General Volcanology

Volcanoes

Technically, a volcano is a vent or chimney connected to a reservoir of molten material, a magma chamber, within the earth's crust. Ejected material usually accumulates around the opening, the vent, to build a cone, or "volcanic edifice." As popularly used, the term volcano includes both the vent and accumulated materials.

A volcano is a vent in the earth's crust from which molten (or partially liquid) rock or steam issues. The term volcano is also popularly applied to the volcanic structure (hill or mountain) which is usually built from the material ejected from such a vent. While in the earth's crust, molten rock is known as magma. Once it issues from the vent, both the liquid material and the solid rock it forms are known as lava.

Origin of Volcanoes

Magma is found in pockets within the earth's crust. These are known as magma chambers. The formation of these magma chambers is probably the result of several factors. Temperatures increase with depth so that 40 miles below the earth's surface temperatures may reach 2200°F. One might expect these rocks to be liquid, but because of the great pressure which exists at this depth, they are solid or semi-solid. When a reduction in the pressure such as associated with a buckling of the earth's crust occurs, then these rocks can liquefy. Liquefaction may also be brought about by increased heat, possibly due to friction along faults or by pockets of radio activity in the crust. The depths of magma chambers vary from a few to twenty or more miles. Once they form, magma tends to rise or be forced to the surface through cracks or fissures. The magma chamber then becomes known as a feeding chamber.

Magma usually collects at various levels within the crust to displace and/or incorporate surrounding rock and form a reservoir, the feeding chamber. These pockets of molten material near the surface may be formed by:

1. Reduction of pressure, typically occurring in volcanic mountain belts.
2. Increase of temperature, usually caused by reduction of pressure, radioactive breakdown of elements such as uranium, thorium, and/or earth movements along faults in the crust.
3. Combination of these.

Once magma forms near the surface crust, it tends to rise, or to be forced to the surface by self-contained gases. A variety of formations may develop:

Basalt plateaus: Magma, under low pressure, may erupt forming swarms of fissures, to spread as floods of basaltic lava. The Northwest's Columbian Basalt Plateau is North America's finest example.

Shield Cones: Copious swellings of more viscous lava construct volcanoes, which in profile resemble low domes or inverted saucers. Examples are Prospect Peak, Mount Harkness and Red Mountain.

Cinder Cones: Magma, under high pressure, will erupt explosively to form steep-sided volcanoes. Usually they are symmetrical in shape and are formed rapidly. Mexico's Paricutin, for example, grew 1,000 feet by the end of the second month. Generally, cinder cones are less than 1,000 feet high. Examples include Red Cinder Cone, Hat Mountain, and Cinder Cone.

Composite Cones: These are formed of alternate layers of lava flows from effusive eruptions and fragmental material from explosive eruptions. When exposed, a banding effect is evident. Examples include the high peaks of the Cascade Range: Mount Rainier, Mount Hood, Mount Shasta and ancient Mount Tehama.

Plug Domes: Extremely viscous masses of lava emerge rapidly and "en masse" from a vent to form a steep-sided, bulbous mound. These may vary from tens to thousands of feet in height. Lassen Peak is considered one of the world's largest plug dome volcanoes. Others are Chaos Crags, and Reading Peak.

Materials ejected from a volcano vary in chemistry as components separate in the magma. As magma cools, the first minerals to crystallize are poor in silica, but rich in iron, calcium and magnesium. As cooling progresses, minerals richer in silica and potassium develop. Heavier crystals, rich in iron, calcium and magnesium sink toward the chamber floor and leave the lighter, silica-rich residual liquid on top. Evidence suggests that eruptions may occur at any stage in the cooling and separation process, and fissures may tap any level of the feeding chamber.

A major effect of crystallization within the magma chamber is a concentration of gas within the remaining liquid. Ultimately, the gas pressure becomes too great for the reservoir roof to withstand and eruptions begin. Gas then becomes the driving force within a volcano.

Initial eruptions or explosions, whether gas, magma or a combination of the two, reduce the pressure and allow more gas to separate from liquid. In this manner, eruptions become self-sustaining.

The Product of Volcanoes

The principal gas, steam, is generally more than 95 percent of the total discharge, seldom less than 82 percent. Carbon dioxide is the second most common gas. Sulfurous gases such as sulfuric acid, H_2SO_4, create the characteristic odor of volcanoes. However, less is released than of water and carbon dioxide. Gases released in minor amounts include hydrogen, ammonium chloride, carbon monoxide, nitrogen, chlorine, and fluorine.

Eruptions may occur at any stage in the cooling and separating process and fissures may tap any level of the feeding chamber, resulting in a variety of lavas and volcanic products and formations.

Volcanic Products

Fragmented or pyroclastic products are named according to size, texture, and composition of materials. Fine-sized materials, smaller than peas, include dust and ash which, when compacted to rock, form volcanic tuff. Fragmental material between pea and walnut size is termed lapilli. Material larger than walnut size is termed block, which when compacted to rock, forms volcanic breccia.

Volcanic Bombs are almond shaped, with twisted "ropes" of lava and cooling cracks. These form as large blobs of molten or semi-solid lava which solidify while falling through the air. Bombs compacted into rock with other large, round ejecta form agglomerates.

Highly vesicular, frothy, light-colored ejecta, with density often low enough to float on water, are termed pumice. Pumice is generally siliceous and acidic in composition. Highly vesicular, frothy, dark-colored ejecta, less siliceous, basic and more dense than pumice is termed scoria.

The layman's term, cinders, is used to include all fragmental material between ash and block in size.

Lavas escape from fissures, rather than from central vents. More copious flows produce no volcanoes, but rather large, level plateaus such as the Columbia River Basalts.

Types of Eruptions

The nature of volcanic eruptions is determined primarily by gas pressure and viscosity of the magma, both of which are controlled by magma composition and stage of cooling. Lava viscosity varies inversely with temperature and gas content. Some of the types of eruptions associated with volcanic activity are:

Icelandic: Lavas escape from fissures, rather than central vents. More copious flows produce no volcanoes, but rather large, level plateaus such as the Columbian Plateau.

Hawaiian: Typified by fluid basaltic lavas in which gases are liberated quietly. Thus little or no fragmental material is produced although fountains of lava may be projected by jets of escaping gas to heights of 1000 feet or more. Abundant outpourings produce flat lava domes forming some of the largest mountains on earth, such as Mauna Loa.

Strombolian: Named after a volcano off the coast of Sicily, these eruptions tend to be of moderate intensity and occur at more or less regular intervals. Eruptions are accompanied white vapor clouds and throw out glowing clots of magma (scoria) which cool to form bombs and lapilli. These eruptions occur with more viscous basalt and mafic andesite lavas.

Vulcanian: Although named after Vucano, Italy, Vesuvius provides better examples of this type of eruption. Here, the crater crusts over solidly between infrequent eruptions. Then strong eruptions, sometimes sufficient to disrupt the cone, occur blowing out of the obstruction. Pinos or huge cauliflower-like clouds of steam charged with fine particles are often formed. Lava may issue from the crater or fissures on the sides of the cone.

Ultra-vulcanian: Only rock fragments are discharged, no lava. Normally these low temperature steam blasts occur as the first outbreak of a new volcano, or as initial explosions of older volcanoes after periods of dormancy.

Pelean: The extreme in explosiveness, it is named after Mt. Pelee on the Island of Martinique, West Indies, where such an eruption in 1902 destroyed the city of St. Pierre and took 30,000 lives. Its distinguishing feature is the pyroclastic flow or glowing avalanche which contains superheated gas that is so full of glowing ash and other particles it obeys the force of gravity, rushing down the slopes of mountains with hurricane force Several have occurred in the Lassen region.

Lava

Lava is the general term for all volcanic material extruded above ground, whether liquid or solid.

Lava character is determined by chemical composition, gas content, magma temperature and environment where extruded. Lavas are classified according to composition and textural character, such as percentage and size of gas cavities, amount of crystallization, and selective size of crystals. Composition, the primary criterion for classification, determines most characteristics of flows. Lavas relatively poor in silica and rich in calcium, iron, and magnesium, the basalts, are more fluid than lavas with the reversed composition, the rhyolites and dacites. Occasionally these move greater distance and at greater speeds, to form thin layers, than the rhyolitic or dacitic lavas, which are pasty and sluggish. Basaltic lavas are generally 1800° to 2220°F. Siliceous lavas are generally 1100° to 1550°.

Surface flows of lava are usually termed pahoehoe if appearing ropey or as cordlike corrugations, and Aa if appearing rough or blocky.

Andesitic lavas are intermediate in chemistry between basalt and dacite.

Pillow lavas form whenever lava flows into water and cools rapidly.

Sometimes fluid lavas form lava tubes as they cool. These interesting caves are formed when the outer surface of a flow cools and hardens while the interior is still fluid. The interior lavas then continue to drain out the end of the flow, leaving a hollow tube behind. There is a trail through a lava tube called Subway Cave, located north of the park in Lassen National Forest.

Sometimes a lava flow is so viscous (characteristic of acid lavas) that it cools before it had a chance to crystallize. Then volcanic glass or obsidian is formed. There is an obsidian flow in Medicine Lake volcano north Lassen.

Basalts: have a silicon dioxide content of less than 52% and are termed mafic. They are dark colored and flow readily, allowing gas to escape with ease. Andesites are intermediate in characteristics between the acid and basic lavas.

Silicic lava: Because silicon dioxide acts as an acid, lavas with silicon dioxide content exceeding 66% by weight are known as silicic lavas. Two of these are found in Lassen Volcanic National Park. Rhyolite has a silicon dioxide content of about 75%, while that of dacite is about 70%. These white to grayish or pinkish lavas are stiff and viscous even at high temperatures and thus permit gas to escape with difficulty often resulting in explosive types of eruptions.

Caldera versus Crater (Hans Rick's Classification)

A bowl-shaped depression or crater is usually associated with the vent of a volcano as a result of the force of explosions. These rarely exceed three-quarters to one mile in diameter. Sometimes as a result of the draining of magma chambers, support is removed from the roof of a volcano and it may collapse on itself. Or perhaps a particularly violent eruption may blow the top away. In either instance,

a caldera or depression much larger than the crater is formed. Calderas usually have steep sides and may have diameters of five to ten miles.

- All calderas are related to volcanic topography. Many craters are not related to volcanic topography.
- Volcanic craters are inseparably related to conduits. Calderas are not related to the roof of the reservoir.
- Volcanic craters are the eruption vents. Calderas are never entirely eruption vents.
- Volcanic craters are the vents through which ejecta passes. They are positive, active volcanic forms.
- Calderas are the result of change in state or volume within the underlying reservoirs. They are negative, passive forms.
- Volcanic craters occur during the active, growing periods of volcanoes.
- Calderas are marks of decadence and age, although caldera formation may be followed by renewal of activity.