Earth Systems - Volcanoes

A volcano is a weak spot in the crust where molten material, or magma, comes to the surface. **Magma** is a molten mixture of rock-forming substances, gases and water from the mantle. When magma reaches the surface, it is called **lava**. After lava has cooled, it forms solid rock. Lava released during volcanic activity builds up Earth's surface.

Volcanoes and Plate boundaries

There are about 600 active volcanoes on land. Many more lie beneath the sea, where it is difficult for scientists to observe and map them. Volcanoes occur in belts that extend across continents and oceans. One major volcano belt is the **Ring of Fire**, formed by the many volcanoes that rim the Pacific Ocean.

Volcanic belts form along the boundaries of Earth's plates. At plate boundaries, huge pieces of the crust diverge (pull apart) or converge (push together). As a result, the crust often fractures, allowing magma to reach the surface. Most volcanoes form along diverging plate boundaries such as mid-ocean ridges and along converging plate boundaries where subduction takes place.

Diverging Boundaries

Volcanoes form along the mid-ocean ridges, which mark diverging plate boundaries. Ridges are long, underwater mountain ranges that sometimes have a rift valley down their center. Along the rift valley, lava pours out of cracks in the ocean floor, gradually building new mountains. Volcanoes also form along diverging plate boundaries on land.

Converging Boundaries

Many volcanoes form near converging plate boundaries where oceanic plates return to the mantle. Volcanoes may form where two oceanic plates collide or where an oceanic plate collides with a continental plate.

Many volcanoes occur near boundaries where two oceanic plates collide. Through subduction, the older, denser plate sinks beneath a deep-ocean trench into the mantle. Some of the rock above the subducting plate melts and forms magma. Because the magma is less dense than the surrounding rock, it rises toward the surface. Eventually, the magma breaks through the ocean floor, creating volcanoes.

The resulting volcanoes create a string of islands called an **island arc.** The curve of an island arch echoes the curve of its deep-ocean trench. Major island arcs include Japan, New Zealand, Indonesia, the Philippines, the Aleutians, and the Caribbean islands.

Volcanoes also occur where an oceanic plate is subducted beneath a continental plate. Collisions between oceanic and continental plates produced both the volcanoes of the Andes Mountains on the west coast of South America and the volcanoes of the Pacific Northwest in the United States.

Hot Spot Volcanoes

Some volcanoes result from "hot spots" in Earth's mantle. A hot spot is an area where material from deep within the mantle rises and then melts, forming magma. **A volcano forms above a hot spot when magma erupts through the crust and reaches the surface.** Some hot spot volcanoes lie in the middle of plates far from any plate boundaries. Other hot spots occur on or near plate boundaries.

A hot spot in the ocean floor can gradually form a series of volcanic mountains. For example, the Hawaiian Islands formed one by one over millions of years as the Pacific plate drifted over a hot spot. Hot spots can also form under the continents. Yellowstone National Park in Wyoming marks a hot spot under the North American plate.

Properties of Magma

Measured from the bottom of the Pacific Ocean, the Big Island of Hawaii is the largest mountain on Earth. The island is made up of massive volcanoes. One of these volcanoes, Mount Kilauea erupts frequently and produces huge amounts of lava.

At a temperature of around 1,000°C, lava from Mount Kilauea is very dangerous. Yet most of the time, the lava moves slower than a person can walk -- about 1 kilometer per hour. Some types of lava move much more slowly -- less than the length of a football field in an entire day. How fast lava flows depends on the properties of the magma from which it formed.

Physical and Chemical Properties

Like all substances, magma and lava are made up of elements and compounds. An **element** is a substance that cannot be broken down into other substances. Carbon, hydrogen, and oxygen are examples of elements. A **compound** is a substance made of two or more elements that have been chemically combined. Water, carbon dioxide, and table salt are familiar compounds. **Each substance has a particular set of physical and chemical properties. These properties can be used to identify a substance or to predict how it will behave.**

Physical Properties

A Physical property is any characteristic of a substance that can be observed or measured without changing the composition of the substance. Examples of physical properties include density, hardness, melting point, boiling point, and whether a substance is magnetic. A substance always has the same physical properties under particular conditions. Under normal conditions at sea level, for example, water's freezing point is 0° C and its boiling point is 100° C. Between its freezing and boiling points, water is a liquid.

Chemical Properties

A Chemical property is any property that produces a change in the composition of matter. Examples of chemical properties include a substance's ability to burn and its ability to combine, or react, with other substances. You can often tell that one substance has reacted with another if it changes color, produces a gas, or forms a new, solid substance.

What is Viscosity?

When you pour yourself a glass of milk, you are making use of a familiar physical property of liquids. Because particles in a liquid are free to move around one another, a liquid can flow from place to place. The physical property of liquids called **viscosity** is the resistance of a liquid to flowing. **Because liquids differ in viscosity, some liquids flow more easily than others.**

The greater the viscosity of a liquid, the slower it flows. For example, syrup is thick, sticky, with high viscosity. Syrup flows slowly. The lower the viscosity, the more easily a liquid flows. Water, rubbing alcohol, and vinegar are thin, runny liquids that have relatively low viscosities.

Why do different liquids have different viscosities? The answer lies in the movement of the particles that make up each type of liquid. In some liquids, there is a greater degree of friction among the liquid's particles. These liquids have higher viscosity.

Viscosity of Magma

At the extremely high temperatures and pressures inside Earth, mantle rock sometimes melts to form magma. Surprisingly, the properties of magma can vary. For example, not all types of magma have the same viscosity. **The viscosity of magma depends upon its silica content and temperature.**

Silica Content

Magma is a complex mixture, but its major ingredient is silica. The compound **silica** is made up of particles of the elements oxygen and silicon. Silica is one of the most abundant materials in Earth's crust. The silica content of magma ranges from about 50 percent to 70 percent.

The amount of silica in magma helps to determine its viscosity. The more silica magma contains, the higher its viscosity. Magma that is high in silica produces light-colored lava that is too sticky to flow very far. When this type of lava cools, it forms a rock rhyolite, which has the same composition as granite.

The less silica magma contains, the lower its viscosity. Low-silica magma flows readily and produces dark-colored lava. When this kind of lava cools, it forms rocks like basalt.

Temperature
How does temperature affect viscosity? Viscosity increases as temperature decreases. On a hot day, honey pours easily. But if you put the honey in the refrigerator, its viscosity increases. The cold honey flows very slowly.

The temperature of magma and lava can range from about 750° C to 1,175° C. The hotter the magma is, the lower its viscosity and the more rapidly it flows. Cooler types of magma have high viscosity and flow very slowly.

Temperature differences produce different types of lava. The lava is called **Pahoehoe** (pah HOH ee hoh ee) **and aa** (Ah ah). Pahoehoe is fast-moving, hot lava that has low viscosity. The surface of a lava flow formed from pahoehoe looks like a solid mass of wrinkles, billows, and rope like coils. Lava that is cooler and slower-moving is called **aa.** Aa has higher viscosity than pahoehoe. When aa hardens, it forms a rough surface consisting of jagged lava chunks.

Volcanic Eruptions
Magma Reaches Earth's Surface
A volcano is more than a large, cone-shaped mountain. Inside a volcano is a system of passageways through which magma moves.

Inside a Volcano
All volcanoes have a pocket of magma beneath the surface and one or more cracks through which the magma forces its way. Beneath a volcano, magma collects in a pocket called a **magma chamber.** The magma moves upward through a **pipe** a long tube in the ground that connects the magma chamber to Earth's surface.

Molten rock and gas leave the volcano through an opening called a **vent**. Often, there is one central vent at the top of a volcano. However, many volcanoes also have other vents that open on the volcano's sides. A **lava flow** is the area covered by lava as it pours out of a vent. A **crater** is a bowl-shaped area that may form at the top of a volcano around the central vent.

A Volcanic Eruption
What pushes magma to the surface? The explosion of a volcano is similar to the soda water bubbling out of a warm bottle of soda pop. You cannot see the carbon dioxide gas in a bottle of pop because it is dissolved in the liquid. But when you open the bottle, the pressure is released. The carbon dioxide expands and forms bubbles, which rush to the surface. Like the carbon dioxide in pop, dissolved gases are trapped in magma. These dissolved gases are under tremendous pressure.

As magma rises toward the surface, the pressure of the surrounding rock on the magma decreases. The dissolved gases begin to expand, forming bubbles. As pressure falls within the magma, the size of the gas bubbles increases greatly. These expanding gases exert an enormous force. **When a**

volcano erupts, the force of the expanding gases pushes magma from the magma chamber through the pipe until it flows or explodes out of the vent. Once magma escapes from the volcano and becomes lava, the remaining gases bubble out.

Kinds of Volcanic Eruptions

Some volcanic eruptions occur gradually. Others are dramatic explosions. **Geologists classify volcanic eruptions as quiet or explosive.** The physical properties of its magma determine how a volcano erupts. Whether an eruption is quiet or explosive depends on the magma's silica content and viscosity.

Quiet Eruptions

A volcano erupts quietly if its magma is low in silica. Low-silica magma has low viscosity and flows easily. The gases in the magma bubble out gently. Lava with low viscosity oozes quietly from the vent and can flow for many kilometers. Quiet eruptions can produce both panhoehoe and aa.

The Hawaiian Islands were formed from quiet eruptions. On the Big Island of Hawaii, lava pours out of the crater near the top of Mount Kilauea, but also flows out of long cracks on the volcanoes sides. Quiet eruptions have built up the Big Island over hundreds of thousands of years.

Explosive Eruptions

A volcano erupts explosively if its magma is high in silica. High-silica magma has high viscosity, making it thick and sticky. The high-viscosity magma does not flow out of the crater. Instead, it builds up in the volcano's pipe, plugging it like a cork in a bottle. Dissolved gases, including water vapor, cannot escape from the thick magma. The trapped gases build up pressure until they explode. The erupting gases and steam push the magma out of the volcano with incredible force. That's what happened during the eruption of Mount St. Helen's.

An explosive eruption breaks lava into fragments that quickly cool and harden into pieces of different sizes. The smallest pieces are volcanic ash -- fine, rocky particles as small as a grain of sand. Pebble-sized particles are called cinders. Larger pieces, called bombs, may range from the size of a baseball to the size of a car. A **pyroclastic flow** occurs when an explosive eruption hurls out of a mixture of hot gases, ash, cinders, and bombs.

Pumice and obsidian form from high-silica lava. Obsidian forms when lava cools very quickly, giving it a smooth, glossy surface like glass. Pumice forms when gas bubbles are trapped in fast-cooling lava, leaving spaces in the rock.

Volcano Hazards

Although quiet eruptions and explosive eruptions produce different hazards, both types of eruption can cause damage far from the crater's rim.

During a quiet eruption, lava flows from vents, setting fire to, and then burying, everything in its path. A quiet eruption can cover large areas with a thick layer of lava.

During an explosive eruption, a volcano can belch out hot clouds of deadly gases as well as ash, cinders, and bombs. Volcanic ash can bury entire towns. If it becomes wet, the heavy ash can cause roofs to collapse. If a jet plane sucks ash into its engine, the engine may stall. Eruptions can cause landslides and avalanches of mud, melted snow, and rock.

States of Volcanic Activity

The activity of a volcano may last from less than a decade to more than 10 million years. Most long-lived volcanoes do not erupt continuously. Geologists try to determine a volcano's past and whether the volcano will erupt again.

Life Cycle of a Volcano

Geologists often use the terms active, dormant, or extinct to describe a volcano's stage of activity. An active, or live, volcano is one that is erupting or has shown signs that it may erupt in the near future. A dormant, or sleeping volcano is like a sleeping bear. Scientists expect a **dormant** volcano to awaken in the future and become active. An **extinct** or dead volcano is unlikely to erupt again.

The time between volcanic eruptions may span hundreds to many thousands of years. People living near a dormant volcano may be unaware of the danger. But a dormant volcano can become active at any time.

Monitoring Volcanoes

Geologists have been somewhat more successful in predicting volcanic eruptions than in predicting earthquakes. Geologists use instruments to detect changes in and around volcano that may give warning a short time before the volcano erupts. These changes help geologists predict that an eruption is about to occur. But geologists cannot be certain about the type of eruption or how powerful it will be.

Geologists use tiltmeters and other instruments to detect slight surface changes in elevation and tilt caused by magma moving underground. They monitor any gases escaping from the volcano. A temperature increase in underground water may be a sign that magma is nearing the surface. Geologists also monitor the many small earthquakes that occur around a volcano before an eruption. The upward movement of magma triggers these quakes.

Volcanic Land forms

Volcanoes have created some of Earth's most spectacular land-forms. The perfect cone of Mount Fuji in Japan and the majestic profile of snowcapped Mount Kilimanjaro rising above the grasslands of East Africa are famous around the world.

For much of Earth's history, volcanic activity on and beneath the surface has built up Earth's land areas and 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 the buildup of magma beneath the surface.

Landforms From Lava and Ash

Volcanic eruptions create landforms made of lava, ash and other materials. These landforms include shield volcanoes, cinder cone volcanoes, composite volcanoes, and lava plateaus. Another landform results from the collapse of a volcanic mountain

Shield Volcanoes

At some places on Earth's surface, thin layers of lava pour out of a vent and harden on top of previous layers. Such lava flows gradually build a wide, gently sloping mountain called a **shield volcano.** Shield volcanoes rising from a hot spot on the ocean floor created the Hawaiian Islands.

Cinder Cone Volcanoes

If a volcano's lava has high viscosity, it may produce ash, cinders, and bombs. These materials build up around the vent in a steep, cone-shaped hill or small mountain called a **cinder cone.**

Composite Volcanoes

Sometimes, lava flows alternate with explosive eruptions of ash, cinder, and bombs. The result is a composite volcano. **Composite volcanoes** are tall, cone-shaped mountains in which layers of lava alternate with layers of ash. Examples of composite volcanoes include Mount Fuji in Japan and Mount St. Helen's in Washington State.

Lava Plateaus

Instead of forming mountains, some eruptions of lava form high, level areas called lava plateaus. First, lava flows out of several long cracks in an area. The thin, runny lava travels far before cooling and solidifying. Again and again, floods of lava flow on top of earlier floods. After millions of years, these layers of lava can form high plateaus. One example is the Columbia Plateau, which covers parts of the states of Washington, Oregon, and Idaho.

Calderas

The huge hole left by the collapse of a volcanic mountain is called a **caldera**. The hole is filled with the pieces of the volcano that have fallen inward, as well as some lava and ash.

How does a caldera form? Enormous eruptions may empty the main vent and the magma chamber beneath a volcano. The mountain becomes a hollow shell. With nothing to support it, the top of the mountain collapses inward, forming a caldera.

Crater Lake in Oregon formed this way about 7,700 years ago when a huge explosive eruption partly emptied the magma chamber of a volcano called Mount Mazama. When the volcano exploded, the top of the mountain was blasted into the atmosphere. The caldera that formed eventually filled with water from rain and snow. Wizard Island in Crater Lake is a small cinder cone that formed during a later eruption inside the caldera.

Soils From Lava and Ash

Why would anyone live near an active volcano? People often settle close to volcanoes to take advantage of the fertile volcanic soil. The lava, ash and cinders that erupt from a volcano are initially barren. Over time, the hard surface of the lava breaks down to form soil. When volcanic ash breaks down, it releases potassium, phosphorus, and other substances that plants need. As soil develops, plants are able to grow. Some volcanic solids are among the richest soils in the world. Saying that soil is rich means that it's fertile, or able to support plant growth.

Geothermal Activity

The word *geothermal* comes from the Greek *geo* meaning "Earth" and *therme* meaning "heat." In **geothermal activity,** magma a few kilometers beneath Earth's surface heats underground water. A variety of geothermal features occur in volcanic areas. **Hot springs and geysers are types of geothermal activity that are often found in areas of present or past volcanic activity.**

Hot Springs

A hot spring forms when groundwater heated by a nearby body of magma rises to the surface and collects in a natural pool. (Groundwater is water that has seeped into the spaces among rocks deep beneath Earth's surface.) Water from hot springs may contain dissolved gasses and other substances from deep within Earth

Geysers

Sometimes, rising hot water and steam become trapped underground in a narrow crack. Pressure builds until the mixture suddenly sprays above the surface as a geyser. A **geyser** is a fountain of water and steam that erupts from the ground.

Geothermal Energy

In some volcanic areas, water heated by magma can provide an energy source called geothermal energy. The people of Reykjavik, Iceland, pipe this hot water into homes for warmth. Geothermal energy can also be used as a source of electricity. Steam from underground is piped into turbines. Inside a turbine, the steam spins a wheel in the same way that blowing on a pinwheel makes the pinwheel turn. The moving wheel in the turbine turns a generator that changes the energy of motion into electrical energy. Geothermal energy provides some electrical power in California and New Zealand.