

## Earth Science 8

May 4 – May 8

*Time Allotment: 30 minutes per day*

Student Name: \_\_\_\_\_

Teacher Name: \_\_\_\_\_

### Packet Overview

Date	Objective(s)	Page Number
Monday, May 4	1. Students will be able to explain the effect of Earthquakes on human civilization and cite specific historical examples.	1
Tuesday, May 5	1. Students will be able to explain the causes and effects of Tsunamis.	4
Wednesday, May 6	1. Students will be able to explain how and where typical volcanoes occur.	6
Thursday, May 7	1. Students will be able to describe and differentiate between the different types of volcanic eruptions, and the different types of lava they produce.	8
Friday, May 8	Students will be able to explain the distinguishing shapes and features of the different types of volcanoes.	13

**Additional Notes:** Students are to designate a specific location in their home for their workspace to learn about Earth and Space.

This could be a table or desk anywhere in the home that could be labeled their school zone. By doing so, the students will have a stable work environment that they will keep all of their learning materials organized, they can visit, and take a rest from.

### Academic Honesty

I certify that I completed this assignment independently in accordance with the GHNO Academy Honor Code.

*Student signature:*

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I certify that my student completed this assignment independently in accordance with the GHNO Academy Honor Code.

*Parent signature:*

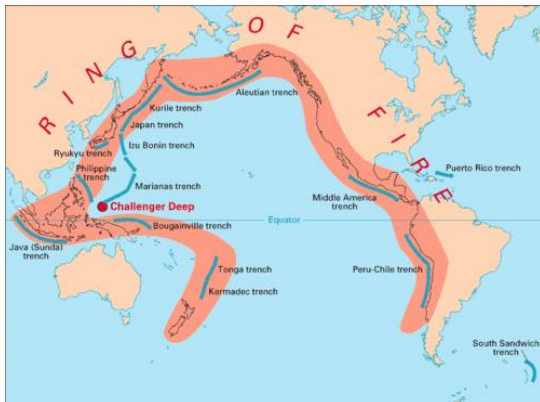
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## Lesson 1: Monday, May 4

### Earthquakes, continued.

Some locations are prone to earthquakes and some are not. Nearly 95% of all earthquakes take place along one of the three types of plate boundaries. Scientists use the location of earthquake epicenters to draw the boundaries of the plates because earthquakes frequently occur along plate boundaries.

The region of the planet with the most earthquakes is the area around the Pacific Ocean. About 80% of all earthquakes strike this area. This region is called the Pacific Ring of Fire because most volcanic eruptions occur there as well. The Pacific Ocean is surrounded by convergent and transform plate boundaries (below).



**Left:** The Pacific Ring of Fire is the most geologically active region of the world. **Right:** Damage after the 1906 San Francisco Earthquake and fire.

About 15% of all earthquakes take place in the Mediterranean-Asiatic belt. This is where convergent plate boundaries are shrinking the Mediterranean Sea and causing the Himalayas to grow. The remaining 5% of earthquakes are scattered around the other plate boundaries with a few occurring in the middle of a plate, away from plate boundaries.

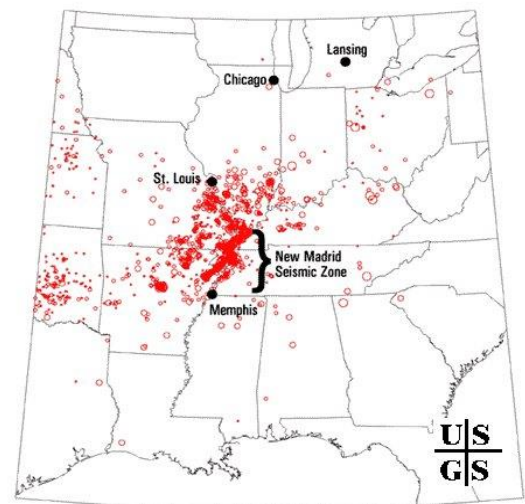
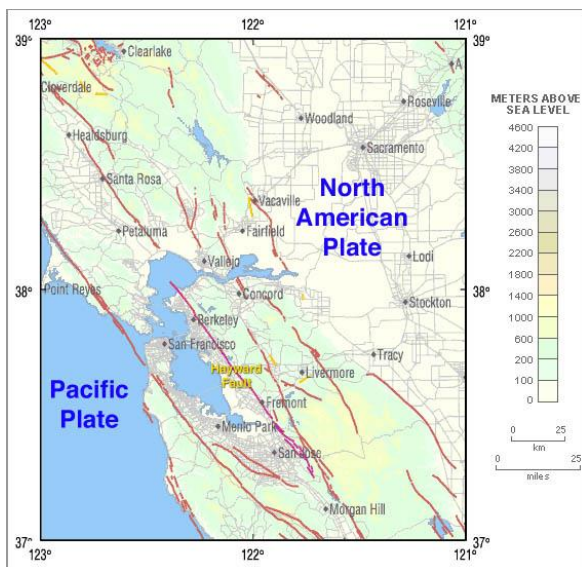
All three types of plate boundaries have earthquakes. Enormous and deadly earthquakes occur at transform plate boundaries. Because the slabs of lithosphere slide past each other without moving up or

down, transform faults have shallow focus earthquakes. The most notorious earthquake fault in North America is the San Andreas Fault that runs through California. The 1,300 kilometer (800 mile) long fault is the transform boundary between the northwestward-moving Pacific plate and the southeastward-moving North American plate. The San Andreas Fault is a right-lateral strike-slip fault.

The largest earthquake on the San Andreas Fault in historic times occurred in 1906 in San Francisco. This earthquake likely measured magnitude 7.8, which is a very large earthquake. The earthquake and the subsequent fire is still the most costly natural disaster in California history. An estimated 3,000 people died and about 28,000 buildings were lost, mostly in the fire.

In 1989, the Loma Prieta earthquake struck near Santa Cruz, California. The magnitude 7.1 quake resulted in 63 deaths, 3,756 injuries and left more than 12,000 people homeless. The property damage was estimated at about \$6 billion. In 1994, an earthquake on a blind thrust fault struck near Los Angeles, California in the neighborhood of Northridge. It registered 6.7 on the moment magnitude scale. Seventy two people died, 12,000 more were injured and damage was estimated at \$12.5 billion.

There are many other faults spreading off the San Andreas Fault, which together with the main fault produce around 10,000 earthquakes a year. While most of those earthquakes cannot even be felt by people nearby, occasionally one is massive. In the San Francisco Bay Area, the Hayward Fault was the site of a magnitude 7.0 earthquake in 1868.



*Left: The San Andreas Fault Zone in the San Francisco Bay Area. Right: The location of the New Madrid Seismic Zone is well within the North American plate far from the nearest plate boundary.*

Convergent plate boundaries also produce massive and deadly earthquakes. Earthquakes mark the motions of subducting lithosphere as it plunges through the mantle. The earthquakes can be shallow, intermediate or deep focus. Convergent plate boundaries produce earthquakes all around the Pacific Ocean basin.

The Philippine plate and the Pacific plate subduct beneath Japan creating a chain of volcanoes and as many as 1,500 annual earthquakes. The great Kanto earthquake of 1923 is thought to have killed

140,000 people, many in the subsequent fire. In Yokohama, 90% of houses were damaged or destroyed and 60% of Tokyo's population became homeless. In the Kobe Earthquake of 1995, 6,434 people died.

Subduction is also taking place along the Cascades Mountains in the Pacific Northwest as part of the Pacific Ring of Fire. The Juan de Fuca plate is plunging beneath the North American plate and forming volcanoes that extend south into northern California. The Cascades volcanoes are active and include Mount Saint Helens, which had a large eruption in 1980. Mount Lassen, Mount Shasta, and Medicine Lake volcano in northeastern California are the three southernmost volcanoes in the Cascades chain.

Yet the Cascadia subduction zone is one of the world's quietest subduction zones, with relatively few earthquakes. Though they don't happen often, they are extremely powerful when they hit. The last major earthquake on the Juan de Fuca occurred in 1700, with a magnitude estimated at between 8.7 and 9.2. The geologic history of the area reveals that major earthquakes occur here about every 300 to 600 years. Since it has now been more than 300 years since the last earthquake in the area, the Pacific Northwest is at risk from a potentially massive earthquake that could strike any time.

The thrust faulting and folding that result from the convergence of continental plates creates massive earthquakes. The region in and around the Himalaya, for example, is the site of many earthquakes. The 2001 Gujarat, India earthquake is responsible for about 20,000 deaths with many more people injured or made homeless.

Earthquakes also occur at divergent plate boundaries. At mid-ocean ridges, these earthquakes tend to be small because the plates are young and hot. The earthquakes are shallow because the new plates are thin. Since divergent plate boundaries in the oceans are usually far from land, they have little effect on peoples' lives. On land, where continents are rifting apart, earthquakes are larger and stronger.

About 5% of earthquakes take place within a plate; that is, away from plate boundaries. A large intraplate earthquake occurred in 1812 when a magnitude 7.5 earthquake struck near New Madrid, Missouri. The earthquake was strongly felt over around 50,000 square miles, and altered the course of the Mississippi River. Because very few people lived here at the time, only 20 people died. However many more people live here today and the New Madrid Seismic Zone continues to be active (above). A similar earthquake today would undoubtedly kill many people and cause a great deal of property damage. Intraplate earthquakes are caused by stresses due to plate motions acting in solid slabs of lithosphere.

**Review Questions:**

1. Why is California so prone to dangerous earthquakes?
2. Use plate tectonics theory to describe why there are far more earthquakes around the Pacific Ocean than anywhere else on Earth.

## Lesson 2: Tuesday, May 5

### Tsunamis

Earthquakes can cause deadly ocean waves called **tsunami**, although tsunami can be caused by any shock to ocean water, including a meteorite impact, landslide, or other massive disturbance. When ocean water is displaced by the sharp jolt of an undersea earthquake, the seismic energy forms a set of waves. The waves travel through the sea entirely unnoticed since they have low amplitudes and long wavelengths. When these waves come onto shore, they can grow to enormous heights and cause tremendous destruction and loss of life. Fortunately, few undersea earthquakes generate tsunamis.

The Boxing Day Tsunami of December 26, 2004 was by far the deadliest of all time. The tsunami was caused by the 2004 Indian Ocean Earthquake, also called the Great Sumatra-Andaman earthquake. This earthquake, with a magnitude of 9.2, **was the second largest earthquake ever recorded**. The energy that reached the planet's surface was 1,502 times the amount released by the atomic bomb dropped on Hiroshima at the end of World War 2, but the total amount of energy released was estimated at 550 million times Hiroshima.



*The location of the 2004 Indian Ocean earthquake and the countries that were most affected by the tsunami. Note that some affected countries are on the opposite side of the ocean.*

The Indian Ocean Earthquake struck 160 kilometers (100 miles) off of Sumatra, Indonesia. In this region the Indian plate is subducting beneath the Burma plate. Slip along the earthquake fault was an incredible 15 meters (50 feet), about two-thirds of that in a horizontal direction and one-third in a vertical direction. The fault ruptured over about 1,600 kilometers (1,000 miles). Faulting went on for up to 10 minutes, the longest duration ever witnessed.

The extreme movement of the crust displaced trillions of tons of water. Water displacement occurred along the entire length of the rupture. This means that tsunami waves formed along a great distance, which increased the area that the killer waves traveled to. Several tsunami were created, with about 30 minutes between the peaks of each one.

The water traveled rapidly across the Indian Ocean outward from the fault. As is typical for tsunami, the waves were not noticeable in open water. Satellites measured the height of the waves across the sea at just 50 centimeters (20"). The first wave hit the northern regions of Sumatra in about 15 minutes. At its worst, the waves rose to around 10 meters (33 feet) in height. Within 1.5 to 2 hours, waves were striking Sri Lanka and the eastern coast of India. Thailand was battered two hours after the earthquake. Somalia was hit seven hours after the earthquake. The size of the waves decreased with distance from the earthquake so that the waves in Sri Lanka, Thailand, and Somalia were relatively small, about 4 meters (13 feet) in height.

Like other waves, a tsunami wave has a crest and a trough. What people see when the tsunami hits the beach depends on whether the crest or the trough hits first. In some locations, the trough of the wave hit the beach first. When this happens, water is sucked out to sea and the seafloor just offshore from the beach is exposed. Curiosity is often fatal in this instance, since people who go out to the beach to see the unusual sight are drowned when the wave crest hits.

One amazing story was that of Tilly Smith, a 10 year old British girl who was visiting Maikhao Beach in Thailand with her parents. About two weeks before the earthquake, Tilly had learned about tsunamis in school. She knew that the receding water and the frothy bubbles at the sea surface indicated an approaching tsunami. As the trough of the tsunami wave hit the beach, she pointed these features out to her parents. They told other tourists and the staff at their hotel and the beach was evacuated. No one on Maikhao Beach died and Tilly is credited with saving nearly 100 people.

On other beaches, people were not so lucky. In all, the tsunami struck eight countries, with Indonesia, Sri Lanka, India and Thailand the hardest hit. About 230,000 people died, with fatalities even as far away as South Africa, nearly 8,000 kilometers (5,000 miles) from the earthquake epicenter. More than 1.2 million people lost their homes and many more lost their ways of making a living.



*A before and after photo of a town in Japan hit by the Tsunami of March, 2011*

Only a few scientists had thought that a massive tsunami would strike the Indian Ocean so no warning system had been in place. Tsunami are much more common in the Pacific due to the enormous number of subduction zones that line the Pacific basin, and communities around the Pacific have had a tsunami warning system in operation since 1948. As a result of the 2004 tsunami, an Indian Ocean warning system was put into operation in June 2006.

Warning systems are of limited use. They base their warnings on the location of earthquakes within an ocean basin. Unfortunately, communities that are very close to the earthquake do not receive the warning in time to move inland or uphill since the wave hits too fast. Still evacuation of low-lying areas could save many people in a large tsunami that is further from the earthquake.

### Review Questions:

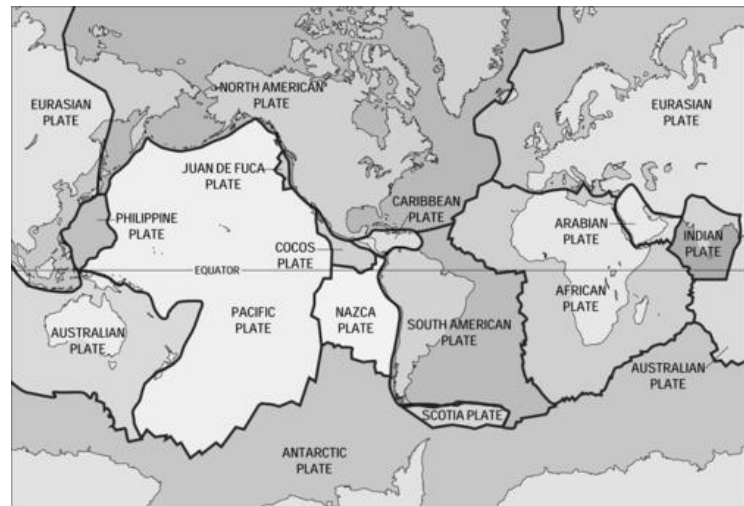
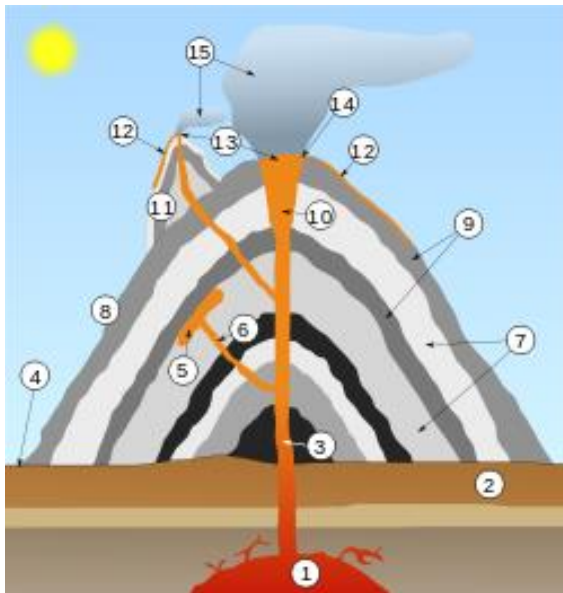
1. What did Tilly Smith notice on the beach in Thailand that caused the adults around her to evacuate the beach before the enormous tsunami hit in 2004? How were these signs evidence of a tsunami?

## Lesson 3: Wednesday, May 6

### Volcanoes

We've all heard of volcanoes- the angry Earth spewing up its wrath, the sudden explosion of a distant mountain top, and lava that slithers ominously toward villages. Volcanoes are fantastic displays of the power of the Earth. But what actually is a volcano? How and where are they formed? Why do some places have a history of volcanic activity? Volcanoes explain a key piece of the Earth's geologic puzzle

### How Volcanoes Form



**Left:** A volcano is a vent through which molten rock and gas from beneath the Earth's surface escape. (1) Large magma chamber (2) Bedrock (3) Pipe (conduit) (4) Layers of ash (5) Layers of lava (6) Lava flow (7) Vent (8) Lava (9) Ash cloud. **Right:** Tectonic plates. Some of the largest tectonic plates meet along the coasts of Asia and North America. Compare this map to the map on page 1.

You have already learned about tectonic plates. Beneath the Earth's surface, powerful forces are at work. These forces move lithospheric plates and produce huge chambers of **magma**, molten rock beneath the Earth's crust. Like water that bursts from a tiny hole in a water pipe, the liquid magma seeks cracks or

**fissures** in the Earth's crust through which it could flow. This is a volcano—an opening in the earth's crust through which magma or gases can erupt onto the surface.

When molten rock escapes from beneath the Earth's surface, it changes from magma to **lava**, molten rock above the Earth's surface. Because the temperatures at the Earth's surface are much lower than in the magma chambers, the lava does not take long to solidify back into rock. As layer upon layer of lava solidifies, a mountain is formed.

As you can see in the image on the left above, magma begins in the lava chamber and comes to the surface through the throat of the volcano. The volcano is constructed layer by layer, as ash and lava solidify, one upon the other. However, other types of volcanoes exist, and will be discussed later in this chapter.

## **Where Volcanoes Occur**

Because volcanoes are vents for magma, it makes sense that volcanoes would be formed above underground magma chambers. If you recall, magma is molten rock that has been heated because of high temperatures and pressures beneath the Earth's crust. This pressure mostly occurs where the tectonic plates meet and subduct. Look at the map of tectonic plates above.

So, volcanic activity tends to occur along subduction plate boundaries, where one plate slides underneath another. The edges of the Pacific Plate make up a long subduction boundary. There are a huge number of earthquakes along these boundaries, because these are regions where the plates are colliding. For the same reason, the majority of the volcanic activity on the Earth also occurs along these convergent boundaries. This is called the *Pacific Ring of Fire* where over 75% of the world's volcanoes are found. The Cascade Range of volcanoes runs through southwestern Canada and the Pacific Northwest of the United States (See map on page 1).

Of course, this is not the only area where volcanoes occur. Beneath the ocean, there are also divergent boundaries, where tectonic plates are pulling away from each other. As the plates pull away from each other, they create a deep canyon or fissure on the sea floor through which molten rock escapes. Mid-ocean ridges, like the Mid-Atlantic ridge from our previous lessons, form here as lava flows out through the fissure. Submarine volcanoes can also form on the ocean floor. At times these volcanoes can grow to create islands above the water's surface.

## **Volcanic Hot Spots**

Although most volcanic activity on Earth occurs at plate boundaries, there are some volcanically active spots that are in the middle of a tectonic plate. These areas are called **hot spots**. The islands of Hawaii formed over a hot spot and are not located on the Pacific Ring of Fire. The Hawaiian islands are the exposed peaks of a great chain of volcanoes that were formed over millions of years. The islands are thought to lie directly above a column of hot rock called a **mantle plume**. Mantle plumes are more or less fixed in place and continuously bring magma up from the mantle towards the crust. As the tectonic plates move above them, they leave a trail of volcanic activity, which forms island chains like Hawaii. Scientists believe there are about 50 hot spots on the Earth. Other hot spots include Yellowstone and the



Galapagos Islands. They are, in other words, an example of the **intraplate activity** we discussed last week.

Don't confuse hot spot volcanoes with islands that are formed by plate tectonics like the Aleutian island chain in Alaska. These long lines of volcanoes form as the edge of a subducted plate melts, producing magma which rises to the surface along the edge of the plate. These volcanic mountains will all be about the same age. When islands form over a hot spot, the youngest island is over the hot spot. As you move along the island chain, each island further from the hot spot will be older than the one before it.

**Review Questions:**

1. Why do some volcanoes occur where tectonic plates **diverge**?
2. What is a mantle plume?
3. What is the difference between magma and lava?

**Lesson 4: Thursday, May 7**

**Volcanic Eruptions**



*Left: Mount St. Helens, Washington state, before its catastrophic eruption. Right: After. Photo taken from the same location.*

In 1980, Mount St. Helens erupted in one of the most deadly and costly volcanic eruptions in United States history. The eruption was particularly deadly since Mount St. Helens, one of the Cascade Range, is in a populated area between Portland, Oregon and Seattle, Washington. The eruption killed 57 people, destroyed 250 homes, and swept away 47 bridges. The elevation of the volcano dropped by over 1,300 feet because of the immense explosion created by the eruption. Today, Mt. St. Helens is still active.

The volcano now has a horseshoe-shaped crater that is nearly one mile across. Within the crater, a new lava dome has formed. How did this eruption occur? Why aren't all volcanoes explosive like Mt. St. Helens? Why did so many people perish if we knew that it was going to erupt? The study of volcanoes has many questions still unanswered. However, scientists have studied volcanoes for many years and are piecing together evidence that explains these powerful geologic phenomena.

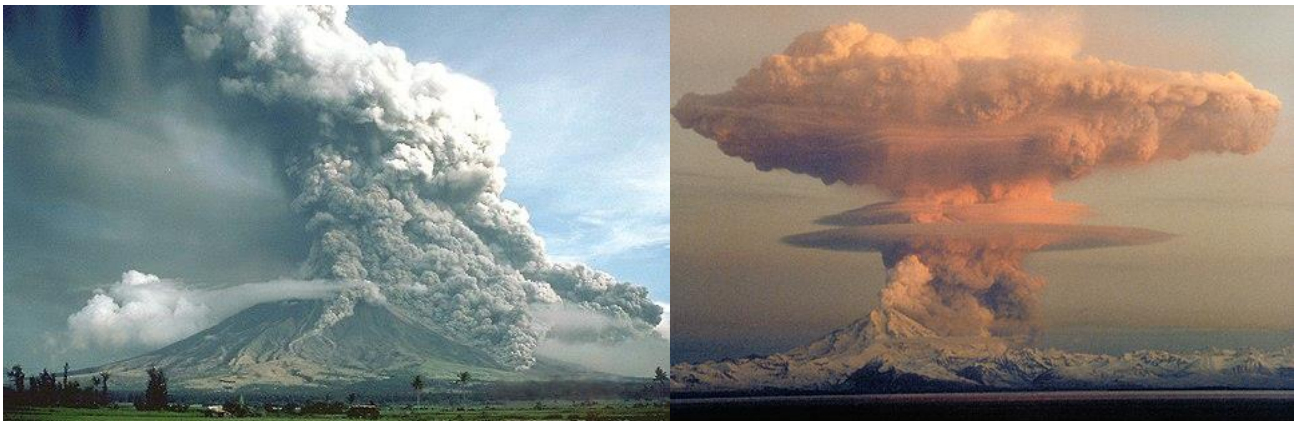
All volcanoes share the same basic features. The magma collects in magma chambers that can be 100 miles beneath the surface. As the rock heats, it expands, which creates even more pressure. As a result, the magma seeks a way out pushing toward the surface, and seeps through cracks in the Earth's crust called vents. Eventually, it reaches the surface; when it comes out, we call it an **eruption**. An eruption can be an outburst or explosion, a violent and sudden occurrence, like a bomb exploding. But an eruption can also be more like honey spilling out of a tipped over jar, gradual and relatively calm. These examples are similar to the two primary kinds of eruptions that we see in volcanoes.

## **Types of Eruptions**

Every geological formation is unique. Their composition and construction depend on so many factors, that it would be impossible for two formations to be exactly alike. In the same way, each volcano and its eruptions are unique. However, we tend to see two major kinds of eruptions. We talked about eruption to mean both a violent explosion or a sort of silent spreading. These are the two types of volcanic eruptions that we see—explosive and non-explosive eruptions. When we think of volcanic eruptions, we often think of huge clouds of volcanic ash ejected high into the atmosphere and then thick rivers of red lava snaking down the mountainside. In reality, these two phenomena rarely occur in the same volcano. Volcanic eruptions tend to be one or the other.

## **Explosive Eruptions**

Imagine the devastation and force caused by the atom bomb dropped on Nagasaki at the end of World War II in which over 40,000 people died. Now imagine an explosion 10,000 times as powerful. Explosive volcanic eruptions can be that powerful. As hot magma beneath the surface interacts with water, gases accumulate, and the magma pressure builds up. This pressure grows and grows until these dissolved gases cause it to burst in an enormous explosion.



**Left:** An explosive eruption from the Mayon Volcano in the Philippines in 1984. **Right:** Explosive eruption of Mt. Redoubt in Alaska, 1989. This huge mushroom cloud reached 45,000 feet

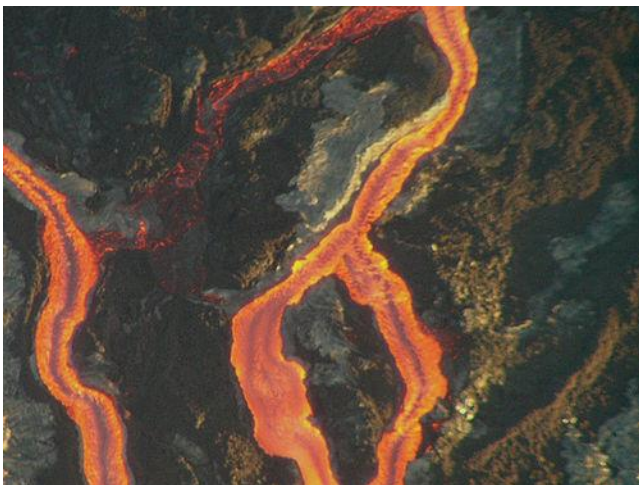
This great explosion takes with it the magma and volcanic gases, which can shoot many kilometers into the sky and forms a mushroom cloud, similar to that formed by a nuclear explosion. The debris travels up into the air at very high speeds and cools in the atmosphere to form solid particles called **pyroclasts**. Some of these particles can stay in the atmosphere for years, which can disrupt weather patterns and affect the temperature of the Earth. The rest of the debris comes falling back to Earth where it rains down for kilometers and kilometers around.

Sometimes secondary explosions occur that are even greater than the first. Additionally, volcanic gases like water vapor, carbon dioxide, sulfur dioxide, hydrogen sulfide, and hydrogen chloride can form poisonous and invisible clouds that roam about the atmosphere. These gases contribute to environmental problems like acid rain and ozone destruction, and can actually cool the Earth's atmosphere.

In the Cascade Range, the explosive eruption of Mount St. Helens was preceded by the eruption of Lassen Peak, one of the three Cascade Volcanoes in northern California. On May 22, 1915, an explosive eruption sent a column of ash and gas 30,000 feet into the air and triggered a high-speed pyroclastic flow, which melted snow and created a lahar. Lassen continues to have geothermal activity and could erupt explosively again. Mt. Shasta erupts every 600 to 800 years. An eruption would most likely to create a large pyroclastic flow, and perhaps a lahar. However, the volcano could explode like Mt. Mazama, which blew itself in an eruption about 42 times more powerful than Mount St. Helens in 1980, to create Crater Lake.

### **Non-Explosive Eruptions**

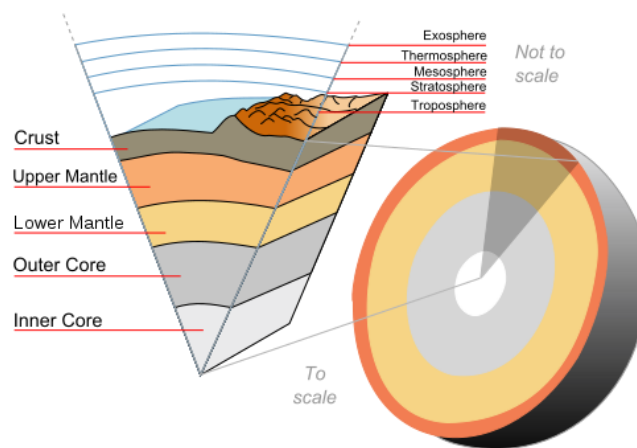
A second type of volcanic eruption is a non-explosive or **effusive eruption**. Because the composition of magma is different in different volcanoes, the properties of the lava are different. In effusive eruptions, lava flows are relatively calm and do not explode out of the volcano. As a result, people generally have a great deal of warning before lava reaches them, so non-explosive eruptions are much less deadly. That does not keep them from being destructive, however. Even when we know that a lava flow is approaching, there are few ways of stopping it, given the huge quantity and temperature of lava.



*When lava flows readily, pressure does not build up so great explosions do not occur.*

## Magma

Deep beneath the Earth, magma forms as the first stage in creating a volcano. This occurs because rock below the surface is subjected to great amounts of pressure from gravity. The decay of radioactive materials generates additional heat. The substantial heat and pressure melt the rock below the surface to form a taffy-like substance. You may have seen a candle that has been left out in the hot sun too long. It becomes softer and more like a liquid. As the molecules absorb heat, they begin to slide past one another becoming more fluid. A similar process occurs with magma. However, different substances melt at different temperatures. For that reason, the temperature at which rocks melt depends on the specific types of rocks. The Earth's crust and mantle are made of many substances so the temperature required to create magma varies. Most magmas are formed between 600°C and 1300°C



*Cutaway of the Earth. The melting of rock in the crust and upper mantle create magma.*

Melted rock or magma can be found in **magma chambers** beneath the Earth. Since the magma chambers are so far beneath the Earth's surface, it is difficult for scientists to study them. Scientists know that magma chambers are created where the heat and pressure are greatest. When tectonic plates collide and rub against each other, magma is formed there. That is how the Pacific Ring of Fire was created. We also know there are volcanoes far away from plate boundaries, so we know there are magma chambers in these areas as well. Magma chambers can be found where there are mantle plumes or hot spots.

Just how or why these hot spots are created isn't exactly known. However, because different substances melt at different temperatures, the creation of magma depends on what substances make it up—its composition. Just like the flavor of a cake depends on the ingredients that you put in it, the behavior of magma and lava depends on its composition. Certain melted rocks act in certain ways. So when the magma becomes lava, not all lava acts the same.

## Lava

Once magma reaches the surface, it becomes lava. Consider different liquids that you might see in your house—honey and a bottle of cola, for example. You might agree that the two liquids are different in many regards. They taste different, have different colors, have different gases in them, and they flow differently. In fact, honey is a liquid that resists flowing, whereas cola flows easily. Honey has a higher

**viscosity** than the cola; it resists flowing. Water has a low viscosity because it flows easily. One of the major differences in different types of lava is their viscosity.

A highly viscous lava is one that doesn't tend to flow easily. It tends to stay in place. Lavas with high silica contents tend to be more viscous. Since it is so resistant to moving, it clogs the vents in a volcano. The pressure becomes greater and greater until the volcano finally explodes. This type of lava is found in explosive eruptions. It also tends to trap a lot of gas. When the gas is released, it makes the eruption more explosive. Most of this lava is shot up into the air where it hardens and becomes solid rock. This molten rock that solidifies in the air is known as **pyroclastic material**. In an igneous rock like pumice, small holes in the solid rock show where gas bubbles were when the rock was still liquid lava.

Low-viscosity lava slides or flows down mountainsides. There is more than one type of low-viscosity lava. The differences between them come from the lavas' different composition and different spots where they come to the surface. The type of igneous formations formed depends on which type of lava it is. The three major categories are a'a, pahoehoe, and pillow lava.

### **A'a Lava**

A'a lava is the more viscous of the non-explosive lavas. This lava forms a thick and brittle crust which is torn into rough and jagged pieces. The solidified surface is jagged and sharp. It can spread over large areas as the lava continues to flow underneath.



*Left: A'a lava flow. Center: Pāhoehoe lava. Right: Pillow Lava*

### **Pāhoehoe Lava**

Pāhoehoe lava is less viscous than a'a lava, and flows more readily. Its surface looks more wrinkly and smooth than the jagged a'a lava. Pāhoehoe lava flows in a series of lobes or rounded areas that form strange twisted shapes and natural rock sculptures. Pāhoehoe lava can also form lava tubes beneath the ground.

### **Pillow Lava**

Pillow lava is lava that comes out from volcanic vents underwater. When it comes out underwater, it cools down very quickly and forms roughly spherical rocks that resemble pillows, from which more lava leaks and creates more pillows. Pillow lava is particularly common along underwater spreading centers.

**Review Questions:**

1. What is pyroclastic material?
2. What are the two basic types of volcanic eruptions, and what distinguishes them from each other?

**Lesson 5: Friday, May 8**

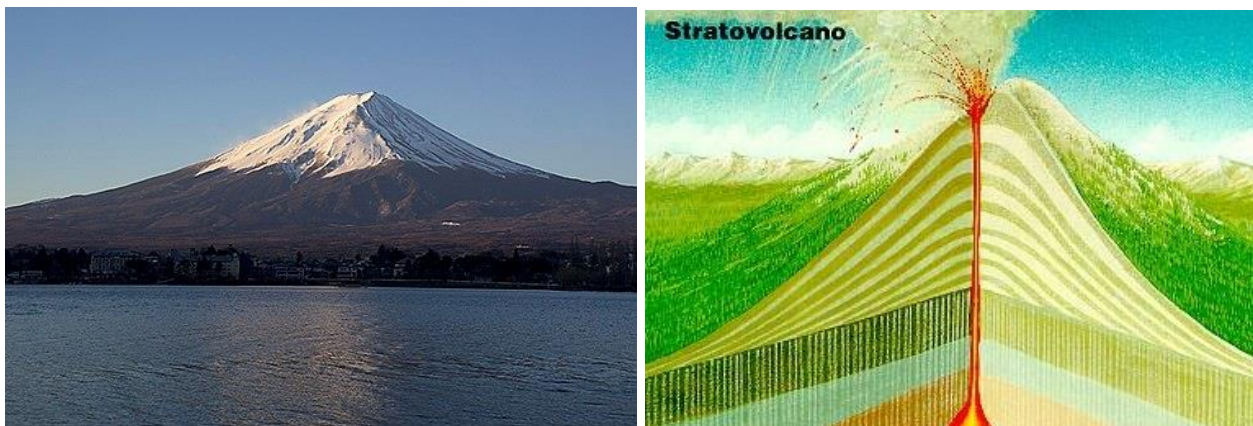
**Volcano Typology**

When you think of a volcano, you may think of a tall mountain with a crater on the top, maybe a little snow at the summit and some trees scattered around the base. There are many volcanoes like this, but volcanoes exist in many other forms as well. Each type of volcano has characteristic features that distinguish it from other types. Volcanoes differ in appearance because of the composition of their magma and the processes that originally created them.

The tall cone shape you usually think of when you think of a volcano describes a composite volcano, one common form of volcanoes. Other types of volcanoes include the shield volcano, the cinder cone, and the supervolcano.

**Composite Volcanoes/Stratovolcanoes**

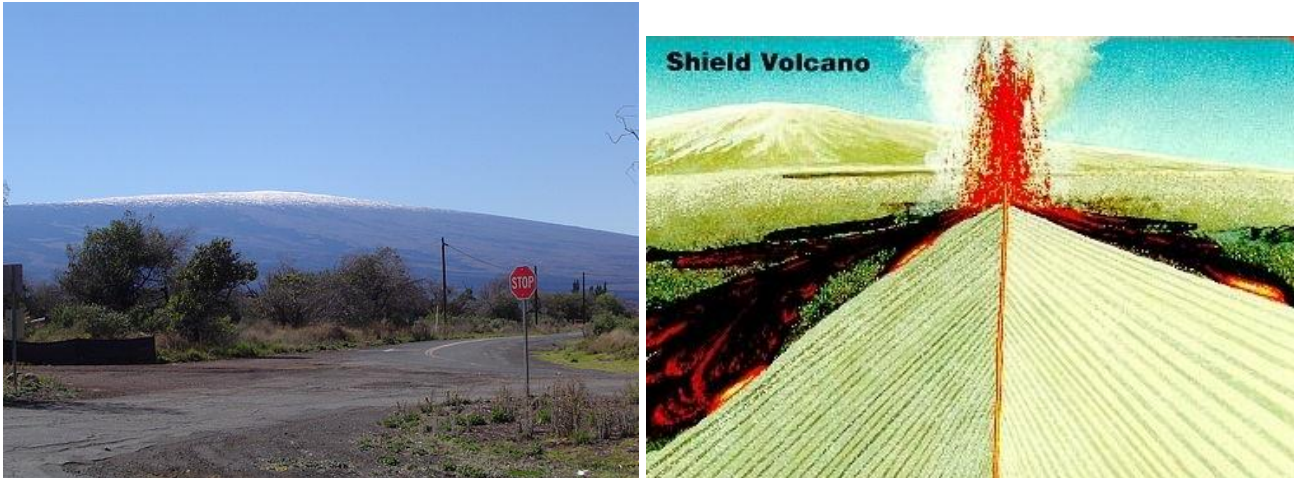
The picture below on the left shows Mt. Fuji, a classic example of the **composite volcano**, also known as a **stratovolcano**. This is the type of volcano many people think of when they imagine volcanoes. Composite volcanoes have broad bases and sides that get steeper and steeper as you get closer to the top. These volcanoes frequently have a large crater at the top created during its last eruption.



**Left:** Mt. Fuji is a dormant stratovolcano that is the highest mountain in Japan. **Right:** This cutaway shows what the interior of a stratovolcano like Mt. Fuji looks like. Note the different layers.

## Shield Volcanoes

Shield volcanoes get their name from their shape—a huge shield laid on its side. The image below on the left shows the Mauna Loa Volcano. You can see that shield volcanoes do not have the steep mountainous sides of composite volcanoes. They have a very wide base and are much flatter on the top than composite volcano. Although they are not steep, they may be very large. The Mauna Loa Volcano has a diameter of over 70 miles and forms a significant part of the Big Island of Hawaii. The Mauna Kea Volcano, also in Hawaii, is another shield volcano that is over 6 miles high from its base below sea level to its peak.



*Left: The Mauna Loa Volcano in Hawaii is the largest shield volcano on Earth. Right: An interior look at a shield volcano.*

Shield volcanoes are more common at spreading centers or volcanic hot spots in the middle of tectonic plates. The magma that creates shield volcanoes is less viscous, so it flows much more easily. For this reason, the eruptions of shield volcanoes are non-explosive. In addition, the less viscous lava spreads out more, which makes shield volcanoes much larger and flatter than stratovolcanoes. Although shield volcanoes are built by many layers over time, the composition of the layers do not alternate between ash and lava, as they do in stratovolcanoes.

## Cinder Cones



*Left: Paricutín erupting in 1943, when it first formed. **Cinder cones** like this one rarely reach even 300 meters high. Right: The ancient supervolcano that makes the island of Santorini in Greece is so large that its circular shape can only be seen directly from space*

**Cinder cones** are both the most common type of volcano and also the smallest. The cinder cone resembles a composite volcano but on a much smaller scale. They rarely reach even 300 meters in height but have even steeper sides than a composite volcano. They usually have a crater at the summit. Cinder cones are composed of small fragments of rock piled on top of one another. These volcanoes usually do not produce streams of lava.

In 1943, a farmer in Mexico witnessed the first eruption of a cinder cone in his field. Within a year, the cinder cone Paricutín grew to 336 meters high. By 1952, it grew to a peak of 424 meters tall, and then stopped erupting. This rapid growth and single eruption cycle is characteristic of cinder cones. For this reason, cinder cones do not reach the sizes of stratovolcanoes or shield volcanoes. Often, cinder cones appear near larger volcanoes, but they also may be found away from all other volcanoes, as was the case with Paricutín. The exact composition of a cinder cone depends on the composition of the lava ejected from the Earth.

## Supervolcanoes

In certain areas of the world, huge **calderas** have been found to be the remains of volcanic eruptions of enormous scale (see image above right) These calderas are volcanic features that are formed by the collapse of a huge amount of land due to the powerful eruptions. Caldera comes from the Latin word *caldāria* (“warm bath”), from *caldus* (“warm”). Calderas are generally circular shaped geographic



formations like the picture in the image above. These are not singular mountains but entire geographical areas. Yellowstone National Park in Wyoming is another caldera that has blown about a hundred times in the last 16 million years.

**Supervolcanoes** represent the most dangerous type of volcano. An eruption from a supervolcano could change life on Earth as we know it for many years. Supervolcanoes were not even accepted in volcanology until this millennium. Many supervolcano eruptions are thought to have occurred, the most recent in New Zealand less than 2000 years ago. That explosion was thought to have ejected about 100 cubic kilometers of material. A supervolcano eruption near what is now Colorado was thought to have let loose over 5,000 cubic kilometers of material millions of years ago. In comparison, the Mt. Saint Helens eruption ejected about 1 cubic kilometer of material.

The eruptions from supervolcanoes can be so large that the ash ejected into the air blocks the Sun and lowers the temperature on the entire planet. The lowered temperatures caused by these eruptions is called a volcanic winter. A supervolcano eruption at Lake Toba in northern Sumatra may have annihilated about 60% of the world's human population about 75,000 years ago. One can only imagine how such a huge eruption would change the world in modern times.

The largest supervolcano in North America is Yellowstone, which had three super eruptions at 2.1 million, 1.3 million and 640,000 years ago, and much more recent smaller (but still enormous) eruptions. Long Valley caldera, south of Mono Lake in California, is the second largest supervolcano in North America, erupting extremely hot and explosive rhyolite around 700,000 years ago. An earthquake swarm in 1980 alerted geologists to the possibility of another eruption in the future, but the timing of such an event is unknown.

Supervolcanoes are a fairly new idea so the exact cause of supervolcano eruptions is still debated. However, scientists believe that an entire and very large magma chamber erupts in a catastrophic explosion. This enormous eruption creates a huge hole or caldera where the surface area collapses.

**Minor Assessment:**

**Rank each of the four types of volcanoes from most dangerous to least dangerous as best you can, explaining your reasoning. Note at least one feature of each type of volcano that distinguishes it from each other type. (4-6 sentences)**

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