Answers to the Review Questions Chapter 5

1. The eruptive cycle represented the ascent of a “new” batch of magma from depth. This eruption was the most powerful in the cycle. After some early, small-volume, ash eruptions, a small magma chamber high in the cone began inflating (filling with more magma). However, the chamber expanded horizontally rather than vertically, causing the upper portion of the cone to bulge outward and, in a sense, to overhang the lower flanks. When this bulged mass of rock broke away from the main cone and slid rapidly downhill, the magma chamber was suddenly 'opened' to the atmosphere and decompressed, generating the powerful May 18 eruption (Box 5.1).

2. The three factors that determine the nature of a volcanic eruption are magma composition, temperature, and the amount of dissolved gases. To varying degrees, these factors affect or control the viscosity of magma. More viscous magmas resist flow and do not allow the dissolved gases to escape during ascent, thus they produce much more explosive eruptions than do magmas with lower viscosities.

Composition is the most important factor affecting viscosity in that higher silica magmas tend to be much more viscous. Consequently, rhyolitic magmas are extremely viscous, producing violent eruptions whereas basaltic magmas are much more fluid. Temperature has an obvious effect on viscosity in that hotter magmas are less viscous. Dissolved gases tend to increase fluidity (decrease viscosity) and ultimately it is the force of these gases escaping from a magma that drives a volcanic eruption.

3. The more fluid magma is typically hotter and has a lower volatile content than the more viscous magma. The most important difference is that the more viscous magma has much more mechanical strength to resist movement and expansion of gas bubbles, thus confining the volatiles, promoting the buildup of excess pressure in the magma chamber, and increasing the likelihood of an explosive event. In a fluid magma, the gas bubbles can freely expand, rise, and escape from the magma chamber, reducing the probability of an explosive eruption.

4. These terms describe basaltic lava flows with different surface and flow-front characteristics. Aa flows are relatively thick with high, steep, flow fronts; their surfaces are covered with angular, congealed, lava rubble. Pahoehoe flows are thinner, the flow fronts are more gently sloping, and the surface is smooth or rippled (ropy). As the pahoehoe flow advances, small lava prongs break out, forming rippled areas that move a short distance beyond the main flow front. When pahoehoe lava congeals, the smooth, rippled surfaces are preserved.

5. Water (H₂O) is generally the dominant gas; carbon dioxide (CO₂) is typically the second most abundant gas in Hawaiian eruptions, but can be dominant at specific volcanoes, such as Mt. Vesuvius. In other eruptions, such as El Chichon, Mexico, and Pinatubo (Philippines), sulfur dioxide (SO₂) was the dominant
volatile. Nitrogen (N₂), hydrogen (H₂), argon (Ar), hydrogen chloride (HCl), and hydrogen fluoride (HF) may also be released to the atmosphere during eruptions and fumarolic activity. Dissolved gases are important in volcanism because the large volume expansion that accompanies their dissolution from the melt pushes magma upward toward the surface and generates explosive overpressures in silicic magma chambers.

6. Both are pebble-sized or larger pyroclastic fragments. Bombs are cooled from ejected magma blobs. They typically have very fine-grained, chilled margins, are vesicular, exhibit surface patterns characteristic of solidified liquid, have rounded, twisted shapes produced in flight, and may be flattened and cracked on impact. Essentially all bombs are vesicular to a greater or lesser extent. Blocks are lithic clasts broken from preexisting rock. They are typically angular and show none of the morphological features associated with impacts, in-flight movements, and solidification of liquid or partly liquid magma masses. Blocks may or may not be vesicular. If present, the vesicles show no particular relationship to edges or interior portions of the blocks.

8. A volcanic crater is a relatively small depression marking the vent or exit site of erupting lava or pyroclastic material. A crater is excavated by the boring or drilling action of the erupting magma and gases. A caldera is a much larger volcanic depression that forms during or following a large outpouring of lava or pyroclastic debris. Extremely rapid emission of huge quantities of magma, such as occurs during a powerful explosive eruption, evacuates upper portions of the former magma chamber. Thus, the rocks above the chamber fail and a large, circular to elliptical volcanic depression is formed by collapse and subsidence.

9. Volcanoes are constructed of erupted volcanic material. With the exception of basaltic cinder cones, volcanoes are products of many eruptions and generally have long (a million years or so) eruptive histories. Cinder cones are small, fairly steep-sided cones comprised mainly, or entirely, of basaltic ash and cinders; they develop during a single, short-lived, eruptive cycle. Internal layering in the pyroclastic strata is parallel to external slopes. Shield volcanoes are very large, gently sloping, dome-shaped mounds built of successive outpourings of basaltic lavas. Composite volcanoes (stratovolcanoes) are massive, steep-sided, volcanic cones built from repeated outpourings of lava and pyroclastic material. Composite volcanoes may erupt some basalt, but are more likely to erupt andesite and other magmas richer in silica, such as rhyolite. Internal layering of lavas and pyroclastic beds is roughly parallel to the external slopes of both shield and composite volcanoes.

10. Cinder cone - Sunset Crater (Fig. 5.14) near Flagstaff, AZ, is a very young, well-preserved, basaltic cinder cone. It was formed about 900 years ago. Sunset Crater, numerous nearby cinder cones, and associated basaltic lava flows have been set aside as a national monument. Composite volcano - The great volcanoes of the world such as Vesuvius near Naples, Italy; Pinatubo in the Philippines; and the Cascade Range volcanoes in Oregon, Washington, and northern California, are good examples. Shield volcano - The very large basaltic volcanoes of Hawaii (Mauna Loa and Kilauea) are good examples.

11. Paricutin is a small, basaltic cinder cone that formed in a cornfield in southern Mexico during a few years of eruptive activity in the 1940s. During the cone-forming phase, mainly pyroclastic materials (bombs, cinders, and ash) were erupted; later in the eruptive cycle, lava flows broke out from the base of the cinder cone and spread over the surrounding countryside. After a few years of continuing activity, the eruptive episode ended as abruptly as it had started.
Kilauea is the most active volcano on Hawaii, the largest of the Hawaiian Islands, and is part of a massive, basaltic, shield volcano complex that forms the island. Eruptions are mainly fluid, basaltic lava flows and minor pyroclastic activity. The volcanic activity began millions of years ago when submarine lava flows were erupted on the ocean floor. With continued activity, a massive, mound-shaped seamount was constructed; eventually it grew above sea level, forming the present-day island of Hawaii.

12. A nueé ardente generated by the 1902 explosive eruption of Mt. Pelé devastated the city of St. Pierre. The nueé ardente was evolved from a massive, pyroclastic flow that sped to the sea along a stream valley outside the city. However, at a fairly sharp curve in the valley, the nueé ardente portion of the flow jumped a low ridge and bore on straight toward the city. It was all over in a few minutes. The hot, violently turbulent, dust-and-ash cloud, moving at hurricane speeds, flattened buildings and suffocated all living beings in its path. Only a few centimeters of hot, very-fine size ash were deposited over the ruined city.

Pompeii and its sister city of Herculaneum were buried over a three to four day, cataclysmic phase of the 79 A.D eruption of Mount Vesuvius. Pompeii was buried by 20 to 30 feet of airfall pumice and ash. Written accounts and archeological excavations suggest that many people escaped during the early phase of the eruption, and others managed to survive a day or two before succumbing to thirst and suffocation. Herculaneum was evidently buried suddenly by mudflows or pyroclastic flows unleashed simultaneously with, or shortly following, the phase of the eruption that buried Pompeii. Additional, detailed, historical accounts and geological interpretations of the Vesuvius eruption can be found in “Volcanoes of the Earth” by Fred Bullard (1976).

13. Crater Lake (Oregon) caldera is about six miles in diameter. It formed following a major eruption of ash and pyroclastic flows about 7000 years ago. Glacial valleys cutting through the caldera rim and other geologic evidence prove that a complex, composite volcano once existed above the site of the present-day caldera. Indian legends and geological evidence suggest that the former mountain, Mount Mazama, had subsided within a few days following the end of the eruption. In contrast, the summit caldera block of Kilauea is about three miles in diameter and acts somewhat like a floating cork, rising when magma is accumulating and sinking after an eruption. The rising and sinking movements are gradual as contrasted with the catastrophic collapse that follows large-volume pyroclastic flow eruptions.

24. The “Ring of Fire” refers to the volcanic mountain ranges and islands that surround much of the Pacific Ocean. Many of the active volcanoes on Earth today are located on the “Ring of Fire.”

26. Very large, composite volcanoes (stratovolcanoes), like those on the “Ring of Fire,” typically erupt explosively. The 1991 eruption of Pinatubo in the Philippines was the second most powerful eruption of the twentieth century, being surpassed only by the 1902 eruption of Santa Maria in Guatemala. The 1980 eruption of Mount St. Helens is another good example.

27. Magma generation along convergent plate boundaries is associated with subduction zones. Partial melting along a subducting slab seems to begin at depths around 100 km. Fluids released from the slab promote melting of hot peridotite in the overlying lithosphere. Also, materials at the top of the slab, such as sediments, hydrated volcanic rocks, and continental-rock slivers are in contact with hot, non-slab peridotite and may undergo partial melting. As the slab tip penetrates to deeper levels, upward, counter
flows of hot peridotite are set in motion, resulting in decompression melting and production of basaltic magma. If the slab is cool and dense enough at the start of subduction, it may sink, unmelted, to depths as great as 700 km, as indicated by the deepest-known earthquake foci.

29. Hot spot volcanism refers to the volcanic activity produced at localized areas not related to tectonic plate boundaries. Hot spots are thought to be the result of large heat plumes in the mantle that induce melting in the overriding lithospheric plate. Yellowstone National Park in Wyoming and the island of Hawaii are good examples of hot spot volcanism.

31. Both Yellowstone and the Hawaiian Islands are associated with hot spot volcanism, as evidenced by the track of volcanic activity and the lack of a plate boundary at both locations. The Cascade Range is a volcanic arc produced at a convergent plate boundary where oceanic crust is being subducted under the North American continental plate. Flood basalt provinces, such as the Columbia Plateau and the Deccan Traps in India, are also the result of hot spot volcanism. The mantle plumes responsible for such vast outpourings of lava are perhaps much larger than those responsible for Hawaii and Yellowstone.

32. Short-term climatic changes produced by volcanic eruptions are caused by the release of large quantities of sulfur dioxide gas, which combines with water to produce tiny droplets of sulfuric acid. These droplets, called aerosols, reflect solar radiation back into space while remaining in the atmosphere for several years. Carbon dioxide, one of the gases released during volcanism, may have a long-term effect on climate because of the greenhouse effect. Carbon dioxide allows short-wavelength solar radiation to reach the surface, but it absorbs some of the longer-wavelength radiation emitted by Earth, this heating the lower atmosphere.