End of Chapter Question Answers
Chapter 4

Review Questions

1. Describe the three processes that are responsible for the formation of magma.
Answer: Magmas form from melting within the Earth. There are three types of melting: *decompression melting*, where magmas form when hot rock from deep in the mantle rises to shallower depths without undergoing cooling (the decrease in pressure facilitates the melting process); *flux melting*, where melting occurs due to the addition of volatiles such as CO_2 and H_2O; and *heat transfer melting*, where melting results from the transfer of heat from a hotter material to a cooler one.

2. Why are there so many different compositions of magma? Does partial melting produce magma with the same composition as the magma source from which it was derived?
Answer: Magmas are formed from many different chemical constituents. Partial melting of rock yields magma that is more felsic (silicic) than the magma source because a higher proportion of chemicals needed to form felsic minerals diffuse into the melt at lower temperatures. Magma may incorporate chemicals dissolved from the solid rock through which it rises or from blocks of rock that fall into the magma. This process is called assimilation. Finally, fractional crystallization can modify magma composition as minerals crystallize out of a melt during the cooling process, causing the residual liquid to become progressively more felsic.

3. Why does magma rise from depth to the surface of the Earth?
Answer: Magma rises toward the surface of the Earth because it is less dense than solid rock and buoyant relative to its surroundings. Buoyancy lifts magma upward through denser rock just as buoyancy lifts less dense Styrofoam upward through denser water. Magma also rises because the weight of the overlying rock produces pressure at depth that literally squeezes the magma upward.

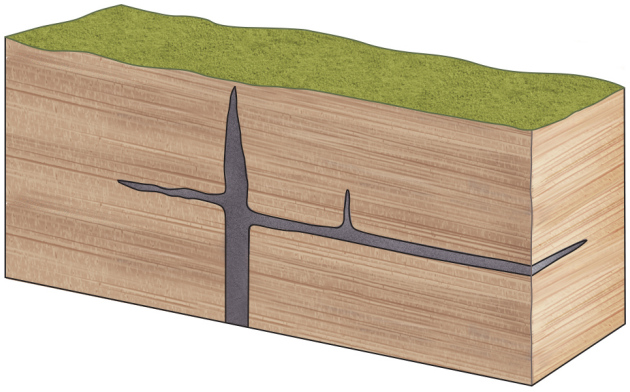
4. Explain the process of fractional crystallization.
Answer: During fractional crystallization minerals that melt and crystallize at higher temperatures solidify and crystallize first and are removed from the melt. This process creates a liquid melt that is changed in composition. As cooling continues minerals progressively crystallize out and produce changed magma compositions. Because fractional crystallization progressively extracts iron and magnesium from the magma, the magma that remains as fractional crystallization takes place becomes progressively more felsic (silicic).

5. What factors control the viscosity of a melt, and how does viscosity affect the behavior of magma or lava?
Answer: Viscosity in a melt is controlled by its composition (specifically, silica content) and temperature. Temperature affects viscosity because heat causes chemical bonds to break more easily. Therefore, a hotter lava of a given composition is less viscous than a

cooler lava of the same composition. Magmas and lavas with higher viscosity are stickier and flow less smoothly.

6. What factors control the cooling rate of a magma?
Answer: The main factor that affects the cooling time of a magma is how fast heat transfers from the melt into its surroundings. The rate of heat transfer depends on the temperature of the environment in which cooling takes place, the shape and size of the molten mass, and the ability of the surroundings to extract heat.

7. What is the difference between a sill and a dike, and how do both differ from a pluton or batholith? Identify the intrusions shown.



Answer: A sill is a tabular, horizontally oriented igneous intrusion, while a dike is a tabular, vertically oriented intrusion. A sill intrudes parallel to pre-existing layering while a dike cuts across pre-existing layering (bedding or foliation) of wall rock. Plutons and batholiths are larger igneous intrusions that are irregular or blob-shaped and may be hundreds of kilometers wide (in the case of a batholith). This figure shows a tabular intrusion.

8. How does grain size reflect the cooling rate of a magma?
Answer: Slow cooling tends to result in larger, coarser crystals in an igneous rock. In general, finer-grained igneous rocks cool quickly, while coarser-grained rocks cool slowly.

9. Why do magmas form in association with subduction?
Answer: In subduction zones volatiles like water are introduced into the asthenospheric mantle above the subducting slab. The volatiles lower the melting temperature of the mantle, thus facilitating the melting process. This type of melting is known as flux melting.

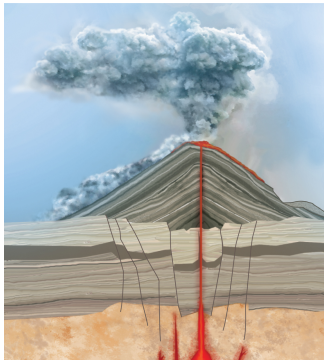
10. Why does melting take place beneath the axis of a mid-ocean ridge?
Answer: At mid-ocean ridges, underlying hot asthenosphere rises from below. Decompression melting occurs in these peridotites at shallow depths as they rise, resulting in mafic magmas.

11. What process in the mantle may be responsible for causing hot spot volcanoes to form?
Answer: Hot spots form where a column of very hot asthenosphere rises from deep in the mantle up to the base of the lithosphere. The rock at the top, or *head*, of the plume

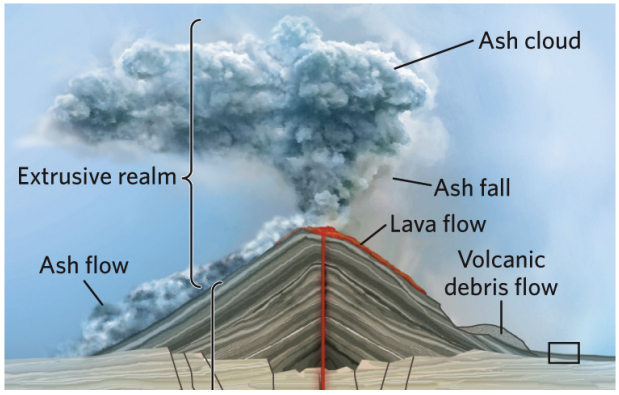
undergoes decompression melting and produces large volumes of mafic magma which erupts on the surface.

12. Describe how magmas are produced at continental rifts. Why can you find both basalt and rhyolite in such settings?
Answer: At continental rifts thinning of the lithosphere causes decompression melting of the underlying asthenosphere which in turn produces mafic magmas. Some of these mafic magmas erupt as basalt. Because the continental crust is relatively thick, some of the magmas rise slowly and may undergo fractional crystallization, which can generate more felsic magmas. In addition, heat-transfer melting of the crust may occur which also leads to more felsic compositions such as rhyolite.

13. What is a large igneous province (LIP), and how might it form?
Answer: A large igneous province (LIP) contains an immense volume of low-viscosity mafic lava that has erupted over a relatively short time and spread out in vast flows, some of which extend over 500 km from the vent. Examples include the Columbia River Plateau in the United States and the Deccan Traps in India.



14. Describe three different kinds of material that can erupt from a volcano. Identify them on the figure.
Answer: Volcanoes can erupt a variety of products including lava, pyroclastic material including ash, lapilli, and bombs, lahars (mudflows), and gases.



15. Describe the differences among shield volcanoes, stratovolcanoes, and cinder cones. How does the composition of their lavas and other factors explain these differences?
Answer: Shield volcanoes are broad, gently-sloped structures formed by effusive eruptions. Cinder cones are symmetrical hills of lapilli (scoria). Stratovolcanoes are large, cone-shaped structures that consist of alternating layers of pyroclastic debris and lava. Magma composition is important because it influences eruptive style and the types of volcanic products that emanate from the volcano, which in turn influences the type of volcanic structure that develops.

16. Identify some of the major volcanic hazards and explain how they develop.
Answer: Volcanic hazards include lava flows, ash, pyroclastic flows, lahars and landslides, and tsunamis. Lava flows are rivers of moving molten rock on the surface, and erupt primarily from effusive volcanoes like shields. Ash and pyroclastic flows result from explosive eruptions in which fragmentation in the eruption column forms tephra (fragmental material) that either falls to Earth (ash fall) or flows out of the eruption

column as a density current of fragments (ash, lapilli, pumice) and gas that is capable of moving at hundreds of miles per hour. Lahars form when fragmental material such as ash and lapilli mix with water (either snow or ice, or from precipitation) and create a mud-like slurry which travels down river valleys adjacent to the volcano. Tsunamis (large geologically derived waves) can occur when volcanoes collapse near or into water or send volcanic materials into bodies of water, thus creating a hazardous wave. Earthquakes associated with volcanism can also cause tsunamis.

17. To what extent can geologists predict volcanic eruptions, and what observations provide the basis for a prediction?
Answer: Scientists can calculate the average time between eruptions (recurrence intervals) based on scientific information. Although it is not possible to predict the exact, long-term timing of eruptions. Scientists may be able to make short-term (weeks to months) predictions by examining earthquake data, changes in heat flow and gas emissions, and changes in the geometry and shape of volcanic structures (deformation).

18. Explain how steps can be taken to protect people from the effects of eruptions.
Answer: In many ways it is impossible to protect people from the effects of eruptions, other than to provide advance warning and evacuate those potentially affected in a timely fashion. Volcano monitoring techniques give us the ability to possibly forecast eruptions in the short term. Long term, a better understanding of volcanoes and eruptions, and more specifically knowing the eruptive histories associated with specific volcanoes, can allow scientists to identify hazards and create hazard maps with the goal of warning the public about the inherent dangers. In special circumstances (Iceland 1973, Italy 1669, 1983, 1992) humans have been able to divert the course of eruptions, but this is not always feasible.

On Further Thought

19. The Cascade Range of the northwestern United States is only about 800 km (500 miles) long. The volcanic chain of the Andes is several thousand kilometers long. Look at a map showing the Earth's plate boundaries and explain why the Andes volcanic chain is so much longer than the Cascade volcanic chain.
Answer: The volcanic chain in the Andes is longer than the Cascade chain because the convergent tectonic boundary is longer, and subduction occurs along a much longer axis. The length of the subduction zone is proportional to the length of the associated volcanic arc.

20. Do people living near the volcanoes of Hawaii face the same kind of volcanic hazards as do people living near Mt. Rainier in the northwestern United States?
Answer: People living in Hawaii do not face the same kind of volcanic hazards as those living near Mt. Rainier because the types of volcanoes and volcanic activity are different in the two locations. Hawaiian volcanism is typically passive and associated with lava flows and the formation of shield volcanoes; Cascade volcanism (which Mt. Rainier is associated with) is typically more explosive and associated with the formation of

stratovolcanoes. It also results in eruption columns that produce ash and pyroclastic flows (fragmental material). Because the styles of eruption are different the hazards are very different.