Environmental Geology An Earth Systems Approach 2nd Edition Merritts Solutions Manual
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***Environmental Geology*, 2e**
Answers to End-of-Chapter Questions

Chapter Two

Review Questions

1. Alfred Wegener recognized that the continents had been connected in the supercontinent Pangaea. He observed that rocks and fossils on opposite sides of the Atlantic Ocean matched. He recognized that the alternate hypotheses proposed to explain the evidence were not viable. Figure 2-2 displays a map illustrating the matching of fossils on the now-separated continents. Figure 2-1 shows Wegener's reconstruction of the supercontinent of Pangaea.

2. The desire to detect German submarines during World War II was important in understanding plate tectonics. Submarines contain a lot of iron and can be detected by making magnetic measurements. The technology of the magnetometer was developed to save lives during WWII. Magnetometers measure magnetic fields. World War II was the start of ocean magnetometer measurements. See Figure 2-14. These measurements showed a zebra-stripe pattern. With further study, it was shown that the zebra-stripe pattern is the result of the seafloor rocks recording the reversals of Earth’s magnetic field. Age dating of the rocks showed that the rocks on opposite sides exhibited a mirror-image pattern of ages. The creation of the new ocean floor helped the acceptance of plate-tectonic theory.

3. Plate tectonics have both aided in the evolution of new species and the extinction of others. When the supercontinent of Pangaea existed, animals and plants could move freely through the different landmasses. Marsupial mammals evolved 100 million years ago. Australia and South America separated from Pangaea before placental mammals evolved. The parts of Pangaea that remained connected lost their marsupial mammals after placental mammals evolved. Australia kept its marsupial mammals due to its isolation and more species evolved in the isolation. South America remained isolated from North America until about 3 million years ago. When North American placental mammals came to South America, most of the South American marsupial mammals became extinct. Opossums from South America migrated to North America. See Box 2-1 Global and Environmental Change.

4. Eduard Suess proposed contraction theory to explain the match of fossils and rocks on opposite sides of the Atlantic Ocean. Suess proposed that as Earth cooled, the interior shrank and formed “Earth’s skin” as the crust wrinkled similar to the skin on a dried

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apple. He proposed that yes, Europe and North America had been connected by dry land in the past but that dry land sank to the bottom of the Atlantic Ocean as Earth's interior contracted.

5. The scientific method starts with questions people have about observations that they do not understand. For example, geologists observed that different fossils are found in different rock layers. What is the reason why different plant and animal fossils are found in different layers? Scientists collect data expanding their observations about the question. When enough observations are collected, a testable hypothesis to explain the observations is proposed. Experiments, field observations, and/or calculations are performed to test the hypothesis. Based on the results of these tests of the hypothesis, the hypothesis is accepted, rejected or changed. When a hypothesis survives enough testing to be successful at predicting outcomes, it becomes a theory. A theory is accepted as valid when it is consistent with all observations.

   Instructors may wish to point out that the colloquial usage of the term theory and the scientific definition are different. Nonscientists use the term theory to signify that something is uncertain, that is, not a demonstrated fact. These different definitions of theory are exploited by groups or individuals with a vested interest. Evolution is dismissed as "just a theory". Many of the same people who dismiss evolution accept that the atomic theory of matter enables people to explode nuclear weapons and operate nuclear power plants.

   Pseudoscience can be distinguished from science by many different ways. Pseudoscience relies on untestable ideas including supernatural forces. The results cannot be replicated and correct predictions are often the result of chance. Findings that do not support the hypothesis are often ignored. Intelligent design is an example of pseudoscience.

6. Continental crust has a lower density than oceanic crust. Oceanic crust is dense enough that it can subduct into the mantle. Cold oceanic crust is denser than young warm oceanic crust and subducts more easily than warm oceanic crust. Continental crust behaves like Styrofoam packing peanuts floating on water. Continental crust is not dense enough to subduct into Earth's mantle. During continent-continent collisions the continental material produces thickened crust. During ocean-continent collisions, the oceanic crust can subduct into the mantle. See Figure 2-7.

7. Mid-ocean ridges are divergent plate boundaries. As the plates are moving apart mantle rock rises. As the rock rises decompression initiates partial melting. New oceanic crust is formed.

8. Geologists classify faults into three general categories, normal faults, reverse faults and strike-slip faults. Although all three types can be found in the different types of plate boundaries, one type tends to be dominant in each type of plate boundary. Normal faulting occurs in areas of extension, so it is predominantly found at divergent boundaries, such as mid-ocean ridges and continental rift zones. Reverse faulting occurs in areas with compression, so it is found at convergent boundaries, such as subduction zones and continent-continent collisions. Transform boundaries are places where two plates move past each other with horizontal motion; strike-slip faults occur in this setting. Figures 2-4 and 2-5 illustrate these concepts.

9. Island arcs and continental chains of volcanoes form above subducting oceanic crust. Subducting oceanic crust is covered with a veneer of water and carbonate rich sediments. With subduction the plates experience pressures and temperatures that dehydrate and decarbonate the veneer. The water and carbonate-rich fluids rise up through the crust and induce melting in the overlying wedge. Addition of the fluids lowers the melting point of the rock. The rising magmas form the chains of volcanoes in the island arcs and on the continents.

10. The Curie point is the temperature above which a material loses its magnetism. Understanding the Curie point is important to understanding how cooling igneous rock records information about the ambient magnetic field.

11. A simple model for Earth's magnetic field is that it behaves similar to Earth having a large bar magnet in the interior. See Figure 2-15. Close to the equator the magnetic field lines are roughly parallel to Earth's surface. Close to the poles the magnetic field lines are roughly perpendicular to Earth's surface. Therefore the angle of the magnetic field is a rough measure of degrees latitude. When an igneous magma solidifies, magnetic minerals that crystallize from the magma orient themselves along the magnetic field lines. Measuring the magnetic properties of the minerals enables geologists to know approximately where the rock solidified. Igneous rocks are generally easy to age date using radiometric age dating techniques. Therefore, by looking at the magnetic data and age dates, it is possible to reconstruct plate motions. Similar measurements can also be performed on some sedimentary rocks, but the principle is simplest to explain using igneous rocks.

12. The solidification of basaltic lava at mid-ocean ridge spreading centers has provided geologists with a straightforward way to study changes of Earth's magnetic field over the last 200 million years. The polarity of Earth's magnetic field shifts at periodic intervals. The orientation of the magnetic field is recorded in the solidified lavas. The oceanic seafloor rocks can easily be age dated using radiometric age dating techniques. Therefore

by studying the magnetic properties of a wide age range of rocks, the past history of magnetic polarity reversals can be reconstructed forming the magnetic polarity timescale. See Figure 2-18.

13. Several hypotheses were proposed to explain why rocks of different ages were magnetized in different directions, and sometimes, polarities: 1. The rocks were originally magnetized in the same direction, but some lost their magnetization, similar to the way that some ID cards or credit cards with magnetic strips become demagnetized; 2. Earth's magnetic field is not constant and the location of the magnetic poles changes over large distances over time; 3. The magnetic poles remained at the same locations and the continents moved.

    Geophysicists reconstructed where the poles had apparently been when a large number of different rocks formed. If the location of the magnetic poles changed over great distances and the continents did not move at all, then rocks with the same age that had formed in different locations should point to the same magnetic pole location. However if the magnetic poles remained in roughly the same location and the continents had moved, then the rocks would point to different magnetic poles. The geophysicists found different paths for the magnetic poles on different continents. This result supported continental drift/plate tectonics, that is, the third hypothesis. See Figures 2-16 and 2-17.

14. Ocean-floor drilling provided evidence supporting plate tectonics. Plate-tectonic theory predicts that the youngest crust is at the mid-ocean ridge and that the age of the crust increases with distance from the ridge. The thicknesses of marine sediments were found to be thin near the ridge crest and thicker with greater distance from the ridge. This is what would be expected because older crust would have more time to accumulate sediments than would younger crust. Additionally, the ages of fossils found in the sediments correlate with the age of the oceanic crust.

15. Although some earthquakes are associated with plate boundaries, for example those generated by isostatic adjustment due to receding continental glaciers, most earthquakes are associated with plate-tectonic activity. Large-magnitude earthquakes are associated with convergent boundaries. Smaller magnitude earthquakes are associated with divergent boundaries. Wadati–Benioff zone earthquakes give geologists a three-dimensional view of subduction zone downgoing slab motions. See Figures 2-19 and 2-20.

16. Thermal energy from radioactive decay and gravitational energy are energy sources driving plate tectonics. Like a boiling pot of water convects to enhance heat flow to its surroundings, the rock in Earth's mantle is thought by many geologists to convect to shed

heat, although there is not unanimous agreement. Gravity also drives plate tectonics. Ocean crust is dense enough to subduct, thus driving the plate motions. In addition, in some hypotheses, subduction is thought to be a driving force of mantle convection due to friction between the plate and mantle. See Figure 2-21.

17. The Hawaiian Island chain and seamounts are believed to have formed from the same magma source as the Emperor seamount chain. For decades, geologists accepted the hypothesis that the hot-spot magma source remained stationary and the plate moved above it, similar to Burger King's flame-cooked burgers moving on a conveyor belt over the flame. The kink or bend in the Hawaiian Emperor chain was interpreted to represent a change in plate motion over the stationary hot spot. Paleomagnetic measurements have demonstrated that the Emperor seamounts did not form at the location of the Hawaiian Islands. Therefore the kink in the chain was formed by movement of the hot spot, not a change in direction of the plate. See Box 2-3 Emerging Research.

18. Due to the compression characteristic of convergent plate boundaries, folded rock layers are common. Arched portions of the rock layers can have impermeable caps. Petroleum is sometimes found in the arched portions of the folded rock layers that are capped with impermeable layers. See Figure 2-9.

19. At convergent boundaries with a subducting plate, the contact between the overriding and subducting plate is a megathrust fault. The largest earthquakes are associated with megathrust faults. The December 2004 Indian Ocean earthquake is of the megathrust type; as was the March 2011 earthquake in Japan.

20. Plate motions are measured at many locations on Earth. The measured motions range from a few mm per year to 15 cm per year, roughly the rate at which fingernails grow. 100 km equals 10,000,000 cm. If a plate was moving at a rate of 2 cm/yr, it would take 20,000,000 years to move 100 km.

Thought questions

1. Strong evidence for plate tectonics existed before the theory of plate tectonics was accepted. The pattern of magnetic polarity reversals recorded in seafloor igneous rocks was instrumental in the acceptance of plate tectonics. If Earth’s magnetic field never reversed polarity, the widespread acceptance of plate tectonics would have been delayed. As the rocks essentially record approximate latitude, magnetic data would have still contributed to deciphering plate tectonics. See the answer to question 11. Additionally, the apparent polar wandering work of the geophysicists discussed in the answer to question 13 would have still enhanced our understanding of plate tectonics.

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2. Since the eastern boundary of the Caribbean plate, the Lesser Antilles subduction zone, is part of the Atlantic Ocean, students may be confused by this question. Instructors should tell students to ignore the presence of that subduction zone when answering the question and just focus on the fact that the Atlantic Ocean is growing in size.

   Since the size of Earth is remaining constant, the fact that the Atlantic Ocean is getting larger with time means that the Pacific Ocean is getting smaller. This is consistent with the presence of multiple subduction zones in the Pacific Ocean basin.

3. The possibility exists that the Pacific Ocean could no longer exist if North America and South America collide with Asia and Australia to form a new Pangaea. This process could take tens of millions of years.

4. Earthquakes frequently occur along faults. At depths less than 30 km, faults exist. The rocks at shallow depths are brittle and cool. At greater depths, rocks deform plastically because the rock is warm and ductile. It is easy for energy to be stored in the brittle rocks and be released at once as an earthquake.

Exercises

1. Fifty million years minus 25 million years equals 25 million years. One thousand km divided by 25 million years equals a rate of 40 km per million years. This calculation assumes that the hot-spot magma source remains stationary and the only horizontal motion is plate motion.

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