Geologic structures

Geologic structures are **usually the result of the powerful tectonic forces that occur within the earth**. These forces fold and break rocks, form deep faults, and build mountains.

Structural geologists are concerned with features resulting from deformation. These include**fractures, faults, folds, boudins, shear zones, cleavages (also knows as schistosities), foliations and lineations**.

The primary goal of structural geology is to use measurements of present-day rock geometries to uncover information about the history of deformation (strain) in the rocks, and ultimately, to understand the stress field that resulted in the observed strain and geometries.

Structural Geology is **the branch of geology dealing with the structure and distribution of the rocks that make up the crust of the earth**. It is the study of permanent deformations and rock failure created due to the changes in stress through geologic time.

Folds

fold, in geology, undulation or waves in the stratified rocks of Earth's crust. Stratified rocks were originally formed from sediments that were deposited in flat horizontal sheets, but in a number of places the strata are no longer horizontal but have been warped. Sometimes the warping is so gentle that the inclination of the strata is barely perceptible, or the warping may be so pronounced that the strata of the two flanks may be essentially parallel or lie nearly flat (as in the case of a recumbent fold). Folds vary widely in size; some are several kilometres or even hundreds of kilometres across, and others measure just a few centimetres or less. The tops of large folds are commonly eroded away on Earth's surface, exposing the cross sections of the inclined strata (*see also* erosion).

Folds are generally classified according to the attitude of their axes and their appearance in cross sections perpendicular to the trend of the fold. The axial plane of a fold is the plane or surface that divides the fold as symmetrically as possible. The axial plane may be vertical, horizontal, or inclined at any intermediate angle. An axis of a fold is the intersection of the axial plane with one of the strata of which the fold is composed. Although in the simpler types of folds the axis is horizontal or gently inclined, it may be steeply inclined or even vertical. The angle of inclination of the axis, as measured from the horizontal, is called the plunge. The portions of the fold between adjacent axes form the flanks, limbs, or slopes of a fold.

fold types

Three forms of folds: syncline, anticline, and monocline.

folding

Folds, progressively decreasing from left to right in the inclination of the axial plane

An anticline is a fold that is convex upward, and a syncline is a fold that is concave upward. An anticlinorium is a large anticline on which minor folds are superimposed, and a synclinorium is a large syncline on which minor folds are superimposed. Asymmetrical fold is one in which the axial plane is vertical. An asymmetrical fold is one in which the axial plane is inclined. An overturned fold, or overfold, has the axial plane inclined to such an extent that the strata on one limb are overturned. Arecumbent fold has an essentially horizontal axial plane. When the two limbs of a fold are essentially parallel to each other and thus approximately parallel to the axial plane, the fold is called isoclinal.

Many folds are distinctly linear; that is, their extent parallel to the axis is many times their width. Some folds, however, are not linear but are more or less circular in plan. A dome is such a fold that is convex upward; this means that its strata dip outward from a central area. A basin is a circular fold that is concave upward—i.e., the stratadip inward toward a central area.

The long linear folds that are characteristic of mountainous regions are believed to have resulted from compressional forces acting parallel to the surface of Earth and at right angles to the fold (*see also* mountain). Some geologists believe that many folds are the result of strata sliding from a vertically uplifted area under the influence ofgravity. The push exerted by an advancing glacier also may throw weakly consolidated rocks into folds, and the compaction of sedimentary rocks over buried hills gives rise to gentle folds. In nature, folds are rarely produced by a single process but by a combination of processes.

What is a Fold in Geology?

A **fold geology** is a wave-like structure created when rocks bend instead of a break during deformation. On the surface geographically, a fold may be depicted by a mountain or a valley, depending on the type of fold. In outcrops on the surface, folds will be identified by layers, or beds, of the same rock running parallel to each other in map view but dipping, or tilting, in opposite directions

Causes of Rock Folding

Folds are caused by deformation in the earth's layers. Rocks must be ductile and behave plastically to bend rather than break. Ductile means to be able to deform or change shape without losing toughness or breaking. The opposite of ductile is brittle, where the material cannot deform without breaking.

Ductile behavior is caused by the conditions of the rock or material, such as pressure and temperature. The rock will experience a large amount of **compressional stress** or pressure and gradually bend over time. Compressional stress is squeezing stress applied to a given surface, such as in a vise.

The stress can be caused by:

- A rock horizon or bedding surfaces where there is a distinct change in lithology.
- Faults or breaks in the earth's surface along which the rock layers can move.
- Intrusive igneous rocks, or input of hot molten rock material from depth.
- Pressure-related flow where a stronger layer intrudes into softer rocks, which fold around the stronger layer.

Linear Types of Folds

The most common types of folds are considered to be **linear**folds. Linear folds are folds with one main horizontal axis around which the rocks have deformed. Types of linear folds include anticlines, synclines, antiforms, synforms, and monoclines.

Anticline Folds

Anticlines are arch-like linear folds that are typically convex up with the oldest beds at the core. In the field, anticlines are often identified by parallel beds of the same age rock dipping away from the center axis or hinge. By moving towards the hinge, the steepness of the dipping rocks decreases, locating the maximum curvature at the hinge.

Anticlines are typically caused by thrust faulting. A thrust fault is a type of reverse fault where the rocks above the inclined fault plane move upwards relative to the rocks below the fault plane. A thrust fault is defined when the angle of the plane is less than 45 degrees.

Syncline Folds

Synclines are linear folds that are typically convex down with the youngest beds at the core. These folds are identified by parallel beds of the same age rock dipping towards the center axis or hinge. Synclines often form valleys on the surface of the Earth.

An image of a typical syncline found near Barstow, California.

Synclines are primarily formed by mountain building deformation in the Earth's crust. Often synclines and anticlines are formed in a sequence during this type of deformation event.

Antiform and Synform folded rocks

Antiform and **Synform** folded rocks are related to anticline and syncline folds.

Antiform can be used to define any fold that is convex upward like an anticline is. However, in an antiform, the rock near the center may not be the oldest as in an anticline. Sometimes, synclines have been overturned through continued deformation and thus are antiforms.

Synforms are the opposite. They are any folds that are concave upward, like a syncline. Similar to antiforms, they do not need the younger rock layers closer to the center hinge. Overturned anticlines would be considered synforms.

Monocline Folds

Monoclines are step-like folds in rock layers. They typically have a zone with more steeply dipping rocks, gently-dipping, or even horizontal rock layers. Monoclines are often formed by localized deformation or warping in horizontal rock layers. This is most often caused by movement on a fault in the rock layers underlying the monocline.

Other types of folds

There are several other types of folds. Some of these classifications include linear folds, but they are not considered linear folds by definition.

These types of folds include:

- Asymmetrical and Symmetrical Folds
- Isoclinal Folds
- Overturned and Recumbents Folds
- Domes and Basins
- Chevron Folded Rocks
- Ptygmatic and Disharmonic Folded Rocks
- Parasitic Folded Rocks
- Plunging Folds

Asymmetrical and Symmetrical Folds

Asymmetrical and **symmetrical** folds are defined by the angle of their center axis or hinge. Therefore, all fold types can be considered to be symmetrical or asymmetrical, including linear folds such as anticlines and synclines.

An asymmetrical fold is one where the angle of the axis is inclined. These folds typically do not have the same dip angles for each rock limb. In contrast, a symmetrical fold has a vertical center axis, which is straight up and down. These folds have the same dip angles for each rock limb.

Isoclinal Folds

An **isoclinal fold** is a type of symmetrical fold. "Iso-" implies same, and "-cline" means angle, so isocline is, by definition, a fold with the same angle. Isoclinal folds typically come in sets, with each hinge or axis will have the same central axis angle as the others. These folds are aligned and parallel to one another.

Overturned and Recumbent Folds

As mentioned when discussing antiforms and synforms, some folds may overturn through continuous deformation. These are**overturned folds**, where the entire fold has rotated over a complete 180 degrees from its original orientation.

Frequently Asked Questions

What are the 3 main types of folds?

The three main types of folds are anticlines, synclines, and monoclines.

- Anticlines are arch-like folds where the oldest rock layers are found in the center.
- Synclines are the opposite of anticlines and are concave up, with the youngest rock layers found in the center.
- Monoclines are folds where one limb of the fold is practically horizontal, while the other limb is steeply dipping.

What are the types of fold?

Folds are geological features created by the deformation of rock due to compressive stress. Types of folds include anticlines, synclines, monoclines, domes, basins, and overturned, recumbent, ptygmatic, disharmonic, chevron, parasitic, and plunging folds.

Classification Of Folds

Anticlines are defined as tho se folds in which
the strata are uparch ed, that is, these become CONVEX UPWARDS ;

the geologically olde r rocks occupy a position in the interior of the fold, oldest being positioned at th e core of the fold and the youngest forming the outermost flank,

the limbs dip away from each other at the crest in the simplest cases.

Synclines
the strata are downar ched, that is, these become CONVEX DOWNWARDS;

the geologically younger rocks occupy a position in the core of th e fold and the older rocks form the outer flanks, provided the normal order of superposition is not d isturbed,
in the simplest cases in synclines, the limbs dip towards a common c enter.

Position of Axial Plane

Depending upon the nature a nd direction of the stresses the axial plane in a r esulting fold may acquire any position in space, that is, it may be vertical, inclined or eve n horizontal. Following main types are re cognized on the basis of position of the axial plane in the resulting fold:

Symmetrical Folds

� These are also called normal or upright folds. In such a fold, the axia l plane is essentially vertical.

� The limbs are equal i n length and dip equally in opposite directions.

it may be an anticline or syncline and when classified, may be described as symmetrical anticline / syncline as the case may be.

Asymmetrical Folds

All those folds, anticlines or synclines, in which the limbs are unequ al in length and these dip uneq ually on ether side from the hinge line are termed as asymmetrical folds.

Overturned folds

� These are folds with inclined axial planes in which both the limbs are dipping essentially in the same general direction.

� The amount of dip of the two limbs may or may not be the same.

� Overfolding indicates very severe degree of folding.

� One of the two limbs (the reversed limb) comes to occupy the present position after having suffered a rotation through more than 90 degrees.

The other limb is known as the normal limb.

� In certain cases, both the limbs of a fold may get overturned because of very high lateral compression.

� It may be originally either an anticline or a syncline but the extreme compression from opposite sides results in bringing the limbs so close to each other that the usual dip conditions may get reversed -anticlinal limbs dip towards each other and the synclinal limbs dip away from each other.

� Such a type of fold is commonly referred to as a fan fold

� In such folds, the anticlinal tops are said to have opened up into a broad, fan-shaped outline due to intense compression in the lower region.

Isoclinal Folds

� These are group of folds in which all the axial planes are essentially parallel, meaning. that all the component limbs are dipping at equal amounts.

� They may be made up of series of anticlines and synclines

Recumbent Folds

� These may be described as extreme types of overturned folds in which the axial plane acquires an almost horizontal attitude.

� In such folds, one limb comes to lie exactly under the other limb so that a drill hole dug at the surface in the upper limb passes through the lower limb also.

� The lower limb is often called the inverted limb or the reversed limb.

� Other parts of a recumbent fold are sometimes named as follows:

the arch, which is zone of curvature corresponding to crest and trough in the upright folds;
the shell, which is the outer zone made up mostly of sedimentary formations;

the core, which is the innermost part of the fold and maybe made mostly of crystalline igneous or metamorphic rocks;

the root or the root zone, which is the basal part of the fold and may or may not be easily traceable; once traced it can throw light whether the fold was originally an anticline or syncline that has suffered further inversion.

Conjugate Folds

In certain cases a pair of folds that are apparently related to each other may have mutually inclined axial planes.

Such folds are described as conjugate folds.

The individual folds themselves may be anticlinal or synchnal or their modifications.
Box Fold

It may be described as a special type of fold with exceptionally flattened top and steeply inclined limbs almost forming three sides of a rectangle.

� In both the anticlinorium and synclinorium, presence of large number of secondary folds, faults and fracture systems is a characteristic feature.

� Similar folding but signifying still larger bending and uplifting of strata on sub-continental scales is expressed by the terms GEANTICLINES AND GEOSYNCLINES respectively.

� Great importance is attached to the major depressions, the geosynclines, in the process of mountain building discussed elsewhere.

� The geosynclines are believed to serve as depositional fields or basins of sedimentation to which sediments derived by the erosion of the adjoining gentilities get accumulated and compacted.

� This material is then compressed and uplifted in the second stage of orogeny, to gradually take the shape of mountain systems.

Faults

fault, in geology, a planar or gently curvedfracture in the rocks of Earth's crust, where compressional or tensional forces cause relative displacement of the rocks on the opposite sides of the fracture. Faults range in length from a few centimetres to many hundreds of kilometres, and displacement likewise may range from less than a centimetre to several hundred kilometres along the fracture surface (the fault plane). In some instances, the movement is distributed over a fault zone composed of many individual faults that occupy a belt hundreds of metres wide. The geographic distribution of faults varies; some large areas have almost none, others are cut by innumerable faults.

Faults may be vertical, horizontal, or inclined at any angle. Although the angle of inclination of a specific fault plane tends to be relatively uniform, it may differ considerably along its length from place to place. When rocks slip past each other in faulting, the upper or overlying block along the fault plane is called the hanging wall, or headwall; the block below is called thefootwall. The fault strike is the direction of the line of intersection between the fault plane and Earth's surface. The dip of a fault plane is its angle of inclination measured from the horizontal.

Faults are classified according to their angle of dip and their relative displacement.Normal dip-slip faults are produced by vertical compression as Earth's crust lengthens. The hanging wall slides down relative to the footwall. Normal faults are common; they bound many of the mountain ranges of the world and many of the riftvalleys found along spreading margins of tectonic plates. Rift valleys are formed by the sliding of the hanging walls downward many thousands of metres, where they then become the valley floors.

types of faulting in tectonic earthquakes

In normal and reverse faulting, rock masses slip vertically past each other. In strike-slip faulting, the rocks slip past each other horizontally.

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A block that has dropped relatively downward between two normal faults dipping toward each other is called a graben. A block that has been relatively uplifted between two normal faults that dip away from each other is called a horst. A tilted block that lies between two normal faults dipping in the same direction is a tilted fault block.

Reverse dip-slip faults result from horizontal compressional forces caused by a shortening, or contraction, of Earth's crust. The hanging wall moves up and over the footwall. Thrust faults are reverse faults that dip less than 45°. Thrust faults with a very low angle of dip and a very large total displacement are called overthrusts or detachments; these are often found in intensely deformed mountain belts. Large thrust faults are characteristic of compressive tectonic plate boundaries, such as those that have created the Himalayas and the subduction zones along the west coastof South America.

Strike-slip (also called transcurrent, wrench, or lateral) faults are similarly caused by horizontal compression, but they release their energy by rock displacement in a horizontal direction almost parallel to the compressional force. The fault plane is essentially vertical, and the relative slip is lateral along the plane. These faults are widespread. Many are found at the boundary between obliquely converging oceanic and continental tectonic plates. Well-known terrestrial examples include the San Andreas Fault, which, during the San Francisco earthquake of 1906, had a maximum movement of 6 metres (20 feet), and the Anatolian Fault, which, during the İzmit earthquake of 1999, moved more than 2.5 metres (8.1 feet).

San Andreas Fault

At the San Andreas Fault in California, the North American Plate and the Pacific Plate slide past each other along a giant fracture in Earth's crust.

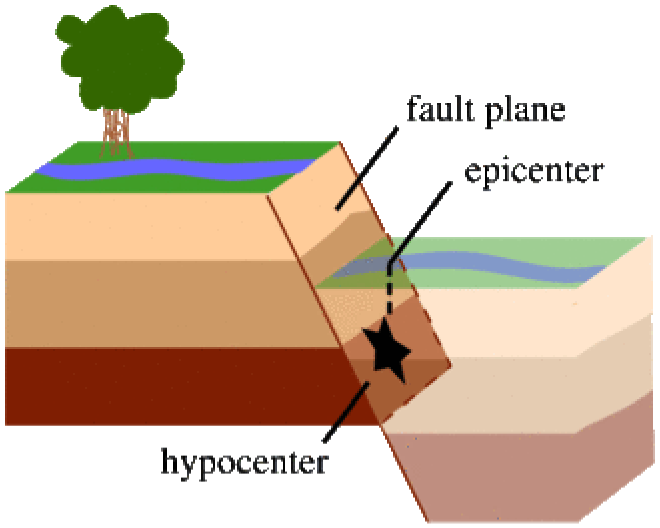
Oblique-slip faults have simultaneous displacement up or down the dip and along the strike. The displacement of the blocks on the opposite sides of the fault plane usually is measured in relation to sedimentary strata or other stratigraphic markers, such as veins and dikes. The movement along a fault may be rotational, with the offset blocks rotating relative to one another.

Fault slip may polish smooth the walls of the fault plane, marking them with striations called slickensides, or it may crush them to a fine-grained, claylike substance known as fault gouge; when the crushed rock is relatively coarse-grained, it is referred to as fault breccia. Occasionally, the beds adjacent to the fault plane foldor bend as they resist slippage because of friction. Areas of deep sedimentary rockcover often show no surface indications of the faulting below.

Movement of rock along a fault may occur as a continuous creep or as a series of spasmodic jumps of a few metres during a few seconds. Such jumps are separated by intervals during which stress builds up until it overcomes the frictional forces along the fault plane and causes another slip. Most, if not all, earthquakes are caused by rapid slip along faults.

Earthquake

What is an earthquake?



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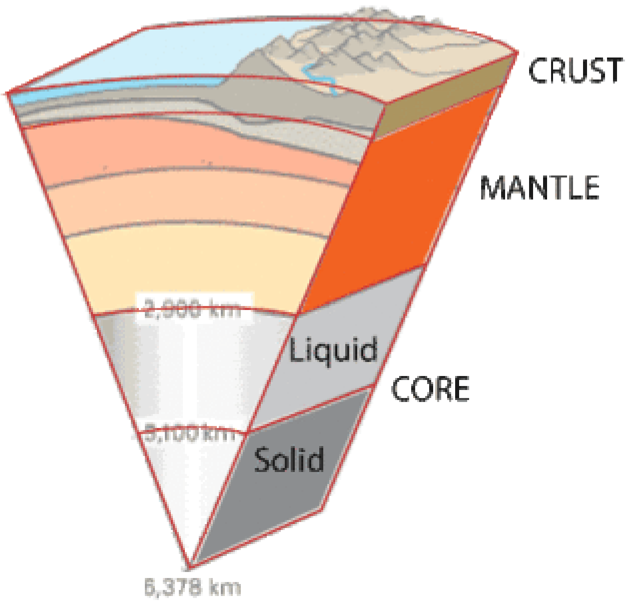
A normal (dip-slip) fault is an inclined fracture where the rock mass above an inclined fault moves down (Public domain.)

An **earthquake** is what happens when two blocks of the earth suddenly slip past one another. The surface where they slip is called the **fault** or **fault plane**. The location below the earth's surface where the earthquake starts is called the **hypocenter**, and the location directly above it on the surface of the earth is called the **epicenter**.

Sometimes an earthquake has **foreshocks**. These are smaller earthquakes that happen in the same place as the larger earthquake that follows. Scientists can't tell that an earthquake is a foreshock until the larger earthquake happens. The largest, main earthquake is called the **mainshock**. Mainshocks always have **aftershocks** that follow. These are smaller earthquakes that occur afterwards in the same place as the mainshock. Depending on the size of the mainshock, aftershocks can continue for weeks, months, and even years after the mainshock!

What causes earthquakes and where do they happen?



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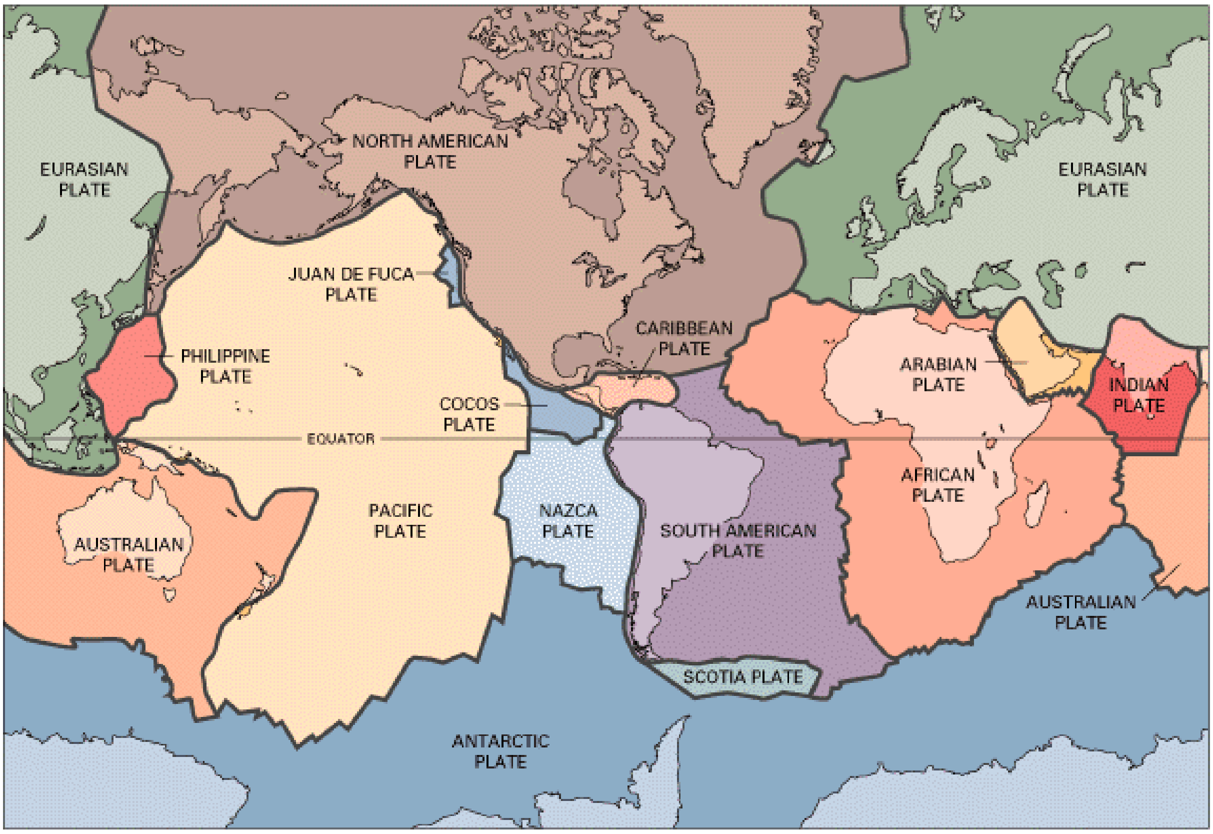
A simplified cartoon of the crust (brown), mantle (orange), and core (liquid in light gray, solid in dark gray) of the earth. (Public domain.)

The earth has four major layers: the inner core, outer core, mantle and crust. The crust and the top of the mantle make up a thin skin on the surface of our planet.

But this skin is not all in one piece – it is made up of many pieces like a puzzle covering the surface of the earth. Not only that, but these puzzle pieces keep slowly moving around, sliding past one another and bumping into each other. We call these puzzle pieces **tectonic plates**, and the edges of the plates are called the **plate boundaries**. The plate boundaries are made up of many faults, and most of the earthquakes around the world occur on these faults. Since the edges of the plates are rough, they get stuck while the rest of the plate keeps moving. Finally, when the plate has moved far enough, the edges unstick on one of the faults and there is an earthquake.



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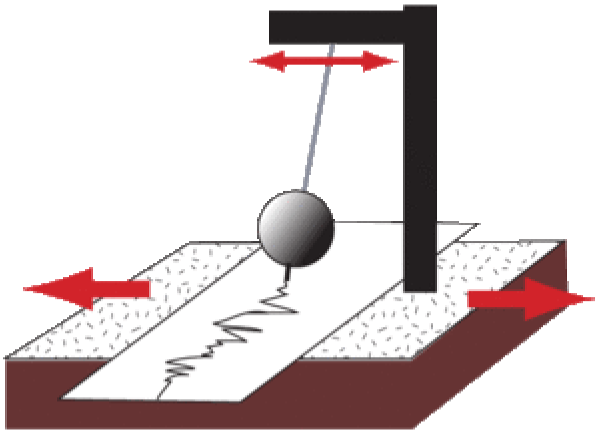
The tectonic plates divide the Earth's crust into distinct "plates" that are always slowly moving. Earthquakes are concentrated along these plate boundaries. (Public domain.)

Why does the earth shake when there is an earthquake?

While the edges of faults are stuck together, and the rest of the block is moving, the energy that would normally cause the blocks to slide past one another is being stored up. When the force of the moving blocks finally overcomes the **friction** of the jagged edges of the fault and it unsticks, all that stored up energy is released. The energy radiates outward from the fault in all directions in the form of **seismic waves** like ripples on a pond. The seismic waves shake the earth as they move through it, and when the waves reach the earth's surface, they shake the ground and anything on it, like our houses and us!

How are earthquakes recorded?



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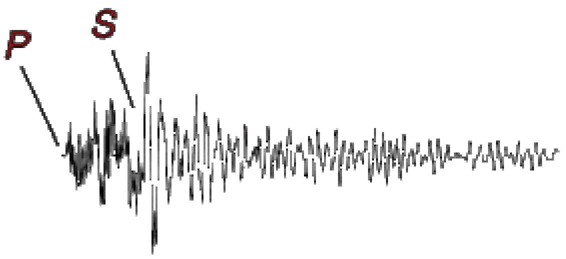
The cartoon sketch of the seismograph shows how the insrument shakes with the earth below it, but the recording device remains stationary (instead of the other way around). (Public domain.)

Earthquakes are recorded by instruments called **seismographs**. The recording they make is called a **seismogram**. The seismograph has a base that sets firmly in the ground, and a heavy weight that hangs free. When an earthquake causes the ground to shake, the base of the seismograph shakes too, but the hanging weight does not. Instead the spring or string that it is hanging from absorbs all the movement. The difference in position between the shaking part of the seismograph and the motionless part is what is recorded.

How do scientists measure the size of earthquakes?



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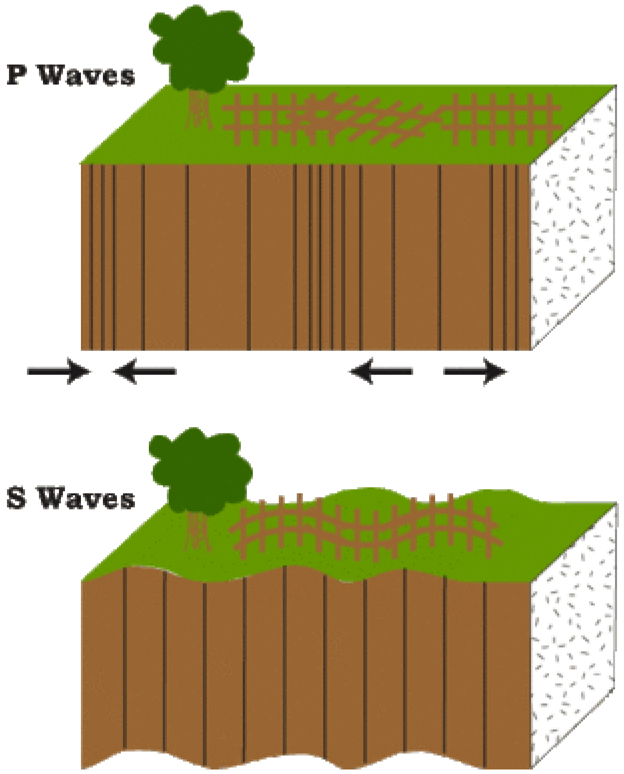
An example of a seismic wave with the P wave and S wave labeled. (Public domain.)

The size of an earthquake depends on the size of the fault and the amount of slip on the fault, but that's not something scientists can simply measure with a measuring tape since faults are many kilometers deep beneath the earth's surface. So how do they measure an earthquake? They use the **seismogram** recordings made on the **seismographs** at the surface of the earth to determine how large the earthquake was (figure 5). A short wiggly line that doesn't wiggle very much means a small earthquake, and a long wiggly line that wiggles a lot means a large earthquake. The length of the wiggle depends on the size of the fault, and the size of the wiggle depends on the amount of slip.

The size of the earthquake is called its **magnitude**. There is one magnitude for each earthquake. Scientists also talk about the*intensity* of shaking from an earthquake, and this varies depending on where you are during the earthquake.

How can scientists tell where the earthquake happened?

Seismograms come in handy for locating earthquakes too, and being able to see the **P wave** and the **S wave** is important. You learned how P & S waves each shake the ground in different ways as they travel through it. P waves are also faster than S waves, and this fact is what allows us to tell where an earthquake was. To understand how this works, let's compare P and S waves to lightning and thunder. Light travels faster than sound, so during a thunderstorm you will first see the lightning and then you will hear the thunder. If you are close to the lightning, the thunder will boom right after the lightning, but if you are far away from the lightning, you can count several seconds before you hear the thunder. The further you are from the storm, the longer it will take between the lightning and the thunder.



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P Waves alternately compress and stretch the crustal material parallel to the direction they are propagating. S Waves cause the crustal material to move back and forth perpendicular to the direction they are travelling. (Public domain.)

P waves are like the lightning, and S waves are like the thunder. The P waves travel faster and shake the ground where you are first. Then the S waves follow and shake the ground also. If you are close to the earthquake, the P and S wave will come one right after the other, but if you are far away, there will be more time between the two.

By looking at the amount of time between the P and S wave on a seismogram recorded on a seismograph, scientists can tell how far away the earthquake was from that location. However, they can't tell in what direction from the seismograph the earthquake was, only how far away it was. If they draw a circle on a map around the station where the **radius** of the circle is the determined distance to the earthquake, they know the earthquake lies somewhere on the circle. But where?

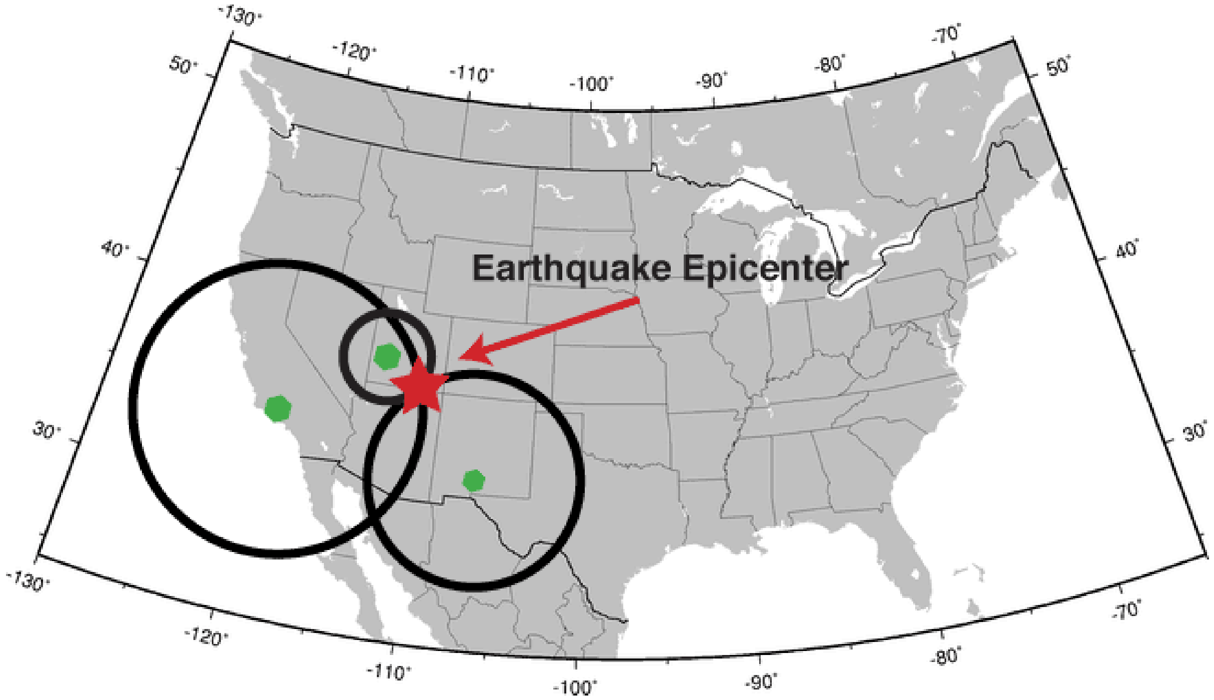
Scientists then use a method called **triangulation** to determine exactly where the earthquake was (see image below). It is called triangulation because a triangle has three sides, and it takes three seismographs to locate an earthquake. If you draw a circle on a map around three different seismographs where the **radius** of each is the distance from that station to the earthquake, the intersection of those three circles is the **epicenter**!

Can scientists predict earthquakes?

No, and it is unlikely they will ever be able to predict them. Scientists have tried many different ways of predicting earthquakes, but none have been successful. On any particular fault, scientists know there will be another earthquake sometime in the future, but they have no way of telling when it will happen.

Is there such a thing as earthquake weather? Can some animals or people tell when an earthquake is about to hit?

These are two questions that do not yet have definite answers. If weather does affect earthquake occurrence, or if some animals or people can tell when an earthquake is coming, we do not yet understand how it works.



Earthquake Epicenter
-130°
-120°
-110°
-100°
-90°
-80°
-70°
50°
40°
30°

Volcanic

A volcano is an opening in the earth's crust from which lava (consisting of magma), gases (sulfur dioxide, carbon dioxide, nitrogen, for example) and ashes are released during eruptions.

The study of volcanoes is volcanology or vulcanology. Volcanic activity is one of the manifestations of the internal activity of the Earth due to the energy stored within it (see "volcanism").

Volcanoes on Earth and in space

On Earth, there are about 600 active volcanoes on the continents, 1,300 if we add those of the seabed. The largest volcano in the solar system is Mount Olympus on Mars. Some volcanoes are considered extinct, others sleep and can see their activity resume.

We distinguish traditionally different types of volcanoes according to their form:

Hawaiian volcanoes (of Hawaii), very flat, from which escape, only by effusion, very fluid lava;

• Strombolian volcanoes (Stromboli, Italy), with pointed cones, formed by debris accumulation and lava flows;

• Vulcanian volcanoes (Vulcano, Italy) formed by explosive debris accumulation;

• Pelican volcanoes (from Mount Pelee in Martinique), with very viscous lava that tends to form needles by climbing through the cracks of previous extrusions. Their eruption under the effect of the thrust of the gases gives rise to the phenomenon of burning cloud, or ejection of melted dust;

• volcanoes formed by cracks.

The morphology of the volcanic apparatus (size and slope of the cone and the crater) results from the accumulation of materials emitted during the eruptions, and depends in particular on the properties of the lava, and the internal conditions of pressure, which can evolve during the activity of the volcano. Small variations in lava composition can result in very different properties, especially for viscosity. Volcanics can be explosive when the pressure exerted by the gases ejects fragments of magma more or less solidified with ash and slag.

Unreliable eruption forecasts

Volcanic activity is extremely difficult to predict; their study has only a few data available, because of the disproportion between the average duration between two eruptions and the human lifespan. The research focuses on the evaluation of deep reservoirs (about 10 km below the surface) that flow through various veins, fissures and conduits. The consequences of an explosion are related to the importance of magma reservoirs. Gas emissions and other warning signs of rising magma can be exploited by active volcano monitoring networks.

The study of outcrops of extinct and eroded volcanic systems also provides information on the mechanisms involved in the activity period.

The different types of volcanoes

Volcano eruptions

There are three types of volcanism:

- ♣ Effusive volcanism: It regularly rejects flows of fluid lava. The lava is at about 1200 ° C.

Effusive volcanism

- ♣ Explosive volcanism: it rejects a lava thick, viscous and does not flow, forming a "plug" on the crater. The eruption sprays the top of the volcano and unleashes destructive hot clouds. The lava is at about 300 ° C to 900 ° C.

Explosive volcanism

- ♣ There is also underwater volcanism that operates differently from continental terrestrial volcanoes. The lava coming to the surface cools immediately forming a sort of cushions called pillow lava. Marine volcanoes sometimes form islands, for example: the island of Reunion. The chimneys are very deep: up to 2 kilometers. Scientists say that there are 20000 volcanoes almost under the sea.

Volcano activity

Volcanoes can also be distinguished according to their activity.

- ♣ Active volcanoes: volcanoes are erupting.
- ♣ Sleeping volcanoes: they can wake up and erupt if gas accumulates too much.
- ♣ The extinct volcanoes: it's the volcanoes that are old and will never be erupted again.

The magma

The magma is formed by melting a rock between 150 and 50 km deep. Only one part of the rock melts giving droplets of liquid. Lighter than the rocks, the droplets slowly migrate upwards and gather to form, under the volcano, in depth, a magmatic chamber.

Once on the surface and released from its gases, the magma takes the name of lava

Famous volcanoes

On earth

- ♣ Vesuvius
- ♣ Etna
- ♣ Stromboli
- ♣ The Kilauea
- ♣ Mount St. Helens
- ♣ The Krakatoa
- ♣ Mount Fuji

- ♣ The Nevado ojos del salado

A **volcano** is a rupture in the crust of a planetary-mass object, such as Earth, that allows hot lava, volcanic ash, and gases to escape from a magma chamber below the surface.

On Earth, volcanoes are most often found where tectonic plates are diverging or converging, and most are found underwater. For example, a mid-ocean ridge, such as the Mid-Atlantic Ridge, has volcanoes caused by divergent tectonic plates whereas the Pacific Ring of Fire has volcanoes caused by convergent tectonic plates. Volcanoes can also form where there is stretching and thinning of the crust's plates, such as in the East African Rift and the Wells Gray-Clearwater volcanic field and Rio Grande rift in North America. Volcanism away from plate boundaries has been postulated to arise from upwelling diapirs from the core–mantle boundary, 3,000 kilometers (1,900 mi) deep in the Earth. This results in hotspot volcanism, of which the Hawaiian hotspot is an example. Volcanoes are usually not created where two tectonic plates slide past one another.

Large eruptions can affect atmospheric temperature as ash and droplets of sulfuric acid obscure the Sun and cool the Earth'stroposphere. Historically, large volcanic eruptions have been followed by volcanic winters which have caused catastrophic famines.

The word *volcano* is derived from the name of Vulcano, a volcanic island in the Aeolian Islands of Italy whose name in turn comes fromVulcan, the god of fire in Roman mythology.[1] The study of volcanoes is called volcanology, sometimes spelled *vulcanology*.[2]

Plate tectonics

Map showing the divergent plate boundaries (oceanic spreading ridges) and recent sub-aerial volcanoes (mostly at convergent boundaries)

According to the theory of plate tectonics, Earth's lithosphere, its rigid outer shell, is broken into sixteen larger and several smaller plates. These are in slow motion, due to convection in the underlying ductile mantle, and most volcanic activity on Earth takes place along plate boundaries, where plates are converging (and lithosphere is being destroyed) or are diverging (and new lithosphere is being created).[3]

Divergent plate boundaries

Main article: Divergent boundary

At the mid-ocean ridges, two tectonic plates diverge from one another as hot mantle rock creeps upwards beneath the thinned oceanic crust. The decrease of pressure in the rising mantle rock leads to adiabatic expansion and the partial melting of the rock, causing volcanism and creating new oceanic crust. Most divergent plate boundaries are at the bottom of the oceans, and so most volcanic activity on the Earth is submarine, forming new seafloor. Black smokers (also known as deep sea vents) are evidence of this kind of volcanic activity. Where the mid-oceanic ridge is above sea level, volcanic islands are formed, such as Iceland.[4]

Convergent plate boundaries

Main article: Convergent boundary

Subduction zones are places where two plates, usually an oceanic plate and a continental plate, collide. The oceanic plate subducts (dives beneath the continental plate), forming a deep ocean trench just offshore. In a process called flux melting, water released from the subducting plate lowers the melting temperature of the overlying mantle wedge, thus creating magma. This magma tends to be extremelyviscous because of its high silica content, so it often does not reach the surface but cools and solidifies at depth. When it does reach the surface, however, a volcano is formed. Thus subduction zones are bordered by chains of volcanoes called volcanic arcs. Typical examples are the volcanoes in the Pacific Ring of Fire, such as the Cascade Volcanoes or the Japanese Archipelago, or the Sunda Arc ofIndonesia.[5]

Hotspots

Main article: Hotspot (geology)

Hotspots are volcanic areas thought to be formed by mantle plumes, which are hypothesized to be columns of hot material rising from the core-mantle boundary. As with mid-ocean ridges, the rising mantle rock experiences decompression melting which generates large volumes of magma. Because tectonic plates move across mantle plumes, each volcano becomes inactive as it drifts off the plume, and new volcanoes are created where the plate advances over the plume. The Hawaiian Islands are thought to have been formed in such a manner, as has the Snake River Plain, with the Yellowstone Caldera being the part of the North American plate currently above theYellowstone hotspot.[6] However, the mantle plume hypothesis has been questioned.[7]

Continental rifting

Main article: Rift

Sustained upwelling of hot mantle rock can develop under the interior of a continent and lead to rifting. Early stages of rifting are characterized by flood basalts and may progress to the point where a tectonic plate is completely split.[8][9] A divergent plate boundary then develops between the two halves of the split plate. However, rifting often fails to completely split the continental lithosphere (such as in an aulacogen), and failed rifts are characterized by volcanoes that erupt unusual alkali lava or carbonatites. Examples include the volcanoes of the East African Rift.[10]

The most common perception of a volcano is of a conical mountain, spewing lava and poisonous gases from a crater at its summit; however, this describes just one of the many types of volcano. The features of volcanoes are much more complicated and their structure and behavior depends on a number of factors. Some volcanoes have rugged peaks formed by lava domes rather than a summit crater while others have landscape features such as massive plateaus. Vents that issue volcanic material (including lava and ash) and gases (mainly steam and magmatic gases) can develop anywhere on the landform and may give rise to smaller cones such as Puʻu ʻŌʻō on a flank of Hawaii's Kīlauea. Other types of volcano include cryovolcanoes (or ice volcanoes), particularly on some moons of Jupiter, Saturn, and Neptune; and mud volcanoes, which are formations often not associated with known magmatic activity. Active mud volcanoes tend to involve temperatures much lower than those of igneous volcanoes except when the mud volcano is actually a vent of an igneous volcano.

Fissure vents

Main article: Fissure vent

Volcanic fissure vents are flat, linear fractures through which lava emerges.

Shield volcanoes

Main article: Shield volcano

Shield volcanoes, so named for their broad, shield-like profiles, are formed by the eruption of low-viscosity lava that can flow a great distance from a vent. They generally do not explode catastrophically, but are characterized by relatively gentle effusive eruptions. Since low-viscosity magma is typically low in silica, shield volcanoes are more common in oceanic than continental settings. The Hawaiian volcanic chain is a series of shield cones, and they are common in Iceland, as well.

Lava domes

Main article: Lava dome

Lava domes are built by slow eruptions of highly viscous lava. They are sometimes formed within the crater of a previous volcanic eruption, as in the case of Mount St. Helens, but can also form independently, as in the case of Lassen Peak. Like stratovolcanoes, they can produce violent, explosive eruptions, but the lava generally does not flow far from the originating vent.

Cryptodomes

Cryptodomes are formed when viscous lava is forced upward causing the surface to bulge. The 1980 eruption of Mount St. Helens was an example; lava beneath the surface of the mountain created an upward bulge, which later collapsed down the north side of the mountain.

Cinder cones

Cinder cones result from eruptions of mostly small pieces of scoria and pyroclastics (both resemble cinders, hence the name of this volcano type) that build up around the vent. These can be relatively short-lived eruptions that produce a cone-shaped hill perhaps 30 to 400 meters (100 to 1,300 ft) high. Most cinder cones erupt only once. Cinder cones may form as flank vents on larger volcanoes, or occur on their own. Parícutin in Mexico and Sunset Crater in Arizona are examples of cinder cones. In New Mexico, Caja del Rio is a volcanic fieldof over 60 cinder cones.

Based on satellite images, it was suggested that cinder cones might occur on other terrestrial bodies in the Solar system too; on the surface of Mars and the Moon.

Stratovolcanoes (composite volcanoes

Stratovolcanoes (composite volcanoes) are tall conical mountains composed of lava flows and tephra in alternate layers, the strata that gives rise to the name. They are also known as composite volcanoes because they are created from multiple structures during different kinds of eruptions. Classic examples include Mount Fuji in Japan, Mayon Volcano in the Philippines, and Mount Vesuvius andStromboli in Italy.

Ash produced by the explosive eruption of stratovolcanoes has historically posed the greatest volcanic hazard to civilizations. The lavas of stratovolcanoes are higher in silica, and therefore much more viscous, than lavas from shield volcanoes. High-silica lavas also tend to contain more dissolved gas. The combination is deadly, promoting explosive eruptions that produce great quantities of ash, as well as pyroclastic surges like the one that destroyed the city of Saint-Pierre in Martinique in 1902. They are also steeper than shield volcanoes, with slopes of 30–35° compared to slopes of generally 5–10°, and their loose tephra are material for dangerous lahars.[15] Large pieces of tephra are called volcanic bombs. Big bombs can measure more than 4 feet(1.2 meters) across and weigh several tons.[16]

Supervolcanoes

A supervolcano is a volcano that has experienced one or more eruptions that produced over 1,000 cubic kilometers (240 cu mi) of volcanic deposits in a single explosive event.[17] Such eruptions occur when a very large magma chamber full of gas-rich, silicic magma is emptied in a catastrophic caldera-forming eruption. Ash flow tuffs emplaced by such eruptions are the only volcanic product with volumes rivaling those of flood basalts.[18]

A supervolcano can produce devastation on a continental scale. Such volcanoes are able to severely cool global temperatures for many years after the eruption due to the huge volumes of sulfur and ash released into the atmosphere. They are the most dangerous type of volcano. Examples include Yellowstone Caldera in Yellowstone National Park andValles Caldera in New Mexico (both western United States); Lake Taupō in New Zealand; Lake Toba in Sumatra, Indonesia; and Ngorongoro Crater in Tanzania. Fortunately, supervolcano eruptions are very rare events, though because of the enormous area they cover, and subsequent concealment under vegetation and glacial deposits, supervolcanoes can be difficult to identify in the geologic record without careful geologic mapping.[19]

Submarine volcanoes

Submarine volcanoes are common features of the ocean floor. Volcanic activity during the Holocene Epoch has been documented at only 119 submarine volcanoes. but there may be more than one million geologically young submarine volcanoes on the ocean floor.[20][21] In shallow water, active volcanoes disclose their presence by blasting steam and rocky debris high above the ocean's surface. In the deep ocean basins, the tremendous weight of the water prevents the explosive release of steam and gases; however, submarine eruptions can be detected by hydrophones and by the discoloration of water because of volcanic gases. Pillow lava is a common eruptive product of submarine volcanoes and is characterized by thick sequences of discontinuous pillow-shaped masses which form under water. Even large submarine eruptions may not disturb the ocean surface, due to the rapid cooling effect and increased buoyancy in water (as compared to air), which often causes volcanic vents to form steep pillars on the ocean floor. Hydrothermal vents are common near these volcanoes, and some support peculiar ecosystems based on chemotrophs feeding on dissolved minerals. Over time, the formations created by submarine volcanoes may become so large that they break the ocean surface as new islands or floating pumice rafts.

In May and June 2018, a multitude of seismic signals were detected by earthquake monitoring agencies all over the world. They took the form of unusual humming sounds, and some of the signals detected in November of that year had a duration of up to 20 minutes. Anoceanographic research campaign in May 2019 showed that the previously mysterious humming noises were caused by the formation of a submarine volcano off the coast ofMayotte.[22]

Subglacial volcanoes

Subglacial volcanoes develop underneath icecaps. They are made up of lava plateaus capping extensive pillow lavas and palagonite. These volcanoes are also called table mountains, tuyas,[23] or (in Iceland) mobergs.[24] Very good examples of this type of volcano can be seen in Iceland and in British Columbia. The origin of the term comes fromTuya Butte, which is one of the several tuyas in the area of the Tuya River and Tuya Range in northern British Columbia. Tuya Butte was the first such landform analyzed and so its name has entered the geological literature for this kind of volcanic formation.[25] The Tuya Mountains Provincial Park was recently established to protect this unusual landscape, which lies north of Tuya Lake and south of the Jennings River near the boundary with the Yukon Territory.

Mud volcanoes

Mud volcanoes (mud domes) are formations created by geo-excreted liquids and gases, although there are several processes which may cause such activity.[26] The largest structures are 10 kilometers in diameter and reach 700 meters high.[27]

The material that is expelled in a volcanic eruption can be classified into three types:

1. Volcanic gases, a mixture made mostly of steam, carbon dioxide, and a sulfur compound (either sulfur dioxide, SO_2, or hydrogen sulfide, H_2S, depending on the temperature)
2. Lava, the name of magma when it emerges and flows over the surface
3. Tephra, particles of solid material of all shapes and sizes ejected and thrown through the air[28][29]

Volcanic gases

Main article: Volcanic gas

The concentrations of different volcanic gases can vary considerably from one volcano to the next. Water vapor is typically the most abundant volcanic gas, followed by carbon dioxide[30] and sulfur dioxide. Other principal volcanic gases include hydrogen sulfide, hydrogen chloride, and hydrogen fluoride. A large number of minor and trace gases are also found in volcanic emissions, for example hydrogen,carbon monoxide, halocarbons, organic compounds, and volatile metal chlorides.

Lava flows

Composition

The form and style of eruption of a volcano is largely determined by the composition of the lava it erupts. The viscosity (how fluid the lava is) and the amount of dissolved gas are the most important characteristics of magma, and both are largely determined by the amount of silica in the magma. Magma rich in silica is much more viscous than silica-poor magma, and silica-rich magma also tends to contain more dissolved gases.

Lava can be broadly classified into four different compositions:[31]

- If the erupted magma contains a high percentage (>63%) of silica, the lava is described as *felsic*. Felsic lavas (dacites or rhyolites) are highly viscous and are erupted as domes or short, stubby flows.[32] Lassen Peak in California is an example of a volcano formed from felsic lava and is actually a large lava dome.[33]

  Because felsic magmas are so viscous, they tend to trap volatiles (gases) that are present, which leads to explosive volcanism.Pyroclastic flows (ignimbrites) are highly hazardous products of such volcanoes, since they hug the volcano's slopes and travel far from their vents during large eruptions. Temperatures as high as 850 °C (1,560 °F)[34] are known to occur in pyroclastic flows, which will incinerate everything flammable in their path, and thick layers of hot pyroclastic flow deposits can be laid down, often many meters thick.[35] Alaska's Valley of Ten Thousand Smokes, formed by the eruption of Novarupta near Katmai in 1912, is an example of a thick pyroclastic flow or ignimbrite deposit.[36] Volcanic ash that is light enough to be erupted high into the Earth's atmosphere as an eruption column may travel hundreds of kilometers before it falls back to ground as a fallout tuff. Volcanic gases may remain in the stratospherefor years.[37]

Felsic magmas are formed within the crust, usually through melting of crust rock from the heat of underlying mafic magmas. The lighter felsic magma floats on the mafic magma without significant mixing.[38] Less commonly, felsic magmas are produced by extremefractional crystallization of more mafic magmas.[39] This is a process in which mafic minerals crystallize out of the slowly cooling magma, which enriches the remaining liquid in silica.

- If the erupted magma contains 52–63% silica, the lava is of *intermediate composition* or *andesitic*. Intermediate magmas are characteristic of stratovolcanoes.[40] They are most commonly formed at convergent boundaries between tectonic plates, by several processes. One process is hydration melting of mantle peridotite followed by fractional crystallization. Water from a subducting slabrises into the overlying mantle, lowering its melting point, particularly for the more silica-rich minerals. Fractional crystallization further enriches the magma in silica. It has also been suggested that intermediate magmas are produced by melting of sediments carried downwards by the subducted slab.[41] Another process is magma mixing between felsic rhyolitic and mafic basaltic magmas in an intermediate reservoir prior to emplacement or lava flow.[42]
- If the erupted magma contains <52% and >45% silica, the lava is called *mafic* (because it contains higher percentages of magnesium(Mg) and iron (Fe)) or basaltic. These lavas are usually hotter and much less viscous than felsic lavas. Mafic magmas are formed by partial melting of dry mantle, with limited fractional crystallization and assimilation of crustal material.[43]

Mafic lavas occur in a wide range of settings. These include mid-ocean ridges; Shield volcanoes (such the Hawaiian Islands, including Mauna Loa and Kilauea), on bothoceanic and continental crust; and as continental flood basalts.

- Some erupted magmas contain <=45% silica and produce *ultramafic* lava. Ultramafic flows, also known as komatiites, are very rare; indeed, very few have been erupted at the Earth's surface since the Proterozoic, when the planet's heat flow was higher. They are (or were) the hottest lavas, and were probably more fluid than common mafic lavas, with a viscosity less than a tenth that of hot basalt magma.[44]

Lava texture

Mafic lava flows show two varieties of surface texture: ʻAʻa (pronounced [ˈʔaʔa]) and pāhoehoe ([paːˈho.eˈho.e]), both Hawaiian words. ʻAʻa is characterized by a rough, clinkery surface and is the typical texture of cooler basalt lava flows. Pāhoehoe is characterized by its smooth and often ropey or wrinkly surface and is generally formed from more fluid lava flows. Pāhoehoe flows are sometimes observed to transition to ʻaʻa flows as they move away from the vent, but never the reverse.[45]

More silicic lava flows take the form of block lava, where the flow is covered with angular, vesicle-poor blocks. Rhyolitic flows typically consist largely of obsidian.[46]

Tephra

Light-microscope image of tuff as seen in thin section (long dimension is several mm): The curved shapes of altered glass shards (ash fragments) are well preserved, although the glass is partly altered. The shapes were formed around bubbles of expanding, water-rich gas.

Tephra is made when magma inside the volcano is blown apart by the rapid expansion of hot volcanic gases. Magma commonly explodes as the gas dissolved in it comes out of solution as the pressure decreases when it flows to the surface. These violent explosions produce particles of material that can then fly from the volcano. Solid particles smaller than 2 mm in diameter (sand-sized or smaller) are called volcanic ash.

Tephra and other volcaniclastics (shattered volcanic material) make up more of the volume of many volcanoes than do lava flows. Volcaniclastics may have contributed as much as a third of all sedimentation in the geologic record. The production of large volumes of tephra is characteristic of explosive volcanism.[47]

Types of volcanic eruptions

Main article: Types of volcanic eruptions

Eruption styles are broadly divided into magmatic, phreatomagmatic, and phreatic eruptions.[48]

Magmatic eruptions

Magmatic eruptions are driven primarily by gas release due to decompression.[48] Low-viscosity magma with little dissolved gas produces relatively gentle effusive eruptions. High-viscosity magma with a high content of dissolved gas produces violent explosive eruptions. The range of observed eruption styles is expressed from historical examples.

Hawaiian eruptions are typical of volcanoes that erupt mafic lava with a relatively low gas content. These are almost entirely effusive, producing local fire fountains and highly fluid lava flows but relatively little tephra. They are named after the Hawaiian volcanoes.

Strombolian eruptions are characterized by moderate viscosities and dissolved gas levels. They are characterized by frequent but short-lived eruptions that can produce eruptive columns hundreds of meters high. Their primary product is scoria. They are named after Stromboli.

Vulcanian eruptions are characterized by yet higher viscosities and partial crystallization of magma, which is often intermediate in composition. Eruptions take the form of short-lived explosions over the course of several hours, which destroy a central dome and eject large lava blocks and bombs. This is followed by an effusive phase that rebuilds the central dome. Vulcanian eruptions are named after Vulcano.

Peléan eruptions are more violent still, being characterized by dome growth and collapse that produces various kinds of pyroclastic flows. They are named after Mount Pelée.

Plinian eruptions are the most violent of all volcanic eruptions. They are characterized by sustained huge eruption columns whose collapse produces catastrophic pyroclastic flows. They are named after Pliny the Younger, who chronicled the Plinian eruption of Mount Vesuvius in 79 AD.

The intensity of explosive volcanism is expressed using the Volcanic Explosivity Index (VEI), which ranges from 0 for Hawaiian-type eruptions to 8 for supervolcanic eruptions.[49]

Phreatomagmatic eruptions

Phreatomagmatic eruptions are characterized by interaction of rising magma with groundwater. They are driven by the resulting rapid buildup of pressure in the superheatedgroundwater.

Phreatic eruptions

Phreatic eruptions are characterized by superheating of groundwater that comes in contact with hot rock or magma. They are distinguished from phreatomagmatic eruptions because the erupted material is all country rock; no magma is erupted.

Volcanic activity

Volcanoes vary greatly in their level of activity, with individual volcanic systems having an *eruption recurrence* ranging from several times a year to once in tens of thousands of years.[50] Volcanoes are informally described as **active**, **dormant**, or **extinct**, but these terms are poorly defined.[51]

Active

Main article: Active volcano

There is no consensus among volcanologists on how to define an "active" volcano. The lifespan of a volcano can vary from months to several million years, making such a distinction sometimes meaningless when compared to the lifespans of humans or even civilizations. For example, many of Earth's volcanoes have erupted dozens of times in the past few thousand years but are not currently showing signs of eruption. Given the long lifespan of such volcanoes, they are very active. By human lifespans, however, they are not.

Dormant and reactivated

It is difficult to distinguish an extinct volcano from a dormant (inactive) one. Dormant volcanoes are those that have not erupted for thousands of years, but are likely to erupt again in the future.[52][53] Volcanoes are often considered to be extinct if there are no written records of its activity. Nevertheless, volcanoes may remain dormant for a long period of time. For example, Yellowstone has a repose/recharge period of around 700,000 years, and Toba of around 380,000 years.[54] Vesuvius was described by Roman writers as having been covered with gardens and vineyards before its eruption of 79 CE, which destroyed the towns of Herculaneum and Pompeii. Before its catastrophic eruption of 1991, Pinatubo was an inconspicuous volcano, unknown to most people in the surrounding areas. Two other examples are the long-dormant Soufrière Hills volcano on the island of Montserrat, thought to be extinct before activity resumed in 1995 (turning its capital Plymouth into a ghost town) and Fourpeaked Mountain in Alaska, which, before its September 2006 eruption, had not erupted since before 8000 BCE and had long been thought to be extinct.

Extinct

Extinct volcanoes are those that scientists consider unlikely to erupt again because the volcano no longer has a magma supply. Examples of extinct volcanoes are many volcanoes on the Hawaiian – Emperor seamount chain in the Pacific Ocean (although some volcanoes at the eastern end of the chain are active), Hohentwiel in Germany, Shiprock in New Mexico, US, Capulin in New Mexico, US, Zuidwal volcano in the Netherlands, and many volcanoes in Italy such as Monte Vulture. Edinburgh Castle in Scotland is located atop an extinct volcano, which forms Castle Rock. Whether a volcano is truly extinct is often difficult to determine. Since "supervolcano" calderas can have eruptive lifespans sometimes measured in millions of years, a caldera that has not produced an eruption in tens of thousands of years may be considered dormant instead of extinct.

Volcanic-alert level

The three common popular classifications of volcanoes can be subjective and some volcanoes thought to have been extinct have erupted again. To help prevent people from falsely believing they are not at risk when living on or near a volcano, countries have adopted new classifications to describe the various levels and stages of volcanic activity.[55] Some alert systems use different numbers or colors to designate the different stages. Other systems use colors and words. Some systems use a combination of both.

Volcano warning schemes of the United States

The United States Geological Survey (USGS) has adopted a common system nationwide for characterizing the level of unrest and eruptive activity at volcanoes. The new volcano alert-level system classifies volcanoes now as being in a normal, advisory, watch or warning stage. Additionally, colors are used to denote the amount of ash produced.

Decade volcanoes

The Decade Volcanoes are 16 volcanoes identified by the International Association of Volcanology and Chemistry of the Earth's Interior(IAVCEI) as being worthy of particular study in light of their history of large, destructive eruptions and proximity to populated areas. They are named Decade Volcanoes because the project was initiated as part of the United Nations-sponsored International Decade for Natural Disaster Reduction (the 1990s). The 16 current Decade Volcanoes are:

- Avachinsky-Koryaksky (grouped together), Kamchatka, Russia
- Nevado de Colima, Jalisco and Colima, Mexico
- Mount Etna, Sicily, Italy
- Galeras, Nariño, Colombia
- Mauna Loa, Hawaii, US
- Mount Merapi, Central Java, Indonesia
- Mount Nyiragongo, Democratic Republic of the Congo
- Mount Rainier, Washington, US
- Sakurajima, Kagoshima Prefecture, Japan
- Santa Maria/Santiaguito, Guatemala
- Santorini, Cyclades, Greece
- Taal Volcano, Luzon, Philippines
- Teide, Canary Islands, Spain
- Ulawun, New Britain, Papua New Guinea
- Mount Unzen, Nagasaki Prefecture, Japan
- Vesuvius, Naples, Italy

The Deep Earth Carbon Degassing Project, an initiative of the Deep Carbon Observatory, monitors nine volcanoes, two of which are Decade volcanoes. The focus of the Deep Earth Carbon Degassing Project is to use Multi-Component Gas Analyzer System instruments to measure CO_2/SO_2 ratios in real-time and in high-resolution to allow detection of the pre-eruptive degassing of rising magmas, improvingprediction of volcanic activity.[56]

Sulfur dioxide concentration over theSierra Negra Volcano, Galapagos Islands, during an eruption in October 2005

Volcanic eruptions pose a significant threat to human civilization. However, volcanic activity has also provided humans with important resources.

Hazards

Main article: Volcanic hazards

There are many different types of volcanic eruptions and associated activity: phreatic eruptions(steam-generated eruptions), explosive eruption of high-silica lava (e.g., rhyolite), effusive eruption of low-silica lava (e.g., basalt), pyroclastic flows, lahars (debris flow) and carbon dioxide emission. All of these activities can pose a hazard to humans. Earthquakes, hot springs, fumaroles, mud potsand geysers often accompany volcanic activity.

Volcanic gases can reach the stratosphere, where they form sulfuric acid aerosols that can reflect solar radiation and lower surface temperatures significantly.[57] Sulfur dioxide from the eruption of Huaynaputina may have caused theRussian famine of 1601–1603.[58] Chemical reactions of sulfate aerosols in the stratosphere can also damage the ozone layer, and acids such as hydrogen chloride (HCl) and hydrogen fluoride (HF) can fall to the ground as acid rain. Explosive volcanic eruptions release the greenhouse gas carbon dioxide and thus provide a deep source of carbon for biogeochemical cycles.[59]

Ash thrown into the air by eruptions can present a hazard to aircraft, especially jet aircraft where the particles can be melted by the high operating temperature; the melted particles then adhere to the turbine blades and alter their shape, disrupting the operation of the turbine. This can cause major disruptions to air travel.

Comparison of major United States supereruptions (VEI 7 and 8) with major historical volcanic eruptions in the 19th and 20th century. From left to right: Yellowstone 2.1 Ma, Yellowstone 1.3 Ma, Long Valley 6.26 Ma, Yellowstone 0.64 Ma . 19th century eruptions: Tambora 1815, Krakatoa 1883. 20th century eruptions: Novarupta 1912, St. Helens 1980, Pinatubo 1991.

A volcanic winter is thought to have taken place around 70,000 years ago after the supereruption of Lake Toba on Sumatra island in Indonesia,[60] This may have created a population bottleneck that affected the genetic inheritance of all humans today.[61] Volcanic eruptions may have contributed to major extinction events, such as the End-Ordovician, Permian-Triassic, and Late Devonian mass extinctions.[62]

The 1815 eruption of Mount Tambora created global climate anomalies that became known as the "Year Without a Summer" because of the effect on North American and European weather.[63] The freezing winter of 1740–41, which led to widespread famine in northern Europe, may also owe its origins to a volcanic eruption.[64]

Benefits

See also: Volcanogenic massive sulfide ore deposit and Geothermal power

Although volcanic eruptions pose considerable hazards to humans, past volcanic activity has created important economic resources.

Volcanic ash and weathered basalt produce some of the most fertile soil in the world, rich in nutrients such as iron, magnesium, potassium, calcium, and phosphorus.[65]

Tuff formed from volcanic ash is a relatively soft rock, and it has been used for construction since ancient times.[66][67] The Romans often used tuff, which is abundant in Italy, for construction.[68] The Rapa Nui people used tuff to make most of the *moai* statues in Easter Island.[69]

Volcanic activity is responsible for emplacing valuable mineral resources, such as metal ores.[65]

Volcanic activity is accompanied by high rates of heat flow from the Earth's interior. These can be tapped as geothermal power.[65]

Volcanoes on other celestial bodies

The Tvashtar volcano erupts a plume 330 km (205 mi) above the surface of Jupiter's moon Io.

The Earth's Moon has no large volcanoes and no current volcanic activity, although recent evidence suggests it may still possess a partially molten core.[70] However, the Moon does have many volcanic features such as maria (the darker patches seen on the Moon), rilles and domes.[*citation needed*]

The planet Venus has a surface that is 90% basalt, indicating that volcanism played a major role in shaping its surface. The planet may have had a major global resurfacing event about 500 million years ago,[71] from what scientists can tell from the density of impact craters on the surface. Lava flows are widespread and forms of volcanism not present on Earth occur as well. Changes in the planet's atmosphere and observations of lightning have been attributed to ongoing volcanic eruptions, although there is no confirmation of whether or not Venus is still volcanically active. However, radar sounding by the Magellan probe revealed evidence for comparatively recent volcanic activity at Venus's highest volcano Maat Mons, in the form of ash flows near the summit and on the northern flank.[72] However, the interpretation of the flows as ash flows has been questioned.[73]

Olympus Mons (Latin, "Mount Olympus"), located on the planet Mars, is the tallest known mountain in the Solar System.

There are several extinct volcanoes on Mars, four of which are vast shield volcanoes far bigger than any on Earth. They include Arsia Mons, Ascraeus Mons, Hecates Tholus, Olympus Mons, and Pavonis Mons. These volcanoes have been extinct for many millions of years,[74] but the European *Mars Express* spacecraft has found evidence that volcanic activity may have occurred on Mars in the recent past as well.[74]

Jupiter's moon Io is the most volcanically active object in the Solar System because of tidal interaction with Jupiter. It is covered with volcanoes that erupt sulfur, sulfur dioxide and silicate rock, and as a result, Io is constantly being resurfaced. Its lavas are the hottest known anywhere in the Solar System, with temperatures exceeding 1,800 K (1,500 °C). In February 2001, the largest recorded volcanic eruptions in the Solar System occurred on Io.[75] Europa, the smallest of Jupiter's Galilean moons, also appears to have an active volcanic system, except that its volcanic activity is entirely in the form of water, which freezes into ice on the frigid surface. This process is known as cryovolcanism, and is apparently most common on the moons of the outer planets of the Solar System.[*citation needed*]

In 1989, the *Voyager 2* spacecraft observed cryovolcanoes (ice volcanoes) on Triton, a moon of Neptune, and in 2005 the *Cassini–Huygens* probe photographed fountains of frozen particles erupting from Enceladus, a moon of Saturn.[76][77] The ejecta may be composed of water, liquid nitrogen, ammonia, dust, or methane compounds. *Cassini–Huygens* also found evidence of a methane-spewing cryovolcano on the Saturnian moon Titan, which is believed to be a significant source of the methane found in its atmosphere.[78] It is theorized that cryovolcanism may also be present on the Kuiper Belt Object Quaoar.

A 2010 study of the exoplanet COROT-7b, which was detected by transit in 2009, suggested that tidal heating from the host star very close to the planet and neighboring planets could generate intense volcanic activity similar to that found on Io.[79]

Many ancient accounts ascribe volcanic eruptions to supernatural causes, such as the actions of gods or demigods. To the ancient Greeks, volcanoes' capricious power could only be explained as acts of the gods, while 16th/17th-century German astronomer Johannes Kepler believed they were ducts for the Earth's tears.[80] One early idea counter to this was proposed by Jesuit Athanasius Kircher (1602–1680), who witnessed eruptions of Mount Etna andStromboli, then visited the crater of Vesuvius and published his view of an Earth with a central fire connected to numerous others caused by the burning of sulfur, bitumen andcoal.[citation needed]

Various explanations were proposed for volcano behavior before the modern understanding of the Earth's mantle structure as a semisolid material was developed.[citation needed]For decades after awareness that compression and radioactive materials may be heat sources, their contributions were specifically discounted. Volcanic action was often attributed to chemical reactions and a thin layer of molten rock near the surface.