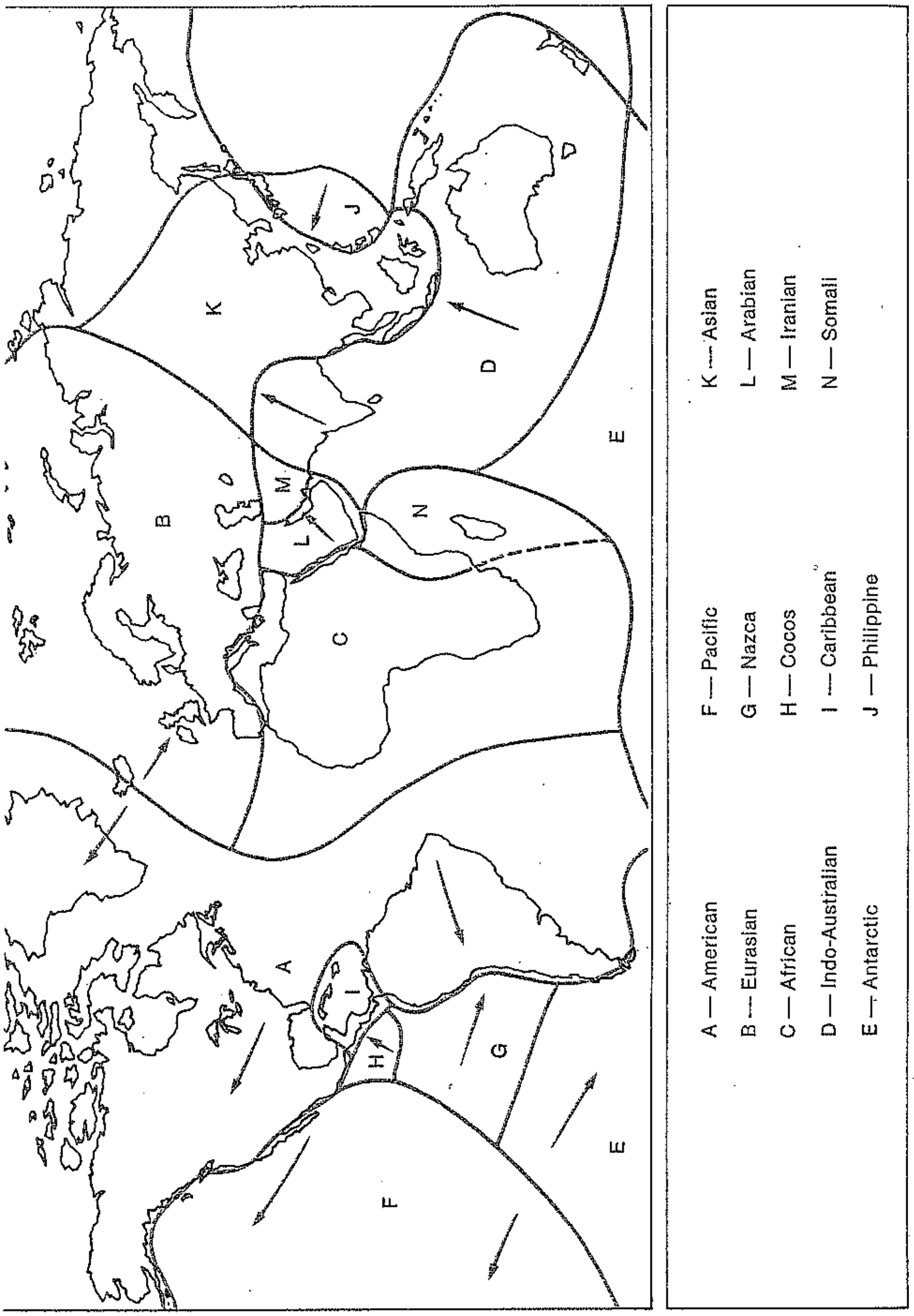


FIGURE 6:8 *Plate Boundaries*

STRUCTURES DUE TO VOLCANISM

As we mentioned earlier, the material beneath the earth's crust is in a solid or plastic state despite its intense heat, because the pressures on it are so great that melting cannot occur. When, for some reason, these pressures are reduced, the material becomes molten and is forced toward the surface. The process involving the transfer of magma from one area to another is known as *volcanism*. The rock structures formed by volcanism can be divided into 2 groups according to the location at which the cooling of the magma takes place.

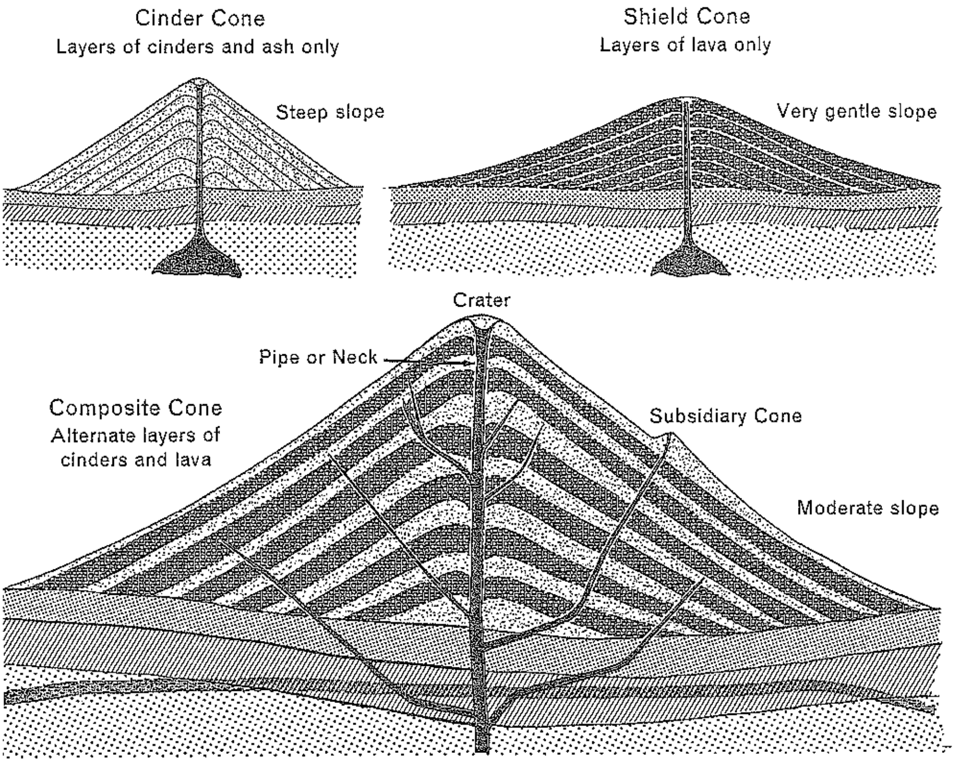
EXTRUSIVE FORMS

When the magma flows out onto the surface of the earth it is said to extrude. The structures resulting are called *extrusive forms*. If a portion of the earth's crust is particularly weak, large volumes of magma may well up through cracks and spread over the surface. In this way, lava flows of considerable thickness and extent may be built up. Under such conditions, existing landforms may be covered by the lava and the resultant structure is a plateau. An excellent example is the Columbia Lava Plateau of the northwest United States, where an area of over 500 000 km^2 has been buried beneath lava flows totalling 0.8 km in depth.

When, however, only a small opening is made in the crust, the molten lava and other material — in the form of rock fragments and incandescent dust — gradually build up a cone-shaped structure surrounding this opening. Such a formation is known as a *volcano*. The funnel-shaped opening at the top of the cone is called the *crater*. As material is ejected through this opening, the force of the explosion sometimes blasts off the walls of the crater or so weakens them that they collapse. The great basin that is thus created is known as a *caldera*.

Types of Volcanoes. The shape of the cone will depend on the type of lava; volcanoes can be classified into 3 groups on this basis.

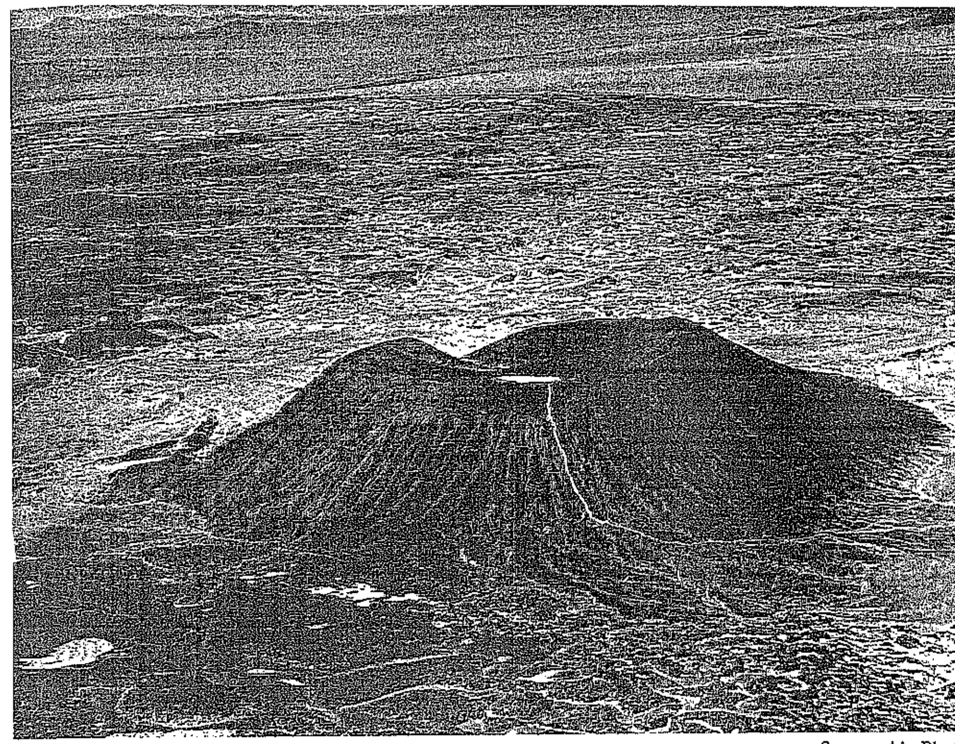
(a) *Cinder cone*. If an *acid magma*, made up of sialic minerals, is emitted, the molten rock cools quickly in the form of cinder and ash. The *cinder cone* type of volcano that results has steep sides and tends to be relatively small in size. Because of the rapid rate of cooling, the neck of such a volcano often becomes plugged before all of the gases and magma have escaped and, as a result, acid volcanoes are noted for their explosive nature. Many of the world's volcanic disasters, a few of which are described on pages 102-5, are associated with this type of volcano. Paricutín, a small volcano in Mexico that first erupted in February 1943 and grew to a height of 500 m by September of that year, is a good example of a recently formed cinder cone.



IGURE 6:9 *Cross-section View of the 3 Major Types of Volcanoes*

(b) *Shield cone*. A volcano formed from a *basic magma*, composed of imatic minerals, has quite different characteristics. The basic magma, be-ause it cools much more slowly, spreads over a large area in the form of heets of lava. The resulting volcano grows to a great size and has gentle lopes. Mauna Loa in Hawaii, a good example of such a *shield volcano*, rises)000 m above the floor of the Pacific Ocean and thus is comparable in height o Mount Everest. Because the basic magma flows freely and the contained ;ases escape easily, this type of volcano has a low explosive tendency.

(c) *Composite cone*. The third class of volcanoes are those formed from ι magma that is a mixture of sialic and simatic elements. Because such a 'olcano builds up in alternate layers of lava and ash, it is known as a *com-)osite* type. The lava layers permit the composite cone to attain a considerable vidth and the layers of cinders encourage vertical growth. As a result, some)f the world's highest volcanic mountains are composite cones, formed in his way. Mount Etna in Sicily and Mount Rainier in the state of Washington ıre good examples of this type.



Spence Air Photos

FIGURE 6:10 *Amboy Crater, California.* Amboy Crater, with its steep sides and small size, is a good example of a cinder-cone volcano.

Volcanoes can also be classified on the basis of their present degree of activity. *Active* volcanoes include the cones that are now erupting or show some sign of internal unrest. Currently inactive volcanoes that have erupted in historic times and show possibilities of future eruption are said to be *dormant*. If no future activity appears possible, a volcano is classified as *extinct*.

Destructive Effects of Volcanism. People generally associate volcanic disasters with tremendous explosions in which rock fragments rain down upon the neighbouring countryside, or with flows of hot lava that cover the surrounding land. While these activities are spectacular and do have a devastating effect, other related phenomena, such as tsunamis, nuées ardentes, and earthquakes, may be even more disastrous. The nature and intensity of these phenomena can be seen in the explosions of the 3 famous volcanoes described on the following page.

Consulate of Japan, Toronto

FIGURE 6:11 *Mount Fuji, Japan.* This composite cone, now extinct, is the highest and most famous mountain in Japan. Rising to a height of 3700 m, it overlooks Tokyo Bay.

Vesuvius. Mount Vesuvius, located 11 km from Naples, was looked upon, before the Christian era, as a dormant volcano. Pressure was building up in the volcano, however, which resulted in a series of earthquakes beginning in A.D. 63 and which culminated in a tremendous explosion in A.D. 79. Rock fragments and dust thrown into the air by the explosion immediately darkened the daytime sky and, within the space of a few hours, settled on the surrounding countryside. The neighbouring town of Pompeii was covered by 6-9 m of suffocating volcanic dust, which buried the unfortunate people who had chosen to remain in the town. Recent excavations have revealed to us the state of panic of these people as disaster struck. In the intervening years, Mount Vesuvius has continued to be active, with major eruptions occurring in 1906 and 1944.

Krakatoa. The volcanic island of Krakatoa, located in the Sunda Strait between Java and Sumatra, provides a good example of the explosive nature of East Indian volcanoes. After being dormant for 200 a, Krakatoa began to show signs of activity in May 1883 with the emission of steam from its

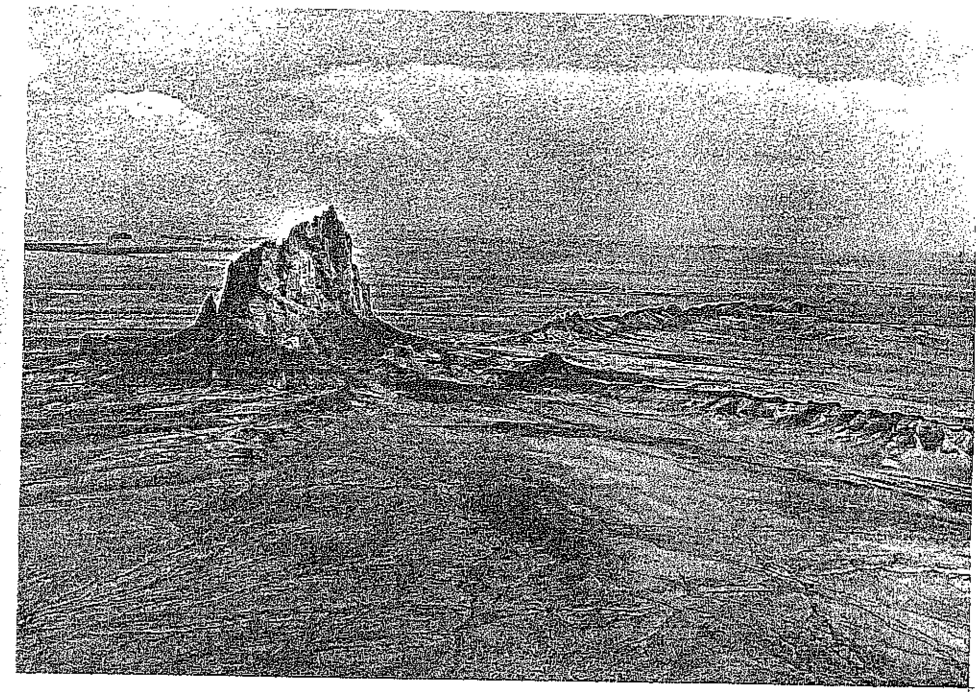


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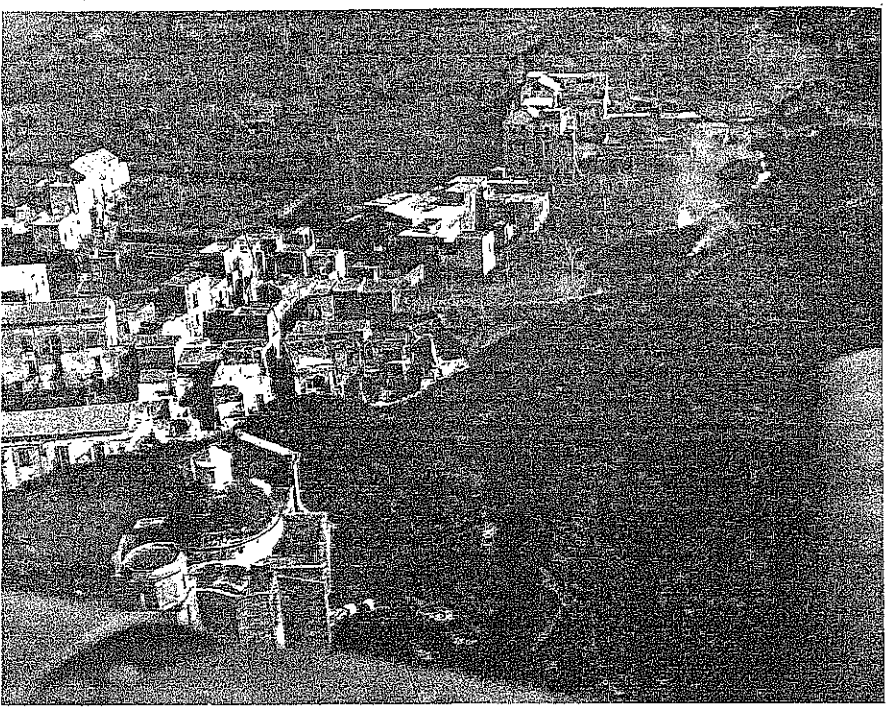
FIGURE 6:12 *Shiprock, New Mexico.* This volcanic neck represents the plug of hardened lava that filled the pipe of a volcano whose sides have since eroded away. Notice the dikes radiating out from the neck.

crater. This was followed, during the next 3 months, by a series of small explosions and earthquakes. The climax was reached on the morning of August 27, when 4 stupendous explosions occurred. The greatest of these explosions produced a noise that was heard 4800 km away in Australia, generated a wave of air pressure that broke windows 160 km away in Batavia, Java, and sent a cloud of glowing ashes 80 km into the atmosphere. A later study of the island showed that the explosions, considered greater in strength than the blast of a hydrogen bomb, had destroyed over 60% of the island and had produced a caldera with a diameter of 6 km.

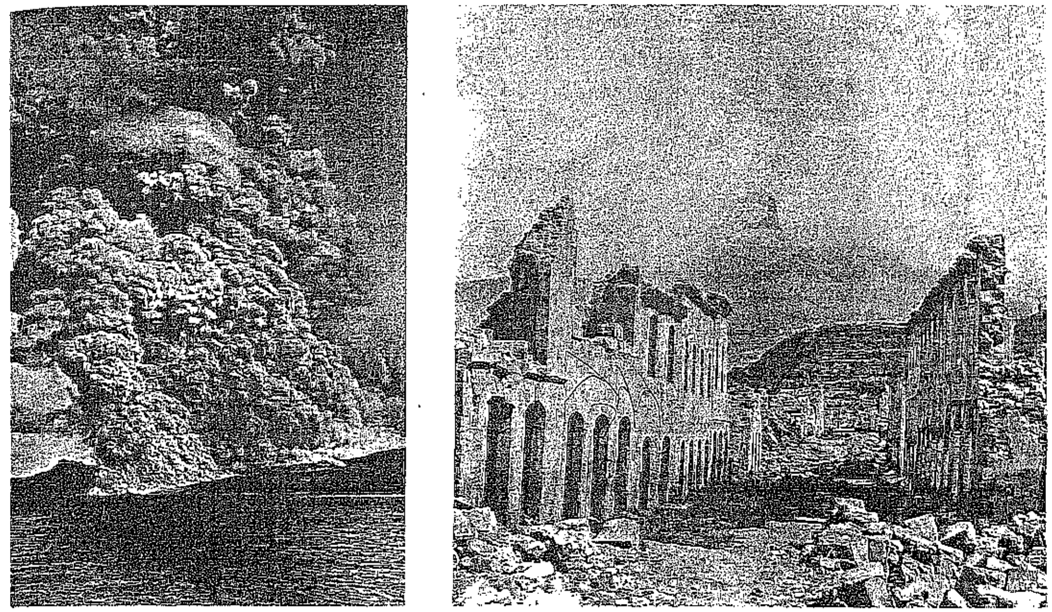
Because Krakatoa was uninhabited at the time of the explosions, the loss of life in the immediate vicinity was small. The explosions, however, generated great sea waves called *tsunamis.* These waves swept across the adjacent waters and, having a height of as much as 40 m, destroyed many seacoast villages on Java and Sumatra. Thirty-six thousand people were drowned by the sea waves produced by the Krakatoa explosions.



Official U.S. Navy Photo

ɛ 6:13 *Lava Flow.* A carpet of lava from Mount Vesuvius sweeps down over the of San Sebastiano on March 25, 1944, evidence that this volcano is still in an state.

ount Pelée. At the turn of the century, St. Pierre was a busy seaport e island of Martinique, a French territory in the Caribbean. The city a picturesque tropical setting, with the landscape dominated by Mount , a dormant volcano located 8 km inland. In April 1902 slight tremors felt and steam began to rise from the summit of the volcano. This was rst activity since 1851. In the course of it, a viscous lava rose up the of Mount Pelée, where it hardened and blocked off the normal exit for nagma and gases inside. While some gases escaped through cracks, formed in the volcano's walls below the plug, the pent-up forces in olcano grew in intensity. Finally, on May 8, an explosion blasted an ing in the south wall of the volcano. A large dark cloud of extremely team and other gases, collectively called a *nuée ardente,* burst through opening and swept down the side of the mountain at a speed of almost /min. Sweeping down upon St. Pierre with the fury of a hurricane, this y "burning cloud" set the town in flames and within seconds annihilated

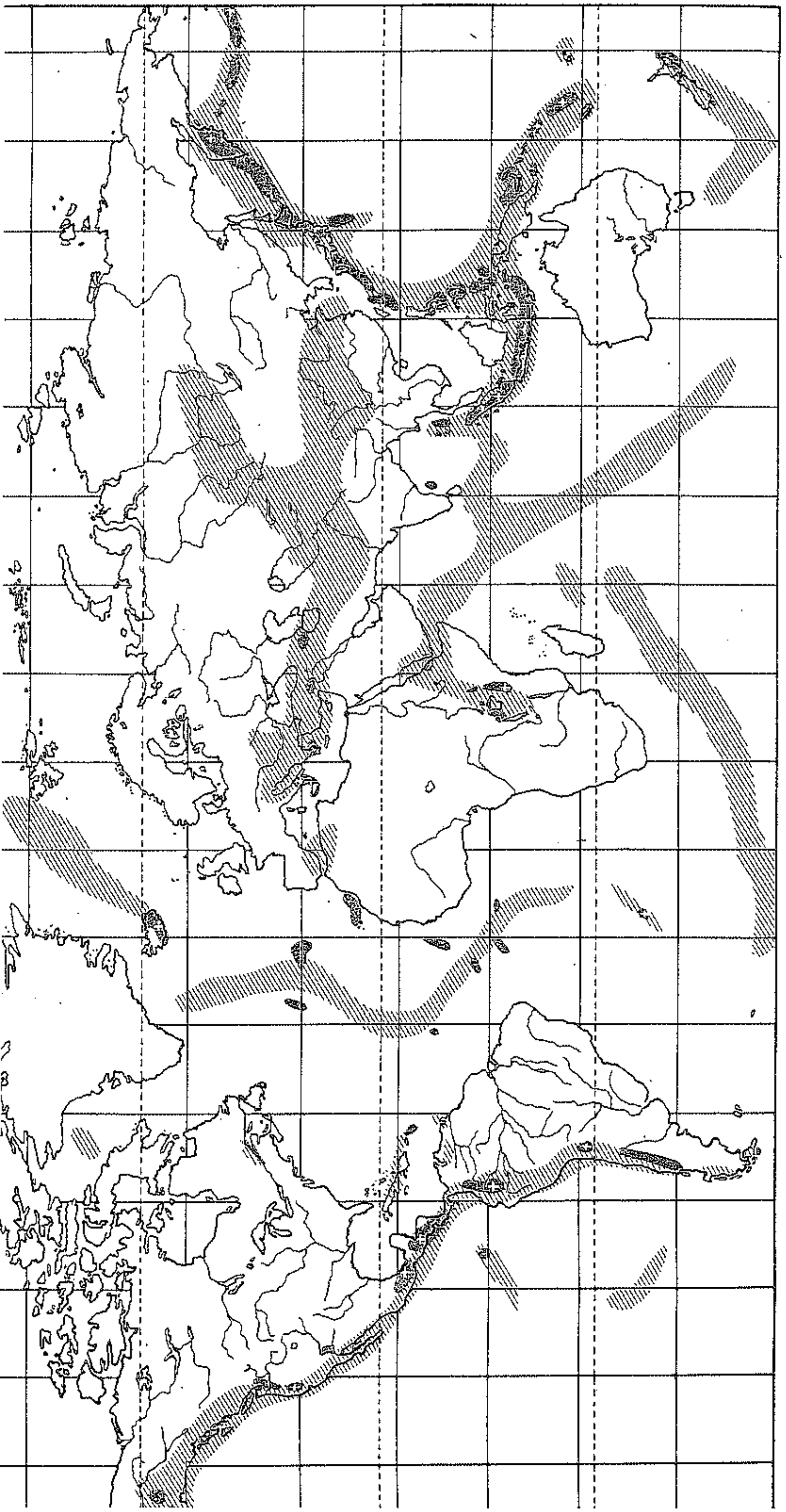


Photos courtesy of the American Museum of Natu

FIGURE 6:14 *Mount Pelée.* (*Left*) Nuée ardente erupting from Mount Pelée and sweeping rapidly down to the sea. (*Right*) The ruins of St. Pierre following the devastating eruptions of 1902. The plug of the volcano can be seen in the background.

all but one of the 30 000 inhabitants. The only survivor was a murderer under sentence of death, who had been locked in an underground dungeon with poor ventilation. The irony of the situation is compounded by the fact that the people of Martinique had received a warning of the impending disaster only 2 d earlier when a similar nuée ardente had wiped out a small town on the nearby island of St. Vincent. In the years since this disaster numerous nuées have been emitted from Mount Pelée, but all have descended to the sea at points well north of St. Pierre.

Beneficial Effects of Volcanism. Although the destructive effects of volcanism are better known because of their spectacular nature, volcanism also has been beneficial. Soils derived from mineral-rich volcanic rock have helped create some of the most productive farming regions in the world. The island of Java is a good example of this. This small island, whose soils are constantly being enriched with the residue of over 30 active volcanoes, is described as the world's most productive tropical area. Its economy, based mostly on its agriculture, supports a population of over 50 000 000 people. Other areas where rich volcanic soils have favoured agriculture include Hawaii, the



6:15 *Volcanic and Earthquake Regions of the World*

Columbia Plateau of the northwestern United States, and the highlands of Kenya in East Africa. The most important benefit from volcanism, however, does not occur on the surface but below it, as we shall discover in the section on intrusive forms.

Volcanic Regions. The chief active volcanoes are, of course, indications of crustal weaknesses in the earth. When plotted on a map (Figure 6:15), they appear in 2 great belts. One is the so-called "ring of fire", which practically surrounds the Pacific Ocean and includes such famous volcanoes as Fujiyama in Japan, Popocatépetl in Mexico, and Aconcagua, the highest peak in the Andes. The other belt of eruptions lies along an east-west line through the Mediterranean Sea. The most famous cone of this group is, of course, Mount Vesuvius.

Earthquakes are generally associated with the same regions of the world as volcanoes. A study of earthquakes is logically included at this point, although an earthquake is not, strictly speaking, a type of landform. If any settling of the earth's crust takes place suddenly, a disturbance is created that may be felt for thousands of kilometres. These movements, known as earthquakes, send out wave motions through the earth's crust that decrease in intensity according to the distance from the "seismic" centre. As we stated earlier, these waves react differently in their passage through the different layers of the earth and, by recording their intensity and direction on seismographs, it has been possible to learn much about the composition of the earth.

The main centres of earthquake activity lie around the Pacific Ocean, where high mountains close to deep seas give rise to rather unstable conditions. The principal volcanic and earthquake regions of the world are shown on the map on the opposite page.

INTRUSIVE FORMS

Most of the magma that penetrates the lithosphere does not reach the surface. Instead, it solidifies in cracks and cavities that it has made as it has forced the surrounding rock apart. Since this magma actually "intrudes" upon the overlying rocks, the structures created are called *intrusive forms*. Figure 6:16 illustrates the various structures of this type.

Magma that cools in a vertical crack forms a wall, or *dike*. Magma that flows between strata of sedimentary rock forms a thin but extensive sheet, or *sill*. (See Figures 6:21 and 6:22.) If the volume of magma is large enough to raise up the overlying strata, the resulting dome of igneous rock is called a *laccolith*. However, when a huge mass of magma has intruded into a wide area and has no known depth, it is called a *batholith*. The Coast Range of British Columbia is a giant batholith of granite that has been exposed by the erosion of the overlying crust.

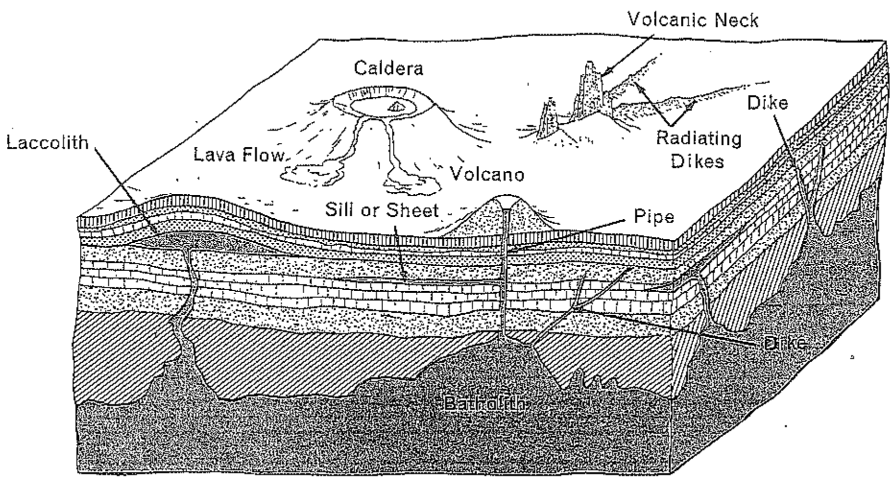


FIGURE 6:16 *Intrusive and Extrusive Structures Associated with Volcanism*

The intrusive structures do not have as striking an effect on the land surface as the products of other tectonic activity. However, they are of major importance because of the mineral deposits associated with them. Most of the highly mineralized areas of the world are ones where intrusions of magma have caused a metamorphism of the existing rocks.

STRUCTURES DUE TO DOMING

The internal forces rarely exert uniform pressures over large surfaces. Instead, they are localized. As a result, the surrounding rock may be forced up into dome-shaped structures. Although there are some examples of prominent domes that interrupt an otherwise flat surface (e.g., the Black Hills of South Dakota), domes are more characteristically giant swells in the landscape with shallow depressions in between. Such dome-and-basin topography is found in the Great Lakes area and in the sedimentary lowlands on either side of the English Channel.

STRUCTURES DUE TO FAULTING

Rocks under pressure or tension often *fracture* under the strain. If movement takes place along a fracture, a *rift* (or *fault*) is formed and the process is known as *faulting*. Along the line of a fault, one section of rock may be forced up or down to create a fault cliff, or *scarp*. Where many faults exist in an area, blocks may be elevated above adjacent regions along the fault lines to form flat tablelands, or *horsts*.

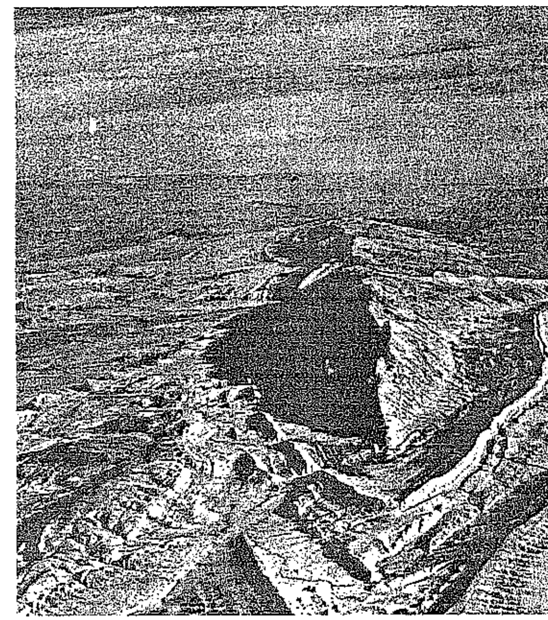


FIGURE 6:17 *Sheep Mountain, Wyoming*. Sheep Mountain is an eroded anticlinal structure. The core of igneous rock is exposed in the centre with the edges of the tilted sedimentary layers facing inward as hogback ridges.

Courtesy of the American

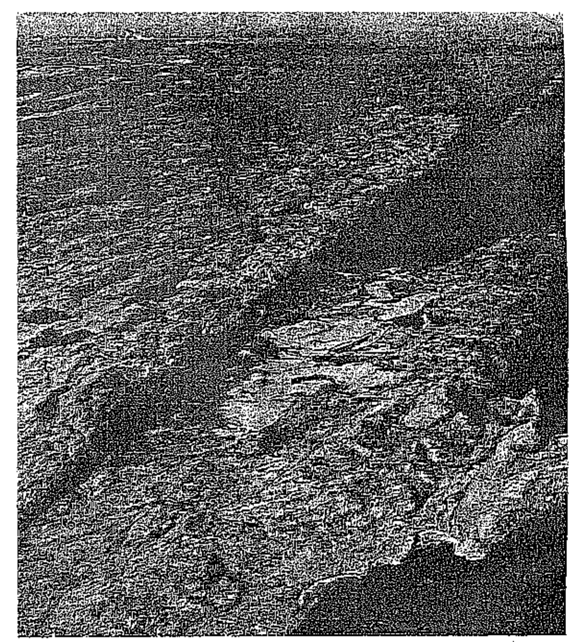


FIGURE 6:18 *A Fault Line Escarpment in the Northwest Territories.* The lake whose shore rests against the scarp is MacDonald Lake near Great Slave Lake. The area shown is a part of the Canadian Shield.

Original photo supplied by the Surveys and Mapping Branc Mines and Resources.