11.4: Environmental Hazards of the Geosphere

Having lain dormant for almost two centuries, the Eyjafjallajokull volcano, one of Iceland'slargest, began to ooze lava on March 20, 2010, visible as a red glow above the huge glacier covering the volcano. Initially, the eruption was nothing more than an interesting tourist attraction and the volcano appeared to revert to its normal state after a few days. However, on April 14 an enormous explosion sent volcanic ash as high as 11,000 meters followed by days in which the volcano spewed ash high into the atmosphere. This presented a significant problem for commercial aviation as the plume of volcanic ash spread eastward across the British Isles and northern and central Europe because volcanic ash can damage jet engines and even cause them to stop running. (In 1982 all four engines of a British Airways 747 stopped when it inadvertently flew into an ash cloud from Indonesia's Mount Galunggung and for several terrifying minutes what suddenly became the world's largest glider descended from 11,000 meters to 4100 meters before the engines restarted enabling an emergency landing in Jakarta.) The result of the Eyjafjallajokull eruption was that within two days most of Europe's major airports were closed canceling thousands of flights. Because of ripple effects across the world this incident became the worst peacetime travel disruption in history stranding millions of travelers, many with diminished financial resources from limited travel budgets. The result was a period of many days of travel chaos as flight bookings were rescheduled to eventually get travelers to their destinations. Airlines estimated financial losses of about $1.7 billion resulting from the cancellation of more than 100,000 flights.

The Iceland volcano eruption has been a reminder of the awesome, potentially destructive forces that reside in the geosphere and of the vulnerability of modern civilization to them. Along with earthquakes, volcanoes are geospheric phenomena that are beyond the power of humans to prevent or even accurately predict. Even in these cases, however, human activities can significantly influence the degree of damage done. As examples, structures constructed on poorly consolidated fill dirt are much more susceptible to earthquake damage than are those attached firmly to bedrock, and the construction of dwellings in areas known to be subject to periodic volcanic eruptions simply means that unstoppable lava flows and other volcanic effects will be much more damaging when they occur. Other, less spectacular, but very destructive geospheric phenomena can be greatly aggravated by human activities. Destructive and sometimes life-threatening landslides, for example, often result from human alteration of surface soil and vegetation.

Earthquakes

Earthquakes consist of violent horizontal and vertical movement of Earth's surface resulting from relative movements of tectonic plates. Plates move along fault lines. Huge masses of rock may be locked relative to each other for as long as centuries, then suddenly move along fault lines. This movement and the elastic rebound of rocks that occurs as a result causes the earth to shake, often violently and with catastrophic damage.

History provides many examples of astoundingly damaging earthquakes. Over 1 million lives(out of a much lower global population than now) were lost by an earthquake in Egypt and Syria in 1201 A.D. The Tangshan, China, earthquake of 1976 killed approximately 650,000. During the latter 1990s and early 2000s, a number of fatalities resulted from earthquakes in Turkey, Greece, Taiwan, Iran, India and China. The May 12, 2008, 7.9 magnitude Wenchuan earthquake in Sichuan Province, China, left 80,000 people dead or missing. Financial costs of earthquakes in highly developed areas are enormous; the 1989 Loma Prieta earthquake in California cost about 7 billion dollars. Phenomena caused by earthquakes can add to their destructiveness. In addition to their direct shaking effects, earthquakes can cause ground to rupture, subside, or rise. **Liquefaction** of poorly consolidated ground, especially where groundwater levels are shallow, occurs when soil particles disturbed by an earthquake separate and behave like a liquid, causing structures to sink and collapse. One of the more terrifying effects of earthquakes are giant ocean waves called **tsunamis** that can reach heights of as much as 30 meters. On December 26, 2004, a huge earthquake off the coast of Sumatra generated a tsunami up to 30 meters high, killing more than 150,000 people in countries around the Indian Ocean.

Earthquakes have defied all efforts to predict them, a fact that makes them all the more frightening. However, earthquake-prone areas, such as southern California, are well known, and loss of life and property can be minimized by taking appropriate measures. Buildings can be constructed to resist the effects of earthquakes using practices that have been known for sometime. For example, some buildings in Niigata, Japan, were constructed to be earthquake-resistant in the 1950s. When a destructive earthquake hit that city in 1964, some buildings tipped over on the liquified soil but remained structurally intact! (Current practice calls for the construction of more flexible structures designed to dissipate the energy imparted to them by an earthquake.) The construction of buildings, roadways, railroads, and other structures to withstand the destructive effects of earthquakes provides an excellent example of designing the anthrosphere in a manner that is as compatible as possible with the geosphere and the natural hazards it poses.

Although humans can do nothing to prevent earthquakes, there is some evidence that anthrospheric activities have helped cause them. Some seismologists have suggested that the pressure of water from newly constructed reservoirs in China provided lubrication that enabled earth movement. At least one experiment in injecting water into hot rock formations to produce steam for power had to be stopped because it caused a number of very small quakes detected by sensitive instruments.

Volcanoes

A volcano results due to the presence of liquid rock magma near the surface. In addition to liquid rock lava at temperatures ranging from 500˚C to 1400˚C that flows from volcanoes, these often very destructive phenomena are manifested by discharges of gases, steam, ash, and particles. Volcanic disasters have always plagued humankind. The 79 A.D. eruption of Mount Vesuvius in ancient Rome buried the city of Pompei in ash, preserving a snapshot of life in Rome at that time. The astoundingly massive eruption of Indonesia's Tambora volcano in Indonesia in 1815 was caused when water infiltrated the hot magma beneath the volcano resulting in an explosion equivalent to 100 million tons of TNT explosive and blasting an estimated 30 cubic kilometers of solid material into the atmosphere. The May 18, 1980, Mount St. Helens eruption in Washington State blew about 1 cubic kilometer of material into the atmosphere, killed 62 people, and caused about $1 billion in damage.

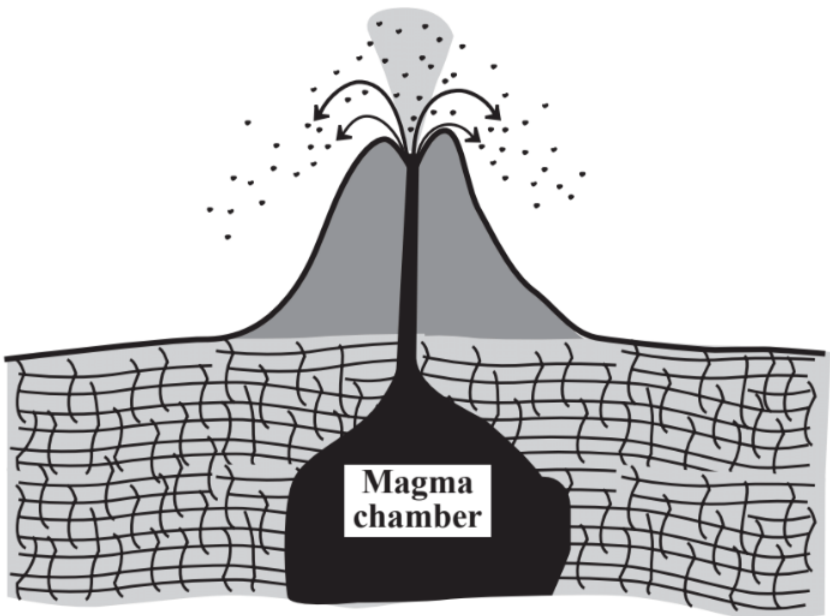

Figure 11.2. A volcano in a classic cone shape produced when molten lava and ash are ejected from a magma chamber underground.

In addition to their immediate effects upon surrounding areas, volcanoes can affect the atmosphere and climate. The Tambora volcano blasted enough particulate matter into the atmosphere to cause a very pronounced cooling effect. The following "year without a summer" caused global crop failures and starvation, and perceptible global cooling was observed for the next 10 years. Huge quantities of water vapor, dense carbon dioxide gas, carbon monoxide, hydrogen sulfide, sulfur dioxide, and hydrogen chloride may be emitted to the atmosphere in volcanic eruptions. People may suffocate in the carbon dioxide or be poisoned by the toxic carbon monoxide and hydrogen sulfide. Hydrogen chloride along with hydrogen sulfide and sulfur dioxide oxidized in the atmosphere to sulfuric acid can contribute to acidic rainfall. Volcanic emissions differ in their atmospheric chemical effects. The 1982 El Chichón eruption in Mexico generated little particulate mineral matter but vast amounts of sulfur oxides that were oxidized to sulfuric acid in the atmosphere. The tiny droplets of sulfuric acid suspended in the atmosphere effectively reflected enough sunlight to cause a perceptible cooling in climate.

Massive, atmospheric-damaging eruptions of volcanoes in recorded history have caused catastrophic crop failures. These will happen again. And since the world as a whole carries little food surplus from year to year, the certainty of food supply disruptions due to volcanic activity point to the desirability of storing substantial amounts of food for emergency use.

Surface Effects

Though less spectacular than major earthquakes or volcanic eruptions, surface earth movement causes enormous damage and significant loss of life. Furthermore, surface earth movement is often strongly influenced by human activities. Surface phenomena result from the interaction of forces that act to thrust earth upward countered by weathering and erosion processes(see Section 11.2) that tend to bring earth masses down. Both of these phenomena are influenced by the exposure of earth masses to water, oxygen, freeze-thaw cycles, alternate saturation with water and drying, organisms and human influences.

Landslides occur when finely divided (unconsolidated) earthen material slides down a slope.The results can be devastating. The 1970 earthquake-initiated landslide of dirt, mud, and rocks on the slopes of Mt. Huascaran in Peru may have killed 20,000 people. A 1963 landslide on slope surrounding a reservoir held by the Vaiont Dam in Italy suddenly filled the reservoir causing a huge wall of water to overflow the dam killing 2600 people and destroying everything in its path.

Along with weather and climate, human activities can influence the likelihood and destructiveness of landslides. Roads and structures constructed on sloping land can weaken the integrity of earthen material or add mass to it, increasing its tendency to slide. In some cases, strong root structures of trees and brush anchor sloping land in place. However, some plant roots destabilize and add mass to soil, increase the accumulation of water underground, and cause earth to slide. Fortunately, predicting a tendency for landslides to occur is relatively straightforward based upon the nature and slope of geological strata, climate conditions, and observations of evidence of a tendency toward landslides, such as movement of earth and evidence of cracked foundations in buildings built on slopes. In some cases remedial actions may be taken, but more important are the indications that structures should not be built on slide-susceptible slopes.

Less spectacular than landslides is **creep** characterized by a slow, gradual movement of earth. Creep is especially common in areas where the upper layers of earth undergo freeze/thaw cycles. A special challenge is **permafrost** which occurs in northern Scandinavia, Siberia, and Alaska. Permafrost refers to a condition in which ground at a certain depth never thaws, and thawing occurs only on a relatively thin surface layer. Structures built on permafrost may end up on a pool of water-saturated muck resting on a mixture of frozen ice and soil. One of the greater challenges posed by permafrost in recent times has been the construction of the Trans-Alaska pipeline in Alaska on a permafrost surface. Global warming is causing thawing of permafrost in Arctic regions such as parts of Siberia and is resulting in significant structural damage.

Expansive clays that alternately expand and contract when saturated with water, then become dried out, can cause enormous damage to structures, making the construction of basements virtually impossible in some areas. **Sinkholes** occur in areas where rock formations are dissolved by chemical action of water (particularly dissolved carbon dioxide acting on limestone). Earth can fall into a cavity generated by this phenomenon causing huge holes in the ground that can swallow several houses at a time.
