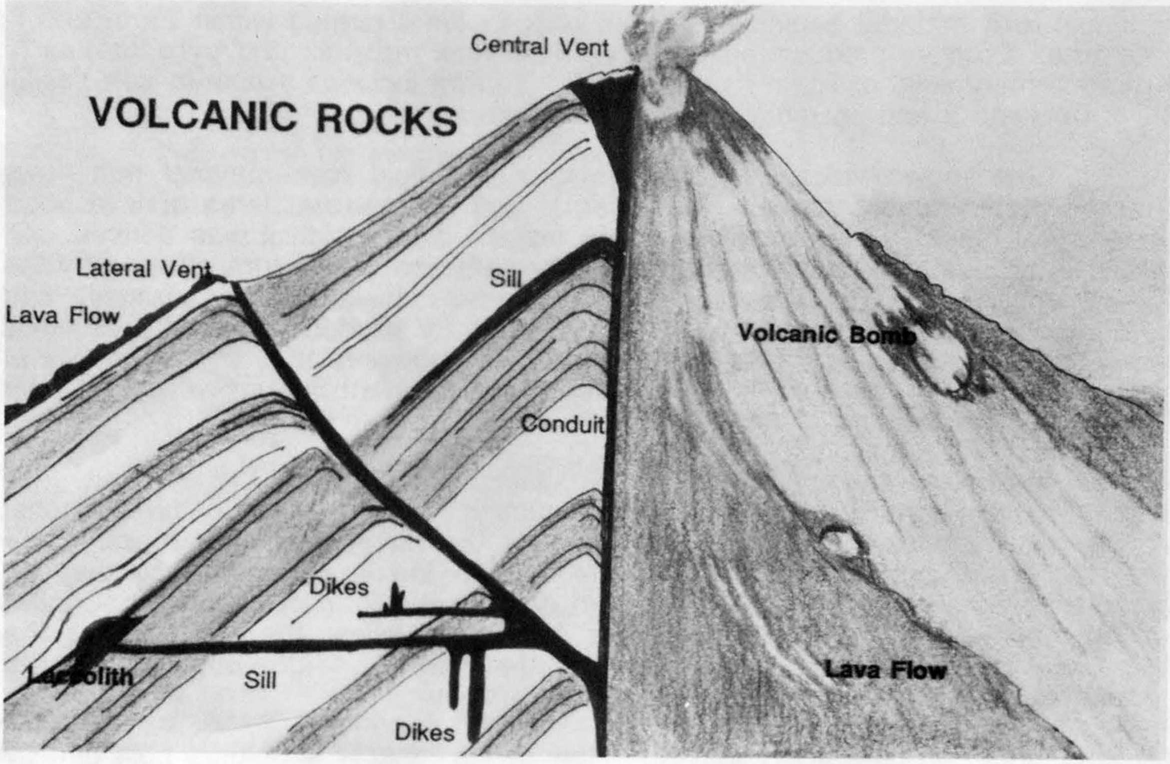

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VOLCANIC ROCKS (VOLCANIC PRODUCTS AND FEATURES)

Volcanoes have contributed significantly to the formation of the surface of our planet. Volcanism produced the crust we live on and most of the air we breathe. Often the remnants of an eruption are as revealing as the eruption itself, for they tell us many things about the eruption. Included here are examples of several volcanic products and other magmatic features, with descriptions of how they were formed and what they tell us about volcanism.

Most volcanic rock material begins as molten rock material formed within Earth and is called **magma**. Eruptive products include **lava** (fluid rock material) and **pyroclastics** or **tephra** (fragmentary solid or liquid rock material). Tephra includes **volcanic ash, lapilli** (fragments between 2 and 64 mm), **blocks**, and **bombs**.

Perhaps the best known volcanic product is lava, the fluid rock material that flows rather quietly from volcanic **vents**. The external and internal structures of lava flows are the result of the physical properties of the magma from which it was derived. Of these physical properties viscosity is the most important and it is in turn affected by the temperature and chemical composition of the magma. Lavas of low viscosity can spread great distances from the vent. Greater viscosity produces thicker lava flows that generally cover less area. The rate of supply of magma relative to the velocity of the lava as it flows from the vent and the external environment through which the lava flows also affect the structure of the solidified lava.

Products of explosive eruptions include pyroclastic (fire broken) rocks and rock fragments. The force that produces explosive eruptions is the release of trapped gas. Ejecta from these explosions may be derived from the magma or from rocks in the vicinity of the volcanic conduit that are blasted out in the eruption. These may be ejected more or less vertically, then fall back to earth in the form of **ash fall deposits**. **Pyroclastic flows** result when the eruptive fragments follow the contours of the volcano and surrounding terrain. They are of three main types: **glowing ash clouds** (**nuée ardente**), **ash flows**, and **mudflows**.

Volcanic structures can take many forms. A few of the smaller structures built directly around vents include **cinder, spatter**, and **lava cones**. Thick lavas may pile up over their vents to form **lava domes**. Larger structures produced by low viscosity lava flows include **lava plains**.

The erosion of volcanoes leaves volcanic remnants, interesting reminders of the volcano's former fury. Erosion of the layers of lava and ash that built the volcano leaves the congealed magma in the **conduit**. This feature, sometimes referred to as a plug or the volcanic **neck** or **throat,** is a dramatic pillar of rock rising above the surrounding plain. These plugs or necks may be composed partially of fragments of the walls of the pipe and partially of congealed magma. They may be as more than a kilometer in diameter. Magma flowing into cracks in the rocks produces **dikes**, **sills** and **laccoliths**. This intrusive rock is generally resistant to erosion and often remains after the surrounding rock has eroded away. These exposed intrusive rocks give us a glimpse of the complex underground network of piping in active volcanoes.

These igneous features are constant reminders of the timelessness of the processes that relentlessly form, and reform, the surface of planet Earth.

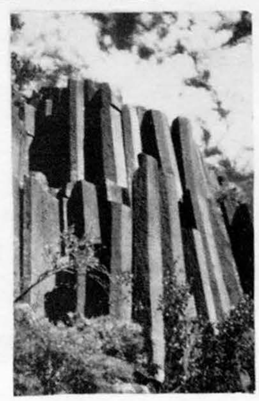
ERUPTION PRODUCTS: LAVA
(Slides 1-7)

1 Lava flows are the most common product of less violent eruptions such as those on the Island of Hawaii. "Pahoehoe" and "aa" are Hawaiian names that describe lava flows having different surface features. This slide depicts a pahoehoe lava flow. The surface of pahoehoe is billowy and undulating and its skin is smooth and continuous. Wrinkling of the plastic skin by flow movement may cause the ropy structure seen on the surface of some flows such as this pahoehoe flow in Hawaii. The thin, congealed skin remains plastic over the red hot fluid interior; it may be sturdy enough to permit someone to walk across the moving flow. The crust of a lava flow, like other rock, is a poor conductor of heat, and the interior of a thick flow may remain hot and fluid for months.

2 Aa flows have a rough, jagged, clinkery surface. This aa flow originating from the Puna rift on the Island of Hawaii partially buried a home and car. Essentially, such flows are rivers of lava that congeal on the front and sides and form steep flow-fronts that are overridden by molten lava within the flows. Pahoehoe may change into aa, particularly where the lava plunges over a steep slope and causes differences in the rate of cooling and gas separation. There is no chemical difference in the two types of lava. The fragmentation of the surface of aa flows results from disruption of the very viscous crust by movement of the flow beneath it. The streams of aa do not harden on the surface as do pahoehoe flows.

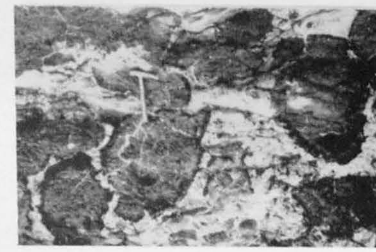
3 A very smooth lava, known as volcanic glass is formed where lava is erupted as a partly congealed, slow-flowing mass, that cools too rapidly to crystalize as in the case of this flow near Mauna Ulu, Hawaii. Such glassy lavas, like all glasses, are solids having the molecular structure of liquids that would have crystallized had they cooled more slowly. Most lava flows are partly glass and silica-rich lavas are largely or entirely glass because of their slower rate of crystallization.

4 Where the surface crust thickens, lava may continue to flow internally in lava tubes. Loss of heat results in solidification of portions of the flow. The interior remains fluid only in the portions of the flow with the most active movement where new heat is constantly being brought. As the supply of magma abates, the river of lava inside the tube subsides, leaving a partially or wholly open tube where the lava had been and forming caves like those at Craters of the Moon, Idaho.



5 Contraction during cooling of thick, extrusive basaltic lava flows causes cracks perpendicular to the cooling surface, which form the polygonal columns of the Devil's Postpile in California. The columns average about 46 cm across. In thick slowly cooled flows the joints normal to the flow surface tend to develop in three directions at roughly 60° to each other and form multi-sided blocks that are cut off by the joints parallel to the flow surface. Jointing of this sort may attain a high degree of regularity. The horizontal joints divide the columns into a series of segments. Such columnar jointing is found in all types of lava flows, including ash flows. It is also conspicuous in dikes and other intrusions.

6 Pasty lava does not flow freely, and its high viscosity inhibits the separation and escape of gases. If gas content and pressure are low, pasty lava extrudes through the vent, like toothpaste squeezing through a tube, and forms volcanic domes. The upper surface of a dome may be covered with sharp, irregular spines that formed when hotter lava squeezed through the partially cooled surface of the dome. Such spines are visible on Shastina, a parasitic crater, and in part a plug dome of lava too viscous and too limited in volume to spill over the rim of its crater. It is located on the west flank of Mt. Shasta, California.



7 Where lava is erupted under water, the lava chills rapidly and forms a glassy, plastic skin around the molten interior. These "pillows" are formed mostly in basalt lavas when eruptions occur beneath the sea, under glaciers, or in areas where lava spills into a lake or marshy ground. It has been suggested that these strange formations formed when portions of lava broke off the face of a pahoehoe toe and tumbled down it to form pillows. These basalt pillows near Oamaru, New Zealand, formed more than 25 million years ago.

ERUPTION PRODUCTS; ASH, CINDERS AND BOMBS (TEPHRA, PYROCLASTICS) (Slides 8-13)

8 Ash, cinders, bombs, and blocks, though less well known than lava, are the most common volcanic eruption products. Ash flows (pyroclastic flows) result from expansion of gas bubbles at the vent, which fragment the lava. Fragments may flow downhill at speeds up to 200 km/hr and come to rest on the lower slopes of the volcano. If volcanic debris is so charged with fragments that it is too heavy to rise, it becomes a nuée ardente or glowing cloud. Where the flowing ashes are overlain by airborne ash, an ignimbrite or tuff is formed. These ignimbrites may cool slowly over a period of years, promoting welding in the interior and partial crystallization of the glassy fragments. Pictured here is a thick layer of welded tuff at Lava Creek in Yellowstone, Wyoming.

9 Diamond Head on Oahu, Hawaii, a palagonite tuff cone, is composed of glassy basaltic ash. When the ash from an eruption is cemented together by deposition of secondary cement between ash grains or by palagonitization (hydration and other alteration of basalt glass) a tuff cone is formed. Ash and tuff cones resemble cinder cones, however, the explosions are usually partly or wholly hydromagmatic and take place at shallow levels. The ejecta are thrown out at a low angle and the fragments accumulate at a considerable distance from the vent. Such cones vary greatly in size. Diamond Head is a large one measuring nearly 2.5 kilometers across at the base with a crater a kilometer across from rim to rim and averaging about 120 meters deep.

10 Explosions caused by the sudden escape of volcanic gas trapped inside the volcano may throw ejecta of various sizes into the air. Bombs are defined as ejecta larger than 64 mm in average diameter that were thrown out in molten condition. Bombs such as these on the flank of Pico de Teide, Tenerife, on the Canary islands were molten when thrown into the air, and may have solidified during flight. A field of lighter-than-water pumice surrounds the bombs.

11 Bombs falling into unconsolidated ash break or compress the ash layers and form bomb sags such as this in Dotsero Crater, Colorado.

12 With a decrease in the explosiveness of eruption, or an increase in the fluidity of the magma, or both, cinder cones grade into spatter cones. (Molten material that solidifies after landing is called spatter.) Sometimes spatter layers alternate with cinder layers. Spatter may become mixed with the cinder and become welded to adjacent fragments. As the proportion of cinder decreases the cones become purely spatter cones. They are usually small rarely reaching heights or more than 30 meters with slopes that are steeper than those of cinder cones. Welded spatter can stand in a bank that is essentially vertical. Little Beggar Cone in the Kilauea caldera was formed where lava at a small vent was thrown into the air and solidified.

13 Small cones formed by liquid spatter and a larger cone formed of solid tephra (cinders) are seen at Craters of the Moon, Idaho. These small cones are part of a row of 55 cones 15 to 242 meters high that marks the fissure vent at this location. The eruptions in this area are less than 2,100 years old.

REMNANT VOLCANIC FEATURES: NECKS, DIKES, SILLS (Slides 14-20)

14 Intrusions of magma cool underground to form igneous rocks. These rocks are seen at the surface only if erosion removes the overlying surface. These intrusions may be revealed in landmarks, such as the plug (neck, throat) or infilled conduit of an old volcano. An eroded volcanic neck of Tertiary trachyte known as Mt. Tibrogargan, Glasshouse Mountains near Brisbane, Australia, is an example of such a fossilized volcanic feature.

15 Devils Tower, Wyoming, is probably a volcanic neck but might also be a laccolith. Note the columnar jointing visible on the sides of the tower.

16 If a volcano is eroded to its roots, the cooled magma in the exposed conduit and in the feeding cracks is exposed. The eroded remnant of a steep, pipe-like conduit that feeds the central vent is called a volcanic neck. Dikes are formed by magma that has congealed in vertical cracks or tension features. They cut across the structure of adjacent rocks. Shiprock in New Mexico is a volcanic neck with radiating dikes. Erosion has stripped away the volcanic cone, leaving only the hard skeletal remains of the central vent and the vertical dikes. Shiprock is 450 meters high, and its dikes form great walls across the desert.

17 The Great Wall dike north of Spanish Peaks in Colorado, as seen in this view looking west, is a spectacular example of a volcanic wall. The well-developed dike pattern in this area has been largely the result of a pre-existing system of joints that developed during the early stages of late Cretaceous orogeny. It is thought that in the formation of dikes, particularly at shallow depths, the magma does not force the fissures apart prior to entry. Instead the fissures were pulled apart by dilation or stretching, and then the magma flowed into the cracks.

18 Some magma congeals in a series of weak, vertical cracks in the surrounding rocks and forms a "dike swarm" such as this deeply dipping swarm (one of which has columnar jointing) north of Hofn, Iceland. Such swarms are believed to have fed the flood plain eruptions that built basaltic lava plains and plateaus such as the Columbian Plain in northwestern United States.

19 Magma flowing between the beds of strata creates rather flat-lying (horizontal) sills, such as that formed in pre-Carboniferous dolerite in the Salisbury Crags near Edinburgh, Scotland. These igneous intrusions have been exposed by erosion and orogenic uplift. In genera, sills are formed by less viscous magma that spreads out to form a thin sheet. They can be considered the intrusive equivalents of lava flows.

20 Less fluid magma may form a sill variation known as a laccolith. These shallow intrusive bodies are actually domes that did not quite break through to the Earth's surface but instead heaved up the overlying beds of older rocks. Both laccoliths and sills may be fed by either dikes or from the central conduit. The rocks overlying large laccoliths are often relative light sedimentary types. This is probably because the lighter sedimentary rock layers are easier for the magma to lift. A more dense rock would instead be broken by the magma in its push toward the surface. This laccolith in Red and White Mountain, Colorado, is of Tertiary age. Overlying layers of rock have been eroded.

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