Answer Key

Study Questions

1. Favourable effects of volcanism:
   - production of fertile soil from weathered volcanic ash and lava (e.g., Hawaii)
   - creation of new land
   - generation of electricity and provision of space or water heating by geothermal energy

   Destructive effects of volcanism:
   - loss of life and burial of cities, etc., by hot ash
   - destruction of landforms and possibly whole islands through explosive eruptions and the creation of giant sea waves
   - alteration of world weather patterns through the solar filtration effect of fine particles and gases propelled into the atmosphere
2. Magma is molten rock.
3. *Mafic rocks* are silica-poor igneous rocks with a relatively high content of magnesium, iron, and calcium; example: basalt.
   Felsic rocks are silica-rich igneous rocks with a relatively high content of potassium and sodium; example: rhyolite.
   Intermediate rocks are rocks with a chemical content between that of felsic and mafic rocks; example: andesite.
4. The violence of an eruption depends on the amount of gas in a lava or magma and the ease or difficulty with which such gas escapes. Lava from which gas has difficulty escaping is likely to erupt more violently than lava from which gas can escape easily. The viscosity of lava determines the ease or difficulty with which gas escapes, and the viscosity of lava is determined by the following factors:
   - the temperature of the lava compared to the temperature at which it solidifies.
   - the silica content of the lava.
   - the degree to which small frameworks of silica tetrahedra have formed in the lava.
   - extent to which gases are dissolved in the magma. Viscosity drops with higher quantities of dissolved gases (note that trapped gas does not equate with dissolved gas).

Mafic lavas are low in silica, while felsic lavas are high in silica and have a greater likelihood of containing silica tetrahedral that have begun to form small frameworks.

5. *vent:* the opening through which an eruption tales place.

   crater: a basin-like depression over a vent at the summit of the cone.

   caldera: a volcanic depression over a vent at the summit of the cone.

6. The three major types of volcanoes are shield, cinder cone, and composite.

   A *shield volcano* has a broad, gently sloping cone formed of solidified lava flows.

   A *cinder cone volcano* is formed from loose rock fragments ejected from a central vent. Cinder cones tend to have steep sides (about a 30% gradient).

   A *composite volcano* or stratovolcano is made up of alternating layers of volcanic rock fragments and solidified lava.

7. A spatter cone is a small, steep-sided cone built from lava sputtering out of a vent. Such a cone forms when a small pocket of gas is trapped in a cooling lava flow, and the gas leaks to escape.

8. *pahoehoe lava:* a lava flow with a ropy or billowy surface

   aa lava: a lava flow that solidifies as a spiny, rubbly surface; lava that is cool enough to have partly solidified; therefore it moves as a slow pasty mass.

9. A volcanic dome forms by viscous, pasty lava (too viscous to flow) squeezing from a vent. The lava is felsic in composition.

10. No cone is built up around the vent of plateau basalts because the associated lava is fluid enough (non-viscous) to flow smoothly.

11. Columnar jointing results from contraction during the cooling of solidified lava.

12. Pillow structures indicate submarine eruption of lava.

13. Extrusive rocks are named and identified on the basis of their composition and texture.

14. Mafic rocks are dark in colour because they contain an abundance of ferromagnesian minerals, which are dark. Felsic rocks are light in colour because they contain abundant quartz and feldspar—light coloured minerals.

15. Rhyolite contains quartz, k-feldspar, plagioclase, and ferromagnesians. Basalt contains plagioclase and ferromagnesians.

16. Neither andesite nor basalt contain quartz; granite does contain quartz.

17. A rock's most important textural characteristic is its grain size.

18. Grain size is determined by the rate of cooling and the viscosity of lava. A rock formed from a lava that cooled rapidly or was very viscous would probably have finer grains than a rock formed from a lava that cooled slowly or was relatively nonviscous. In each case, the determining factor is the degree to which individual atoms can move: ease of movement leads to larger crystals, and hence to larger grain sizes.

19. Obsidian is volcanic glass and is not composed of minerals.

20. Check the figure you have drawn against Figure 3.7 in the textbook. A porphyritic texture indicates two stages of solidification: phenocrysts form during the slow cooling, when the magma is underground; and the fine-grained matrix forms when the lava is erupted and cools rapidly.

21. Both tuffs and volcanic breccias have fragmental textures. In tuffs the fragments are <2mm, in volcanic breccias, the fragments are >2mm.

22. A vesicular texture shows a series of cavities formed by bubbles of gas trapped in a lava when it solidified. Pumice is a frothy glass formed from viscous lava; scoria is a highly vesicular basalt.

23. An intrusive rock is one which formed from magma that cooled below the Earth's surface.

24. *country rock:* older rock into which igneous rock has intruded.
xenolith: a fragment of rock that is distinct from the body of igneous rock in which it is enclosed.
chill zone: finer-grained rock on the outer rim of an intrusive body. Chill zones result from quick solidification because of rapid loss of heat to the cooler country rock.

25. Compare your diagram to Figure 3.1 in this *Study Guide*, and refer to the description in the section of the textbook titled "Intrusive Bodies" (Chapter 3).

26. A *pluton* is a body of igneous rock that formed at great depth. A *stock* is a small, discordant pluton with an outcrop area of <100 km^2. A *batholith* is a large, discordant pluton with an outcrop area of >100 km^2.

27. The intrusive igneous rock corresponding to basalt is gabbro; to rhyolite, granite; to andesite, diorite.

28. K-feldspar and quartz are present in granite, but absent in basalt and gabbro (see Figure 3.5 in the textbook).

29. An ultramafic rock is composed almost entirely of ferromagnesian minerals. Ultramafic rocks form far below the Earth's surface, usually in the mantle. Very high temperatures are needed to melt ultramafic rocks.

30. Pegmatite is extremely coarse-grained igneous rock. Pegmatites form from very slow cooling of low viscosity fluids made up mostly of water under high pressure. A rare element commonly found in pegmatites is lithium.

31. A granodiorite has more plagioclase, less orthoclase (K-feldspar), and somewhat more ferromagnesian minerals than does granite.

32. Partial melting is a process in which only the chemical components of the asthenosphere with the lowest melting temperatures liquefy, while minerals with the higher temperatures remain crystalline.

33. Two factors that could cause melting in the asthenosphere are the addition of extra heat, which raises the temperature above the melting points for some components of the asthenosphere, and the reduction of pressure.

34. Compare your diagram to Figure 3.26 of the textbook, and refer to the subsection of Chapter 3 titled "Igneous Processes at Divergent Boundaries."

35. In the Hawaiian archipelago, an eruption is caused by a mantle plume or hot spot beneath the Pacific Plate, which creates magma in the asthenosphere. Eventually, this magma must erupt.

36. The igneous rock you would expect to find under the oceans is basalt; on continents, granite; and on or near continental margins, andesite.

37. The geothermal gradient is the rate at which temperature increases with increasing depth beneath Earth's surface.

38. Differentiation is the process by which different ingredients separate from an originally homogeneous mixture.

39. In the continuous branch of Bowen's reaction series, plagioclase crystallizes, and as crystallization continues, the sodium content of the magma gradually increases and its calcium content decreases. The result is a series of zoned crystals of plagioclase that are more calcium rich in the centre and more sodium rich on the rim.
    In the discontinuous branch, olivine begins to crystallize first and eventually recrystallizes as pyroxene. If the magma has not yet totally solidified, any remaining olivine and pyroxene react with the melt so

that amphibole and biotite begin to form. In this branch, previously formed minerals are destroyed to create new minerals; this process does not occur in the continuous branch.

40. According to Bowen's reaction series,
    a. olivine forms at a higher temperature than amphibole.
    b. biotite forms at a higher temperature than potassium feldspar.
    c. calcium-rich plagioclase forms at a higher temperature than sodium-rich plagioclase.
    d. pyroxene forms at a higher temperature than amphibole.

41. Compare your answer to the discussion in the section of the textbook titled "How Magmas of Different Compositions Evolve" (Chapter 3). The relevant section ends at "Partial Melting."

42. Six possible mechanisms by which granitic and andesitic magma could form at convergent plate boundaries:
    - partial melting of basalt
    - melting of sedimentary rock
    - partial melting of the mantle
    - assimilation of crustal rocks
    - partial melting of the lower crust
    - heating by transient magma or underplating