VOLCANOLOGY

Earth's Eruptions

Volcanoes, Like Earthquakes, Generally Are Found Where Altitude Differences Are Extreme, Crust Weak

TITANIC builder and destroyer is the volcano.

Together with its companion phenomenon, the earthquake, both evidences of a living earth enclosed in the sun-heated shell, it has intrigued the imagination of man from the beginnings of history.

Only within the last generation, however, have plausible theories, supported by an accumulation of experimentally determined facts, been possible. The roots of a volcano are many miles deep. There is no possibility of actual observation of what happens in the depths of the earth before an eruption, and everything must be deduced from surface phenomena.

Much observation and experimentation leading to a clearer picture of the mechanism of volcanism have been carried on by geophysicists and geologists of the Geophysical Laboratory of the Carnegie Institution of Washington. Together with the work of other scientists, these studies aid understanding of conditions at the bottom of the earth's crust.

The present distribution of these fire mountains gives a clue to the mechanism responsible for them. With very few exceptions they are found in regions where there are very great variations in altitude, with lofty mountains alongside abysmal ocean depths. This is the case, for example, around most of the Pacific basin.

Reaction To Restore Balance

Where such irregularities exist, weaknesses in the crust of the earth may be inferred. They are shown, in fact, by other evidence, such as anomalies in gravity. There is constantly in progress a redistribution of the materials at the bottom of the granitic crust and the 25-mile-thick shell of basalt underneath. This is a natural physical reaction, to restore balance. An extremely heavy mass at one point tends to push up the somewhat plastic rock beneath it through any crack which happens to develop because of the overloading.

The same basic mechanism is responsible for earthquakes. It is noteworthy that volcano regions also are earthquake regions. The reverse, however, does not hold, and some areas which are subject to severe shakings from time to time never have experienced volcanism. The association is highly suggestive and indicates that the volcano is a more specialized phenomenon than the earthquake.

Just what happens in the earth's depths, of course, can only be conjectured, but more and more plausible hypotheses to account for the fire mountains are resulting from continued observations.

A much debated problem has been the source of the molten rock.

The temperature of the earth's interior as is well known, increases with depth and pressure. The rate of increase is about 30 degrees centigrade per kilometer on an average, although it varies enormously with local conditions. At one place in South Africa the gradient is 90 degrees per kilometer. But, assuming that this gradient continued unchanged, it would be necessary to go far towards the earth's center to encounter temperatures sufficient to melt rock.

Giant Thermos Bottle?

But the earth originally was a molten mass, presumably torn out of the surface of the sun in some titanic cataclysm. Did all the heat of this enormous ball escape into space as the earth cooled? A logical hypothesis is that the cooling reaction caused a very rapid crystallization and solidification of the first few miles of the surface. This proved a fairly good insulating material through which heat from the interior could escape very slowly. Thus the planet might be pictured as a giant thermos bottle.

So the rocks 15 to 20 miles down may still be molten. This does not mean that they are liquid. They are under enormous pressure, sufficient to keep them in the solid state in spite of their intrinsic heat. But there must be a critical point where this pressure is barely enough—where, if it were relaxed a trifle, the rocks would become liquid.

There are two types of volcanoes, and each emits its characteristic type of lava —the basaltic, of low silica content, and the andesitic and rhyolitic, of high silica content.

The first is characteristic of some of the largest and best-known fire mountains, notably Kilauea in Hawaii. Hot molten rock seeps from the earth's depths, cools, and builds great mountains. There seldom is a violent explosion. The lava contains a relatively large percentage of iron and other metals combined with silica. Such materials have considerable fluidity at the temperature of 1,100 degrees centigrade noted during eruptions of the basaltic type.

Now it is known that immediately below the granite crust of the earth there is a layer of basalt. The pressure ordinarily is sufficient to keep it rigid. But there are various ways in which this pressure could be relaxed in specific localities. It would be reduced by long continued erosion of heavy mountains. It would be released almost entirely by a crack in the crust due to grossly unequal weight distribution.

Would Push Liquid Up

Under such conditions, with a vent to the surface open, the pressure of the crust on all sides would tend to push the liquid upwards to the surface with just such a seepage phenomenon as is observed at Kilauea. There is no need to assume continuously existing pools of molten basalt in the depths of the earth, as has been done by some geophysicists in the past. Merely a considerable release of pressure over a limited area without a corresponding loss of heat would turn part of the planet's inner shell into a liquid.

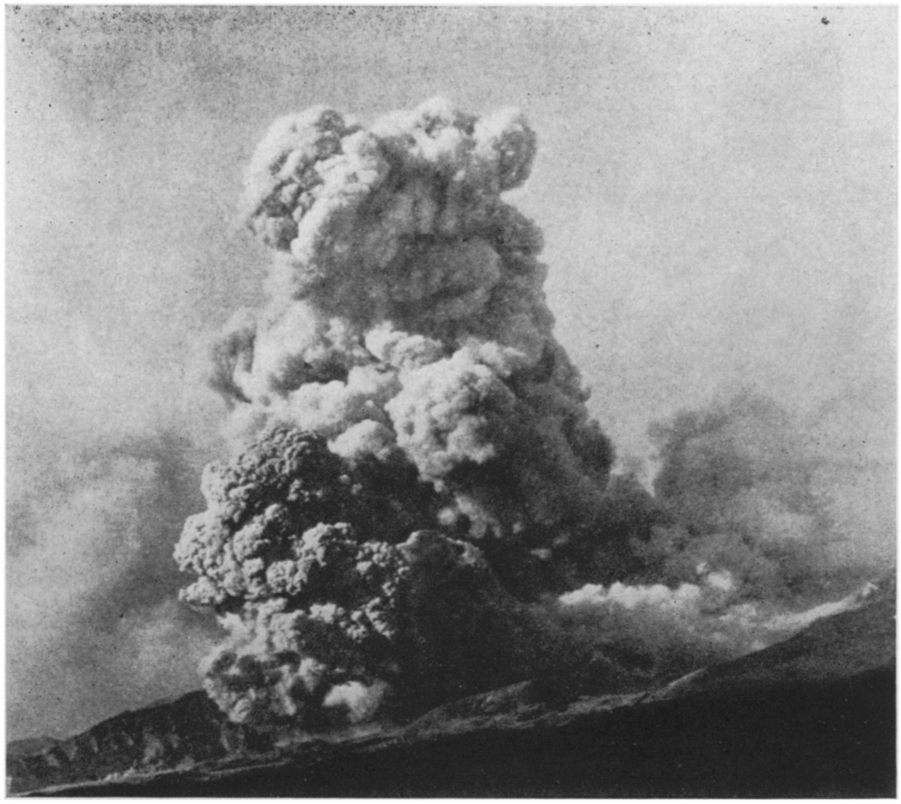
The "pool" hypothesis, however, need not be entirely discarded, say Carnegie geophysicists. Such subterranean lakes of molten rock may exist. The normal balance between temperature and pressure could be disturbed in several ways. One mechanism would be a concentration of heat-producing elements, such as uranium and thorium, in a limited area at the bottom of the crust. Another would be a blanketing effect—the piling up of extraordinary amounts of light but effectively insulating material at some place on the surface, say a mountain range.

But this type of volcano is an exception. A more complex theory is necessary to account for the best known type, those which at intervals belch forth with explosive violence great masses of siliceous lava. The most notable element in this is silica. It is also the most notable element in the granite crust of the earth. Such lavas are, by contrast with the basaltic lavas, exceedingly viscous at the temperature of about 1,100 degrees centigrade which prevails during an eruption. The composition of the lava is about what would be expected for rocks melted at the bottom of the earth's outer crust.

A silicate composition differs notably from basalt. It has been determined in the past few years that silicate rocks, such as obsidian and granites, contain some water and various gases such as hydrogen sulfide and carbon dioxide. These are held in solution, bound up very closely with the molecules of the rocks under pressure. They can be released by melting and the amounts measured by various chemical methods.

Presumably these same substances are in solution in the solid-liquid state ten or fifteen miles below the surface. There is a release of pressure, just as in the case of the basalt. The siliceous mass becomes liquefied. In the process some of the gases, and especially the bound water, escape.

With the intense temperature found at such depths, the result is an enormous pressure of steam, too much for the lid of the kettle. There is a steam boiler explosion, with the eruption breaking through at the weakest point in the crust. Volcanoes of this type are Etna and Vesuvius in Italy and those of Iceland, Mexico, Japan, and Central and South America.



PILLAR OF FIRE

This glowing cloud flowing down the slope of Mt. Pelee on Martinique was photographed by Frank A. Perret of the Carnegie Institution of Washington.

Express Train Speed

Titanic glowing clouds of finely divided matter are shot into the air with extreme violence and express train speed. They sink over vast areas of countryside, and all life may be wiped out under the fiery blanket they lay down. This cools rapidly to form a cinder-like pumice. The explosive elements in the original molten material are now a subject of major study, and what happens is still far from clear.

The actual eruption of a volcano is extremely picturesque and often tragic. The most striking feature is the pillar of cloud which arises from the crater. The closest observations of these pillars of cloud were made at the paroxysmal eruption of Mt. Vesuvius in 1906. They were emitted in three stages. The clouds of the first stage ascended to great heights and were composed of glowing particles mixed with much dark material. The former presumably came from the molten lava, the latter from detritus blown from the cone of the mountain itself.

Flashes of lightning shot through the cloud. The explosive force of the gases increased and carried it to still greater heights. As the eruption progressed, it became almost black as more material was blown from the crumbling cone. Here the volcanologist Frank A. Perret photographed for the first time what he described as "flashing arcs."

These were luminous circles which appeared at the beginning of each explosion and were repeated at intervals of about two seconds. They progressed upward and disappeared. They never have been explained satisfactorily.

Dense Clouds

This first period of activity continued for about three days and was followed by a period during which there was continuous and powerful expulsion of gases carrying only a small amount of solid particles. The cloud ascended to about 13 kilometers. The third period followed the second in a few hours and lasted about three weeks. There were intermittent, paroxysmal expulsions of pillars of cloud that were often so dense they literally flowed down the mountain. These carried electrical charges opposite to that of the earth, as was shown by brush discharges from the metal buttons worn by attendants bold enough to walk through them.

The same type of clouds was observed in the eruption of Mt. Pelee on the island of Martinique, which engulfed the populous town of St. Pierre. Here the first clouds reached such proportions that, in spite of the enormous explosive force with which they were expelled from the mountain, gravity promptly asserted itself and they rolled down the slopes with appalling swiftness.

Carried Hundreds of Miles

The finer material in a pillar of cloud is carried off by the winds, often hundreds of miles. When the force of the explosion is sufficient to project it into the upper atmosphere, it may be held in suspension for several years and carried around the world. Sunsets are more colorful for a time, and the heat received by the earth from the sun a trifle less. The coarser particles promptly fall to the earth. Boulders several feet in diameter will be found near the vent, whereas finer dust particles may be precipitated many miles away.

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