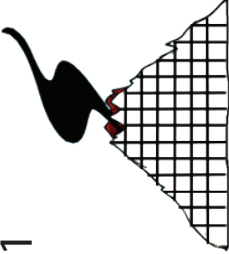
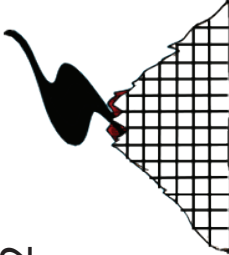
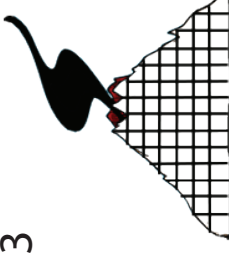
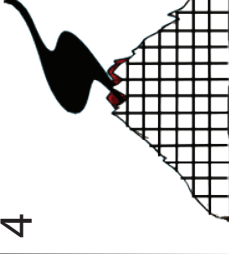
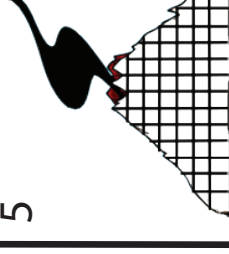
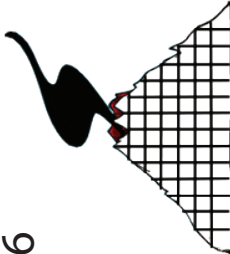
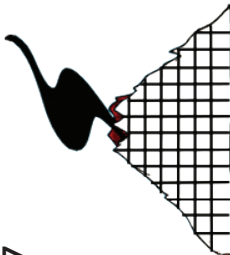
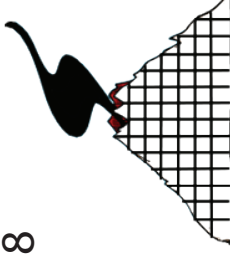
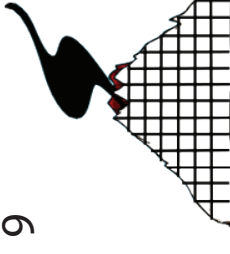
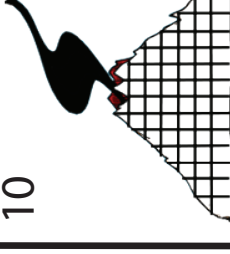
INVESTIGATION REPORT

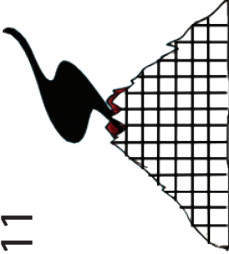
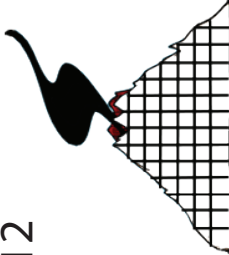
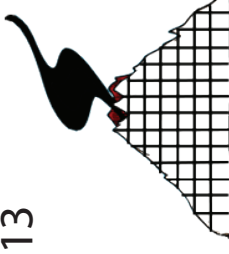
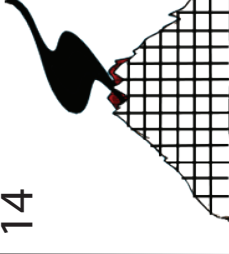
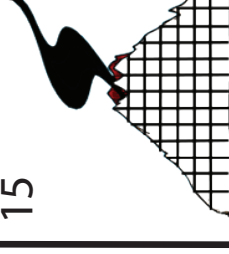
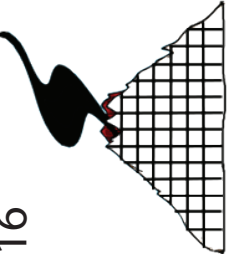
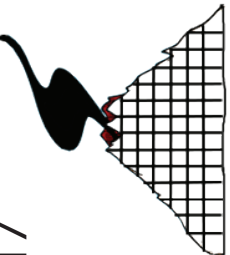
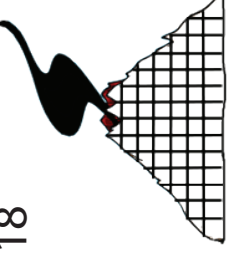
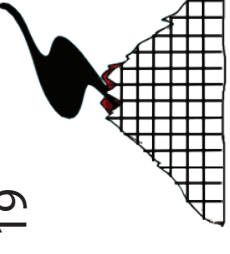
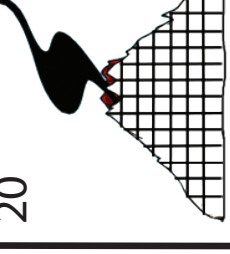
Name: _____

Volcano Detective Solar System Map

Name: _____



1	 <p>Kasatochi Island</p> <p>VEI: _____</p> <p>Observations: _____</p>	2	 <p>Kilauea</p> <p>VEI: _____</p> <p>Observations: _____</p>	3	 <p>Mount St. Helens</p> <p>VEI: _____</p> <p>Observations: _____</p>	4	 <p>Yellowstone</p> <p>VEI: _____</p> <p>Observations: _____</p>	5	 <p>Popocatepetl</p> <p>VEI: _____</p> <p>Observations: _____</p>	6	 <p>Nevado del Ruiz</p> <p>VEI: _____</p> <p>Observations: _____</p>	7	 <p>Galeras</p> <p>VEI: _____</p> <p>Observations: _____</p>	8	 <p>Llaima</p> <p>VEI: _____</p> <p>Observations: _____</p>	9	 <p>Mount Vesuvius</p> <p>VEI: _____</p> <p>Observations: _____</p>	10	 <p>Kilimanjaro</p> <p>VEI: _____</p> <p>Observations: _____</p>
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11	 Siberian Traps	VEI: _____ Observations:
12	 Toba	VEI: _____ Observations:
13	 Krakatoa	VEI: _____ Observations:
14	 Mount Tambora	VEI: _____ Observations:
15	 Mount Pinatubo	VEI: _____ Observations:
16	 Mount Fuji	VEI: _____ Observations:
17	 Lake Taupo	VEI: _____ Observations:
18	 Olympus Mons	VEI: _____ Observations:
19	 Loki Patera	VEI: _____ Observations:
20	 Triton	VEI: _____ Observations:

Further Reading and Resources

United States Geological Survey (USGS)

Volcano Hazards Program

<http://volcanoes.usgs.gov/observatories/cvo/>

Yellowstone Fact Sheet

<http://pubs.usgs.gov/fs/2005/3024/>

Plate Tectonics In-Depth Descriptions

http://vulcan.wr.usgs.gov/Glossary/PlateTectonics/description_plate_tectonics.html

Volcano Types

http://vulcan.wr.usgs.gov/Outreach/AboutVolcanoes/volcano_types_quick_reference.html

Dartmouth College

The Electronic Volcano

<http://www.dartmouth.edu/~volcano/>

NASA

The Great Dying

http://science.nasa.gov/science-news/science-at-nasa/2002/28jan_extinction/

Io, Jupiter's moon

http://solarsystem.nasa.gov/planets/profile.cfm?Object=Jup_lo

Activities and Websites

Snack Tectonics, a way to demonstrate plate tectonics in the classroom

http://www.windows2universe.org/teacher_resources/teach_snacktectonics.html

Map of currently active volcanoes

http://www.geocodezip.com/v2_activeVolcanos.asp?lat=20.149&lon=163.535&type=map&zoom=1

Weekly Volcanic Activity Report

<http://www.volcano.si.edu/reports/usgs/>

Earthscope, a collection of data from all over North America recording seismic events

<http://www.earthscope.org/en0>

Volcano Explorer interactive website that allows you to build your own volcanoes and make them erupt

<http://kids.discovery.com/games/build-play/volcano-explorer>

Volcano World, from Oregon State University filled with activities and resources for all things volcano

<http://volcano.oregonstate.edu/>