Lesson 1 Handout

A volcano discovery Web Quest

Name: _________________

Instructions: Follow each link provided (find the links in your google classroom), and answer the questions accommodating each link in complete sentences. All answers are found using these links. Be sure to click on every link provided within the simulation, and read carefully!

Link 1: Introduction to Volcanism
http://pbs.panda-prod.cdn.s3.amazonaws.com/media/assets/wgbh/ess05/ess05_int_volcanintro/index.htm

1. Draw and label a diagram of a volcano. Provide a short description for each part.

2. The _____________ that forms from layers of ___________ and __________ is called a _________________.

3. Volcanoes are classified as active, dormant, or extinct. Describe what those classifications mean.

4. There are 4 main types of volcanoes. How are they classified?

5. What are the two primary types of volcanoes? What are the two secondary types? Why are they secondary?

6. List one fact about each type of volcano. Draw the basic shape of each type.

7. What are the three places that volcanoes commonly occur?

8. How many hot spots have been identified around the world?

9. What is Hawaii?

10. What kind of volcanoes are associated with hot spots? What other features are associated with hot spots?

11. ______________________________ are places where tectonic plates are moving away from one another.

12. What is much of the oceanic crust made of?

13. _________________ is the word used to describe melted or molten rock inside Earth.

14. What is magma made of?

15. What determines the eruption style, rock type, and volcano shape?

16. List the three types of magma and what type of volcano each type comes out of.

17. _________________ rocks are formed when molten rock cools and hardens.

18. What are the two classes of igneous rocks? Where are they found? (Below or on top of Earth's surface?)

Link 2: Volcanic Eruptions and Hazards

http://pbs.panda-prod.cdn.s3.amazonaws.com/media/assets/wgbh/ess05/ess05_int_volcanerupt/02_Effusive.htm

19. ___________________ eruptions are generally considered to be gentler than explosive eruptions.

What types of hazards can result from this type of eruption? List 3.

20. ____________________ eruptions are the most hazardous, involving large volumes of tephra and gases emitted from the volcano.

What types of hazards can result from this type of eruption? List 3.

Extra Credit (Extension for advanced students)

Follow this link to a third simulation: Volcanic Features.

http://pbs.panda-prod.cdn.s3.amazonaws.com/media/assets/wgbh/ess05/ess05_int_volcanfeatr/03_Caldera.htm

21. How do we know that Yellowstone is actually a volcano? Provide details.

22. What is Devils Tower?

Lesson 2 Opener Slides

Viscosity

How quickly a substance flows depending on internal friction. How "sticky" a fluid is.

- The faster and easier the flow, the lower the viscosity.
- The slower, and stickier the flow, the higher the viscosity.
  - Water = ?
  - Pudding = ?

Factors that influence viscosity

- Temperature
- Chemical structure
  - The interactions of the molecules that make up the fluid

Viscosity of magma and lava

- Viscosity of magma increases with increasing silica content due to silica chains
  - Silica = Silicon + Oxygen: 50%-70% of magma
- High viscosity lavas flow slowly and typically cover small areas.
- In contrast, low viscosity magmas flow more rapidly and form lava flows that cover thousands of square kilometers.
- Low viscosity magmas allow gases to escape easily whereas gas pressures can build up in high viscosity magmas - resulting in violent eruptions
  - (Blowing through a straw, it's easier to get the oil to bubble than the nacho cheese)

Lesson 2 Handout

Viscosity Lab Investigation

Name: ___________________________

What you need:

* 4 small plastic cups
  Fill 1 cup ½ full of Nacho cheese
  Fill 1 cup ½ full of vegetable oil
* 1 straw per person, cut in half
* 1 lab tray
* 1 ruler
* 1 timer: phone or stopwatch

Part 1 Instructions:

* Each person will grab ½ of a straw.
* One person at a time, place the straw into the cup of oil.
* Blow bubbles like you would do with a soda.
* Observe how hard you have to blow, and the force and size of the bubbles once the air gets through.
* Do the same with the Nacho Cheese using your other 1/2 of the straw.

Record your observations below. All group members will do this.

a. Blowing in the oil:

b. Blowing in the nacho cheese:

Part 2 Instructions:

* One team member will be the pourer, while another is the timer.
* The pourer will first grab the cup with vegetable oil. Holding the ruler vertically (either person can hold the ruler), the pourer will hold the cup approximately 12 inches above an empty cup.
* The timer will begin the timing as soon and the pourer begins to pour the oil into one of the empty cups.
* The timer will stop the stopwatch as soon as the cup of oil is empty. Record this time in the table below.
* Repeat steps 3-5 with the nacho cheese and the other empty cup.
* Get some chips and eat your cheese if you want!

Liquid	Time in Seconds
Oil	
Nacho Cheese	

Answer the questions below.

1. Describe your flow-test results. Why did you get the results you did?

2. Is the viscosity of the oil higher or lower than the nacho cheese? How do you know?

3. One way to decrease the viscosity of a liquid is to __________ (heat/cool) the fluid?

4. What factors affect the viscosity of a substance?

5. What would happen to the viscosity of the oil and the nacho cheese if you heated it up? What if you cooled it down?

6. Can magma have different viscosities? What influences the viscosity of magma? (conduct research if you need to)

7. If magma in a volcano has a high viscosity, would the eruption be quiet or explosive? Why? (Think of how the fluids reacted to you blowing air into them)

8. Could viscosity affect how often a volcano erupts? Why?

9. What are some dangers of a volcanic eruption with high viscosity magma?

10. What are some dangers of a volcanic eruption with low viscosity magma?

Bonus: Do you prefer mashed potatoes with low or high viscosity? Explain.

Hot Spot at Yellowstone

by Abby Dress

The poster inserted in this month's issue, "To Eat or Be Eaten," focuses on the dynamic predator-prey relationships going on above ground at Yellowstone National Park (see Windows Into Wonderland on page 39). However, the park is even more famous for the dynamic processes that occur below ground. That is why a visit to Yellowstone National Park is not only a unique experience, but also a really "cool" opportunity to observe hydrothermal features. From the north gate that leads visitors to the main interpretive center and the hot springs in Mammoth on down to where Old Faithful Geyser has been thrilling sightseers and scientists alike with its regular eruptions for years, visitors cannot help but notice the entire region seems like a steamy hot spot. In the truest sense, it is.

***Abby Dress** is an associate professor of media arts at Long Island University's C.W. Post Campus in Brookville, New York, and works with Yellowstone National Park and the Yellowstone Park Foundation.*

Within this huge national park (over two million acres spread across Wyoming, Montana, and Idaho) are steaming geysers, hot springs, bubbling mudpots, and fumaroles, or steam vents. Drives on the main roads of Yellowstone take tourists through the major hot attractions, which also include Norris Geyser Basin, Upper and Lower Geyser Basin, West Thumb, and Mud Volcano. This unfenced territory, however, steams and smokes off the beaten track as well. That is because Yellowstone "preserves the largest hydrothermal area on the planet," as the official trail guide touts. Its hidden volcanic, tectonic, and hydrothermal forces constantly are at work underground reshaping the landscape.

According to geothermal expert Henry Heasler, park geologist at the Yellowstone Center for Resources, Yellowstone has the largest concentration of active geysers in the world and over 10,000 hydrothermal features. None of these would exist, however, without the tremendous hot rock, or geothermal source, beneath the surface.

The world's first and largest national park is a hot spot, which contains the Yellowstone Caldera. This is one of a few dozen such hot spots on Earth where heat from the Earth's interior is brought from the mantle closer to the surface. (Visit us online at *www.nsta.org/middleschool* to learn how Mount St. Helens is linked geothermally to Yellowstone.) Some scientists theorize that the magma plume hovers within 13 kilometers. Pressure from the molten rock is so close to the surface that it actually has created two bulges, or domed areas, at the park. One is located north of Yellowstone Lake and the other east of Old Faithful near Mallard Lake.

Believed by scientists to be about 640,000 years old, the Yellowstone caldera is quite young geologically and is about 48 by 72 km in size. It originally was formed through subsequent volcanic eruptions that began in western Idaho and northern Nevada some 16 million years ago. Volcanic activity continues to this day in Yellowstone. Geologist Heasler indicates that hundreds to thousands of earthquakes occur there each year. It is a dynamic environment, where even the ground constantly moves up and down, accruing changes of about 2.5 millimeters a year due to the massive volcanic energy.

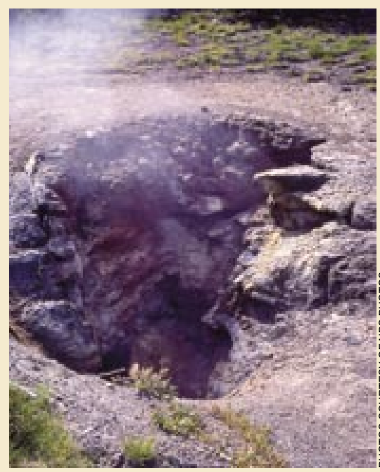
Hot springs are the most common hydrothermal resources found in the park. Their activity constantly changes, particularly since these features are influenced by seasons and weather. Readily available sources of water from snow and rain trickle through the porous rock and are heated by the magma close to the surface. This superheated water circulates up and cools as it reaches the surface. Then it is replaced by hotter water from below and the cycle continues. This ongoing process is called convection. Hot springs typically do not reach the temperatures that lead to eruptions associated with geysers.

Travertine is found in four thermal areas of the park, but the expansive travertine terraces found at Mammoth Hot

Windows into wonderland

A website designed for middle school students at *www.windowsintowonderland.org* is sponsored by the Yellowstone Park Foundation through Eyes on Yellowstone, which is made possible by Canon U.S.A., Inc. This free site features 50-minute electronic field trips that let students travel through the backcountry of Yellowstone National Park, the world's first and oldest national park, which remains one of the last wildernesses in the United States. Yellowstone, which is primarily situated in Wyoming, but also crosses into Montana and Idaho, has a greater number of a greater variety of free-roaming wild animals in their natural habitat than anywhere else in the 48 contiguous states.

Students can learn about the park's unique predator-prey relationships (featured on the poster in this issue), geothermal activities, geological richness, and extraordinary wildlife. The trips feature scripted dialogue, animations, streaming video, and audio content. Lesson plan ideas, a vocabulary list and appropriate links are included online to extend the experience.



PHOTOS COURTESY OF NPS PHOTOS

Springs draw the most tourists. The whitish gray terraced landscape looks like some scene expected on a visit to another planet. Limestone, or calcium carbonate, was deposited here millions of years ago when seawaters covered the area. When hot water from the springs is added to the rock, it dissolves the calcium carbonate. This carbonate is carried to the surface by the thermal waters and then left behind as travertine when they recede.

Microscopic bacteria and algae also thrive in many of the hot springs. These thermophiles thrive in water that is much too hot for most other life forms. These primitive organisms grow and are influenced by the temperature and chemistry of the hydrothermal pools. Some pool wall edges are ringed with sequential color bands from these organisms. From the hotter water areas on out to the cooler rims these life forms are distinguished by color—yellow, green, red/orange, and brown, respectively. One specialized microbe, *Sulfolobus acidocaldarius*, feeds on sulfur compounds in the water. Oxidizing these, the organism turns the compound into sulfuric acid. Some pools become so acidic with a pH of 1.3 that they inhibit the growth of the more colorful bacteria and algae that are prevalent in most of the hot springs.

Visitors, however, mostly come to see the geysers at Yellowstone. Geysers are also hot springs, but their plumbing is constricted. They not only depend on a water source for their eruptions, but also create their own pressurized system. When underground, the hot water forms a pool or fills a fissure. Heated by the molten rock, the hot waters rise and coat the walls with silica, creating a tighter seal. Both the rock and water pressure ultimately prevent the water from cooling or vaporizing. Even though the water temperature increases and exceeds boiling, it remains in a liquid state. The result is superheated water that is less dense than the heavier water that sinks around it. As this superheated water rises, steam forms. The steam expands as it nears the surface.

Steam bubbles literally and forcefully push the water up and out of geysers. Cone geysers have more narrow jets of water, while fountain geysers spray water in different directions. During both these processes, steam and boiling water are expelled faster than cooler water can enter. Though pressure and heat begin to decrease during the expulsion process, the eruption stops when the water reservoir empties of hot water. There is an interval of time between eruptions that depends on the size of the water source and how close it is to the hot rocks.

Mudpots are hot springs turned into gurgling muddy pools that often have pungent odors. They tend to be acidic, unlike most of the park's hot springs and geysers. With their limited water supplies, steam is formed underground. This steam tends to break down the rocks chemically and clay forms. Over time, steam, hydrogen sulfide, carbon dioxide and other gases burst through the clay as escaping bubbles. Minerals, such as sinter (a form of silica), sulphur, and iron, are responsible for the mudpot colors, gray, yellow, red/orange, and black, respectively.

The fumaroles or steam vents are the hottest hydrothermal features. Their limited water supplies are converted almost entirely into steam before escaping to the surface. From close up, these vents hiss loudly and spit out steam and gases. Large steaming plumes can be seen that make the hills look like they are smoking. On the one hand, these areas look like some cataclysmic after-effect; on the other hand, the huffing and puffing activity makes the mountainsides look alive.

It should be noted that Lake Yellowstone, North America's largest high-altitude lake at about 2,500 meters above sea level, also has thermal activity. At its north end near Mary's Bay, scientists have discovered hydrothermal pits at the lake's bottom with temperatures above the boiling point. In other parts, where hot areas also have been recorded, spires made of diatoms about 30 meters tall have been documented. Currently, no one seems to know how these towers were formed.

This is the magic of Yellowstone. It is a paradox of landscapes. From the forests of lodgepole pines that grow tall despite shallow roots and survive in the rocky soil of Yellowstone's Grand Canyon to the great plains of Hayden Valley, where one of the domes of molten rock is not so far below, Yellowstone National Park is a scientific treasure trove. It is a constant work-in-progress and challenge to monitor, but one that provides exciting new discoveries and knowledge all the time.

Resources

Internet

www.windowsintowonderland.org—Official Windows into Wonderland website

http://volcanoes.usgs.gov/yvo—Yellowstone Volcano Observatory

http://volcanoes.usgs.gov/cascades—Cascades Volcano Observatory

Publications

Smith, R., and L. J. Siegel. 2000. *Windows into the Earth: The geologic story of Yellowstone and Grand Teton National Parks*. New York: Oxford University Press.

U.S. Department of the Interior U.S. Geological Survey. 1995. *Yellowstone: Restless volcanic giant*. Volcano Hazards Fact Sheet. Open-file report 95-59, U.S. Geological Survey.

Yellowstone National Park. 2003. *Yellowstone resources and issues 2003*. Mammoth Hot Springs, WY: Division of Interpretation, National Park Service.

Lesson 3 Nearpod Slides

VOLCANIC LANDFORMS

FOR MUCH OF EARTH'S HISTORY, VOLCANIC ACTIVITY ON AND BENEATH THE SURFACE HAS BUILT UP EARTH'S LAND AREAS. VOLCANIC ACTIVITY ALSO FORMED THE ROCK OF THE OCEAN FLOOR. SOME VOLCANIC LANDFORMS ARISE WHEN LAVA FLOWS BUILD UP MOUNTAINS AND PLATEAUS ON EARTH'S SURFACE. OTHER VOLCANIC LANDFORMS ARE THE RESULT OF BUILDUP OF MAGMA BENEATH THE SURFACE.

Presentation: Volcanic Landforms 1/35

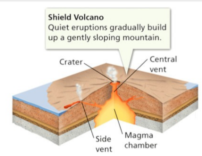
If runny, thin lava flowed out from a small area, would it form steep sides or gentle sides?

- Steep sides
- Gentle sides

Presentation: Volcanic Landforms 3/35

LANDFORMS FROM LAVA AND ASH

- Shield Volcanoes: thin layers of lava pur out of a vent and harden on top of previous layers.
  - Gradually build wide, gently sloping mountains
  - Hawaiian Islands



Presentation: Volcanic Landforms 4/35

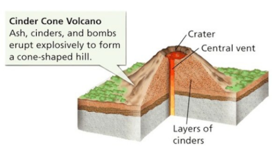
Which type of volcano could form when thick, sticky lava is blown apart and falls as ash and cinders?

- Shield
- Cinder Cone

Presentation: Volcanic Landforms 6/35

LANDFORMS FROM LAVA AND ASH

- Cinder Cone Volcanoes:
  - Lava has high viscosity; it may produce ash, cinders, and bombs.
  - Build up around the vent in a steep, cone-shaped hill, or small mountain called a cinder cone.



Presentation: Volcanic Landforms 7/35

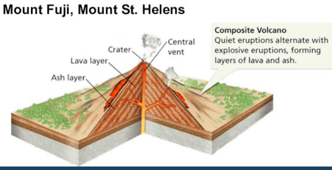
Which type of volcano do you think would form from flows of thick lava and some ash?

- Composite
- Shield

Presentation: Volcanic Landforms 9/35

LANDFORMS FROM LAVA AND ASH

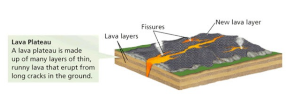
- Composite Volcanoes
  - Alternate lava flows, and explosive eruptions of ash, cinder, and bombs.
  - Tall cone-shaped mountains in which layers of lava alternate with layers of ash.
  - Mount Fuji, Mount St. Helens



Presentation: Volcanic Landforms 10/35

LANDFORMS FROM ASH AND LAVA

- Lava Plateaus: High, level areas
  - Lava flows out of several long cracks
  - Thin, runny lava travels far before cooling
  - Again and again, floods of lava flow on top
  - Millions of years
  - Columbia Plateau



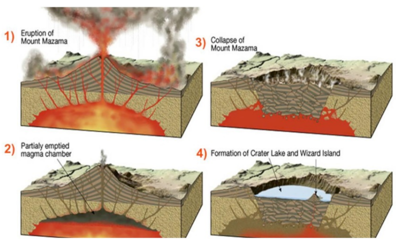
Presentation: Volcanic Landforms 11/35

LANDFORMS FROM LAVA AND ASH

- Calderas: Huge hole left by the collapse of a volcanic mountain.
  - Hole is filled with pieces of the volcano, as well as some lava and ash.
  - Enormous eruptions may empty the main vent and the magma chamber beneath a volcano.
  - Mountain becomes hollow shell with no support and the top collapses inward

Presentation: Volcanic Landforms 12/35

CALDERA FORMATION



SOILS FROM LAVA AND ASH

Why would anybody live near an active volcano?

- Fertile volcanic soil
- Lava, ash, and cinders initially barren
- Break down over time to form soil: releases potassium, phosphorus, and other substances plants need.
- Some among the richest soils in the world.

Can you think of any examples?

Provide an example of an area that has benefited from volcanic activity.

LANDFORMS FROM MAGMA

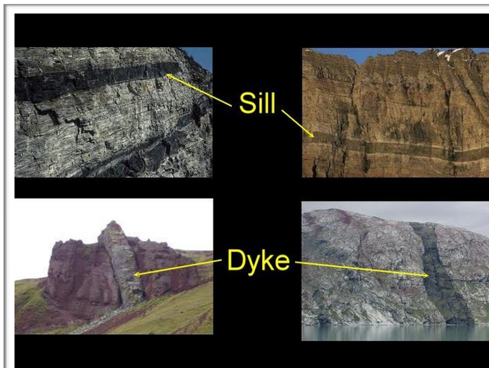
Sometimes magma forces its way through cracks in the upper crust, but fails to reach the surface. There the magma cools and hardens into rock. Over time, the forces that wear way Earth's surface — such as flowing water, ice, or wind — may strip away the layers above the hardened magma and finally expose it.

LANDFORMS FROM MAGMA

- Volcanic Necks: looks like a giant tooth stuck in the ground.
  - Magma hardens in a volcano's pipe
  - Softer surrounding rock wears away

LANDFORMS FROM MAGMA

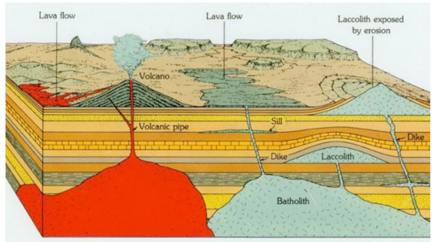
- Dikes and Sills
  - Magma that forces itself across rock layers hardens into a dike.
  - When magma squeezes between horizontal layers of rock, it forms a sill.



LANDFORMS FROM MAGMA

- Batholiths: Large rock masses form the core of many mountain ranges.
  - a mass of rock formed when a large body of magma cools inside the crust

Presentation: Volcanic Landforms 23/35 nearpod



Presentation: Volcanic Landforms 24/35 nearpod

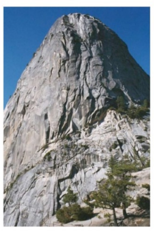
LANDFORMS FROM MAGMA

- Dome Mountains: other, smaller bodies of hardened magma
  - Uplift pushes a batholith or smaller body of hardened magma toward the surface.
  - Hardened magma forces the layers of rock to bend upward into a dome shape
  - Rock above dome wears away, leaving it exposed.
  - Black hills in South Dakota

Presentation: Volcanic Landforms 25/35 nearpod

Dome mountain

- hardened magma
- forms when uplift pushes batholith toward surface



Presentation: Volcanic Landforms 26/35 nearpod

How could water beneath Earth's surface be heated?

Presentation: Volcanic Landforms 28/35 nearpod

Where might heated water reach Earth's surface?

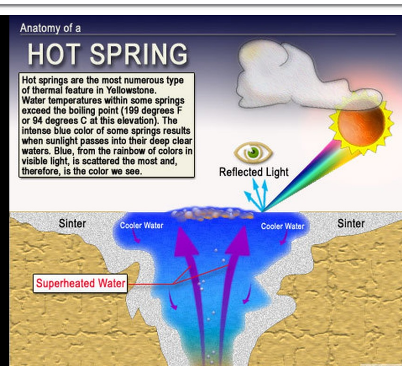
Presentation: Volcanic Landforms 30/35 nearpod

GEOTHERMAL ACTIVITY

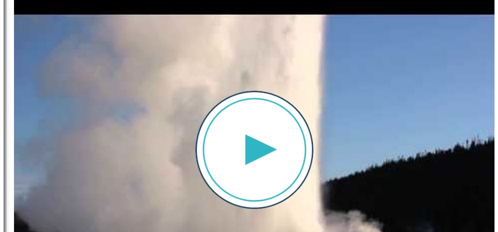
Has anybody visited any Hot Springs or Geysers?

- A variety of geothermal features occur in volcanic areas. Magma heats underground water
  - Yellowstone
  - Hot springs: groundwater is heated by nearby magma or hot rock. Water rises to the surface and collects in a natural pool.
  - Geysers: Rising hot water and steam become trapped underground in a narrow crack. Pressure builds until the mixture suddenly sprays out.

Presentation: Volcanic Landforms 31/35 nearpod



Presentation: Volcanic Landforms 33/35 nearpod



https://www.youtube.com/embed/wE8NDuzt8eg

Presentation: Volcanic Landforms 35/35 nearpod

Lesson 4 Instructions

Thunder Island Simulation

This activity is a volcano monitoring simulation. It involves students dealing with “real-time” data that they have to process within a short timeframe and then provide their expert advice to another team.

The class will be divided into four teams:

- ° Seismic Team
- ° Deformation Monitoring Team
- ° Well Water and Weather Team
- ° Eruption Center

Each tam has a sheet of instructions that they will need 10 minutes to read and ask questions.

There are three pages of data sheets — one for the Seismic Team (SEISMIC), one for the Deformation Monitoring Team (DISTANCES), and one for the Well Water Weather Team (TEMPERATURES). The Eruption Center team obtains its data from each of the other teams as the simulation progresses.

Eat page has six boxes of data that correspond to each “hour” of the simulation. Each team will need a copy of these sheets. Teams are only given one box of data at a time in a time interval — 8 minute intervals works well.

Starting the Simulation

Have each team sit in a corner of the room. Hand them the first hour’s data sheets and start the clock The Eruption Center team has no data until the other teams provide them with some. The next data sheets will be distributed after the time interval has passed.

Teams will feel that they don’t have enough time to make decisions about heir data before the next lot comes in. … but his is an important lesson about dealing with real time data. Some teams will have no problem, others will be stressed.

Some Background

Thunder Island is a small volcanic island in the southwestern Pacific Ocean. It has a population of 3,500 located in five small townships. The island was discovered by the Dutch in 1720 and a small settlement grew up around Safe Bay, which was used as a safe anchorage by Dutch trading ships during the monsoon storm season. Within ten years of discovery, Shakey Harbor was established as a jail for convicts (mostly pirates) and a small township started to grow around a fresh water stream at Valleyside. Released convicts moved into hermit side in 1750. In 1978, a tourist resort was built, known as The Resort. It caters for 200 people.

Township population (including estimated tourists)

- * Safe Bay _______1300
- * Valleyside_______100
- * Shakey Harbor ___800
- * The Resort ______250
- * Hermitside ______50

The Island has no roads and all transport is by foot or boat. A telephone system does operate to all townships except Hermitside, which is a 20-minute walk from Safe Bay or 35 minutes by boat.

Volcanic History

Two active volcanoes, Big Thunder and Little Thunder, occur on the island.

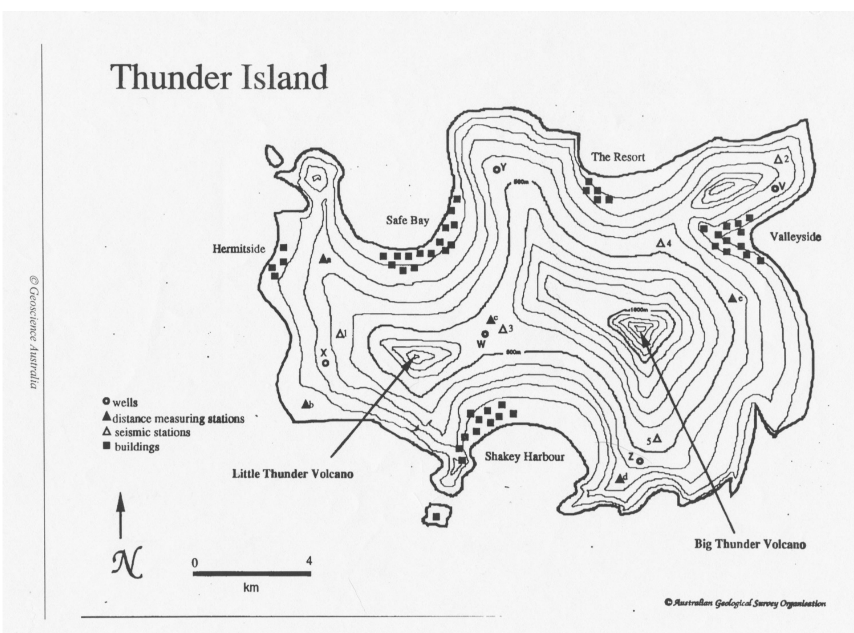
Big Thunder Volcano

Big Thunder erupts approximately once every nine years. It normally produces an amount of ash with the occasional andesitic lava flow. Eruptions are preceded by a rise in the temperature of water in the local wells and by increased seismic activity. During the last eruption eleven years ago, large amounts of ash covered Vallehside and a lava flow ran down a ridge between The Resort and Safe Bay. No one was injured, but Vallehside residents were forced to evacuate.

Little Thunder Volcano

Little Thunder has an erratic eruption history. It is known to have erupted eight times since settlement, each time releasing vast amounts of basaltic lava and ash. Many buildings in Shakey Harbor were destroyed by a lava flow in 1823. The last eruption in 1916 was prior to the setting up of monitoring devices on the island.

In 1984, seismic stations and distance measuring equipment was set up on the island to monitor future eruptions.



Lesson 4 Printouts and Handouts

Hour 1
SEISMIC

Station 1	1	2	1	2	0	1	2	1	2	0	1	1
Station 2	2	3	2	3	2	2	3	3	2	1	2	3
Station 3	3	4	3	4	3	4	4	4	4	3	4	4
Station 4	4	4	4	3	4	4	3	4	3	3	2	2
Station 5	3	2	3	2	2	2	3	2	3	2	3	2

Hour 2
SEISMIC

Station 1	1	2	3	2	3	2	1	2	3	2	1	1
Station 2	2	3	3	2	3	3	3	2	3	2	3	2
Station 3	3	4	4	4	5	4	4	3	4	4	4	5
Station 4	2	3	3	3	4	4	4	3	4	4	4	3
Station 5	3	3	3	3	3	3	3	4	3	3	3	3

Hour 3
SEISMIC

Station 1	2	3	2	3	2	3	2	2	2	2	3	2
Station 2	3	4	3	3	2	3	2	3	4	4	3	4
Station 3	4	4	3	4	4	3	4	3	4	3	4	4
Station 4	4	4	4	4	3	4	4	4	43		4	4
Station 5	2	3	2	3	4	2	3	2	3	2	1	3

Hour 4
SEISMIC

Station 1	3	4	4	3	2	1	2	1	2	2	2	1
Station 2	3	2	2	3	2	1	1	2	3	2	3	2
Station 3	4	4	4	4	3	4	3	4	3	4	3	4
Station 4	3	3	3	4	3	4	4	3	3	3	4	5
Station 5	3	2	2	2	3	2	3	2	3	1	3	2

Hour 5
SEISMIC

Station 1	2	3	2	1	2	2	1	2	2	2	1	2
Station 2	3	4	3	4	3	2	3	4	3	2	3	2
Station 3	4	5	5	4	5	5	6	4	3	4	5	4
Station 4	4	4	4	5	5	5	6	6	5	6	4	5
Station 5	2	3	4	4	4	4	4	5	6	4	4	4

Hour 6
SEISMIC

Station 1	3	4	5	4	3	4	4	4	3	4	3	4
Station 2	4	4	4	3	4	4	4	3	4	5	4	3
Station 3	5	6	5	6	5	5	5	6	7	7	7	-
Station 4	4	5	6	7	7	7	-					
Station 5	4	5	6	5	4	5	4	3	4	3	4	3

10 on Blue

DISTANCES *Hour 1*

a-b	1	2	1	2
a-c	2	3	1	1
c-d	2	2	1	1
c-e	2	2	1	1
e-d	1	2	1	1
d-b	0	3	2	1

DISTANCES *Hour 2*

a-b	2	2	1	2
a-c	2	1	0	1
c-d	3	3	2	3
c-e	4	3	2	3
e-d	4	1	1	3
d-b	3	2	9	3

DISTANCES *Hour 3*

a-b	1	1	1	2
a-c	2	3	2	1
c-d	4	5	4	5
c-e	1	2	3	2
e-d	6	5	4	5
d-b	2	1	2	3

DISTANCES *Hour 4*

a-b	2	3	4	2
a-c	1	2	2	2
c-d	1	2	3	3
c-e	3	3	3	3
e-d	3	4	3	3
d-b	4	5	3	2

DISTANCES *Hour 5*

a-b	2	2	3	2
a-c	1	1	0	2
c-d	5	6	4	5
c-e	6	6	7	8
e-d	9	6	7	5
d-b	4	3	2	5

DISTANCES *Hour 6*

a-b	2	2	3	2
a-c	2	3	2	1
c-d	5	6	7	8
c-e	10	9	8	8
e-d	9	9	11	8
d-b	5	5	5	6

10 Copies on Green

TEMPERATURES *Hour 1*
V 2
W 3
X 2
Y 4
Z 5
Wind Speed 15 Wind Direction W

TEMPERATURES *Hour 2*
V 7
W 7
X 3
Y 8
Z 7
Wind Speed 13 Wind Direction WSW

TEMPERATURES *Hour 3*
V 8
W 7
X 5
Y 6
Z 7
Wind Speed 10 Wind Direction SW

TEMPERATURES *Hour 4*
V 9
W 9
X 8
Y 10
Z 11
Wind Speed 14 Wind Direction SSW

TEMPERATURES *Hour 5*
V 12
W 19
X 3
Y 8
Z 24
Wind Speed 10 Wind Direction SW

TEMPERATURES *Hour 6*
V 10
W 12
X 5
Y 9
Z 26
Wind Speed 16 Wind Direction S

10 copies on Pink

ERUPTION CENTER

The Resort Headquarters

Your role is to advise the local people of the eruption warning for each hour. You need to assess the information provided by the other three teams and release the following warnings if needed:

NO ALERT - TESTING WARNING SYSTEM
This is issued when there is no activity warnings from any team. It lets local people know that the warning system is working.

ERUPTION GREEN
This is issued if any two teams advise of unusual activity. Locals should keep listening to further warnings.

ERUPTION ORANGE BIG/LITITE
This is issued if any two teams give warning of activity at either of the volcanoes. Locals in ash fall areas are on notice of evacuation.

ERUPTION RED BIG/LITTLE
This is issued if all three teams give warnings of activity. Locals in ash fall areas are evacuated to safer townships.

ERUPTION - ERUPTION - ERUPTION
An eruption.

ERUPTION DOWNGRADE (ORANGE/GREEN/NO ALERT)
A decrease in risk.

While you wish to advise people of risk, you do not wish to cause panic in the local people, as it is important that they trust your judgements. (Remember the boy who cried, "Wolf"!)

Well Water &Weather Team

Safe Bay Headquarters

Your role is to monitor the temperature changes in the five wells (V-Z) dotted around Thunder Island. Automatic thermometers are located in each well and information is sent via radio to headquarters where it is received by computer. The computer prints out the maximum temperature rise from the normal temperature of the well waters each hour. A fluctuation of 10° C is not uncommon, however, any rise beyond 10° C is a warning of moving magma.

Also, attached to a post at well W is a device that measures speed and direction of winds in the center of the island. Past eruption studies have shown that volcanic ash is blown 1 km X the wind speed.

Your job is to analyze the information and provide advice to the Eruption Control Center on your assessment of the eruption risk and location.

For example:

V: 6
W: 4
X: 8
Y: 4
Z: 3
Wind speed: 5 Wind direction (from) : S

Well temperatures are within limits. Well X is getting hot and further reading will need to be recorded. Ash falls could occur to the north of both volcanoes for 5 km. Safe Bay is in ash fall zone. ADVISE ERUPTION CENTER OF WELL X AND WEATHER.

Or :

V:2
W:12
X:3
Y:8
Z:16
Wind speed: 10 Wind direction : SE

Well temperatures indicate rise of magma under Big Thunder. Ash fall zone from Big Thunder will be 10km to the northwest. Safe Bay is under risk. WARN ERUPTION CENTER.

Deformation Monitoring Team

Valleyside Headquarters

Your role is to monitor deformation of the slopes of the volcano. Your information comes from accurate laser measurements between five distant measuring stations (a-e) on Thunder Island. The process of measuring the distances is automatic and is taken every 15 minutes, which are sent to you via telephone lines every hour (4 readings).

The normal readings are:

a-b	5110m	c-e	8590m
a-c	6450m	e-d	7475m
c-d	7190m	d-b	1155m

The instruments vary in their readings by + 1m. However, it is not unknown for some readings to change as much as 3 m during non-eruptive times. Any change larger than this and for more than one hour may indicate the rise of magma in the volcanic vent. The readings are fed into a computer that prints out the variation in meters from the normal measurements.

Your job is to analyze the information and provide advice to the Eruption Control Center on your assessment of the eruption risk and location.

For example

a-b 1,2,3,2
a-c 1,0,0,1
c-d 2,1,0,1
c-e 2,3,4,3
e-d 1,0,1,3
d-b 0,0,0,1

Distance measurements appear within limits. However the distance c-e may indicate activity on the northern slope of Big Thunder. ADVISE ERUPTION CENTER.

Or
a-b 0,1,2,1
a-c 3,2,1,2
c-d 2,3,3,4
c-e 3,3,3,4
e-d 2,3,4,5
d-b 3,2,3,2

Major deformation is occurring around Big Thunder. The southeastern slope is bulging up to 5m from normal measurements. WARN ERUPTION CENTER.

Seismic Team

Shakey Harbor Headquarters

Your role is to monitor seismic activity as recorded by the five seismic stations located on Thunder Island (1-5). The seismic recorders only measure strong ground motions in the close vicinity of the recorder. The information is sent via telephone lines to your headquarters in Shakey Harbor.

Each recorder produces an average reading of seismic intensity every five minutes. These are sent to you each hour as a steam of 12 numbers from each center. The scale for these numbers is:

0 - no activity	4 - sub-major activity
1 - very minor activity	5 - major activity
2 - minor activity	6 - dramatic activity
3 - substantial activity	7 - extreme activity

Eruptions are normally preceded by intensities of 5 or more, recorded by stations surrounding the volcanic vent. The recorders are built to withstand intensity 7 for 10 minutes only, after which they may cease to operate.

Your job is to analyze the information and provide advice to the Eruption Control Center on your assessment of the eruption risk and location.

For example:

Station 1) 3,4,3,4,5,6,6,5,6,5,6,6
Station 2) 2,1,2,1,0,0,1,0,1,2,0,0
Station 3) 3,4,4,3,4,5,4,3,4,5,6,4
Station 4) 3,2,3,1,2,1,2,3,2,3,2,3
Station 5) 3,4,4,4,3,2,3,2,3,2,3,2

Activity is taking place on the western side of Little Thunder with maximum intensity being described as dramatic. The intensity has increased over time. This is confirmed by a station on the eastern side of Little Thunder. All other stations have had high but stable intensities. Conclusion is that Little Thunder may erupt. WARN ERUPTION CONTROL CENTER

or

Station 1) 1,2,2,3,2,3p,1,2,3,2,2
Station 2) 3,2,3,2,3,4,3,2,3,2,3,2
Station 3) 1,2,2,3,2,2,1,2,2,1,2,2
Station 4) 3,2,3,3,2,3,2,2,2,2,3,2
Station 5) 2,1,2,1,2,2,3,3,2,1,2,1

Activity is stable. Fluctuations are within normal limits. NO WARNINGS NEEDED.