17.3 New Evidence of a Dynamic Earth

During Word War II, an American scientist named Harry Hess commanded a navy ship equipped with new technology that bounced sound waves off objects below to measure how deep they were. Hess realized that he could do some science at the same time as his military duty and kept the depth finder on at all times, even far out to sea. If the ocean floors were ancient and undisturbed, as was thought, then they should be flat and featureless. Instead, Hess found crevasses, trenches, mountain ridges, and volcanoes.

Undersea mountains were noticed by engineers laying the first trans-Atlantic telegraph cables, but the extent of the ridges was unknown. After World War II, oceanographers discovered a massive undersea mountain range running along the middle of the Atlantic Ocean. This Mid-Atlantic Ridge features a deep, wide canyon running the length of its centre. Other **mid-ocean ridges** were soon discovered, linking up and running 75 000 km throughout the world's oceans. Deep ocean trenches were also discovered along the edge of some continents. When plotted on a map, earthquakes and volcanoes line up along the ridges and trenches (Figure 1).

Did You KNOW?

Travel to the Ocean Floor

More people have been on the Moon than in the deepest place in the ocean. A crew of two reached the bottom of the Mariana Trench aboard the U.S. Navy research submersible *Trieste* in 1960. A Japanese remote submersible descended the 11 km in 1995, but no other submersible has since returned.

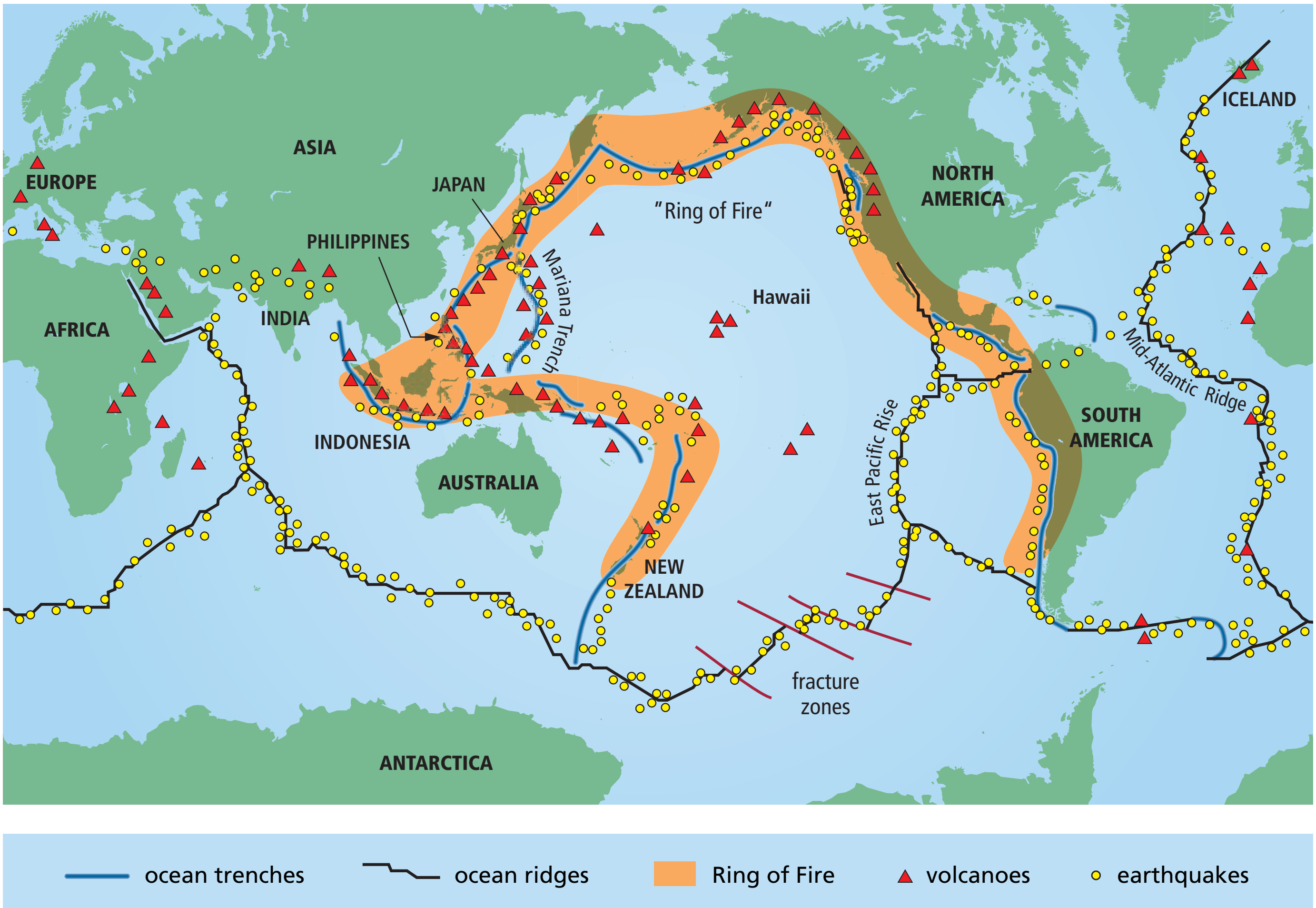

Figure 1 This world map shows how the distribution of volcanoes and earthquakes lines up with the network of ridges and trenches.

LEARNING TIP

Headings summarize primary topics within the section, while subheadings expand upon the topics. As you read pages 502 and 503, set a purpose for your reading by turning headings and subheadings into questions. Then read to answer the questions.

Sea-Floor Spreading

In 1960, Hess hypothesized that the sea floor was widening at the mid-ocean ridges (also called a spreading ridge). He called this process **sea-floor spreading** (Figure 2). Later work by Canadian Tuzo Wilson and others led to the understanding that the sea floor also cycled back into Earth at **ocean trenches**, the extensive elongated depressions where two plates converge. Molten magma from within Earth rises up and cools, filling the gap in the ridge with new rock. Hess thought convection currents in the mantle, proposed much earlier by British geologist Arthur Holmes, caused the spreading and forced the magma up. Chapter 18 examines this process in more detail.

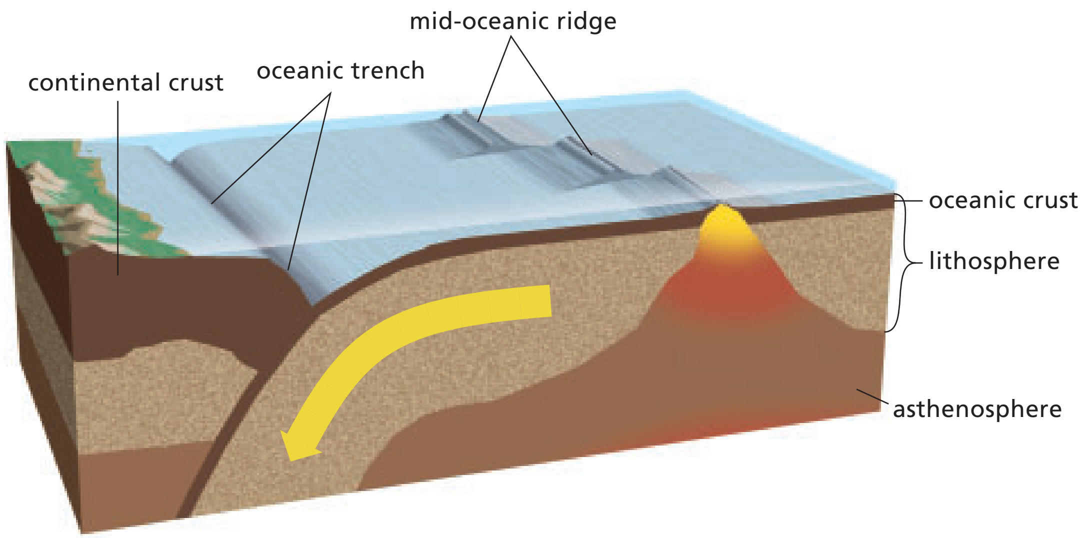

Figure 2 Sea-floor spreading happens when magma rises from the mantle, filling the crack left by the parts of the sea floor moving apart. In this example, the other edge of the sea floor is pushed beneath the continent. As it descends, it pulls the oceanic crust back into the mantle.

Did You KNOW?

Heat Measures Age

Between 1862 and 1897, the respected scientist Lord Kelvin calculated Earth to be about 24 million years old. He calculated the rate at which Earth would have lost the heat present from its formation and compared that to the current temperature. Unfortunately, he did not account for the heat that has been generated by natural radioactive decay, which was not discovered until 1898. Based on half-life measurements of certain substances, we now believe Earth to be about 4600 million years old.

Earth's Heat Source

Temperature increases closer to Earth's core, but where does this heat come from? Some heat is left over from the initial creation of the planet. Additional heat comes from naturally occurring radioactive substances as they break down and turn into other substances. By 1944, Arthur Holmes completed calculations showing that radioactive decay within Earth could provide the energy necessary for convection currents in the mantle.

Radioactive Dating

Radioactive substances decay (and turn into other substances) at a specific rate called the half-life, as discussed in Unit C. By comparing the amount of the original and new substances in a sample, the age of the sample can be determined. Ernest Rutherford demonstrated this technique in 1904, but it wasn't until the 1950s that the technique was sophisticated enough to give the age of rock drill core samples. Radioactive dating of core samples confirmed evidence that the sea floor is older the further it is from the ridges.

Magnetic Evidence

Basalt rock is rich in iron. When basalt lava cools and solidifies, the iron particles in the rock align with Earth's magnetic field, like a compass needle. Basalt lava flows record the orientation of Earth's magnetic field as the lava solidifies. In 1906, French physicist Bernard Brunhes examined layers of successive basalt lava flows and showed that Earth's magnetic field has reversed polarity repeatedly (approximately every 500 000 years). In the 1950s, British scientists Patrick Blackett and S.K. Runcorn studied the ancient magnetic patterns in British rock formations, which indicated that Britain had spun around and moved north in the past. Finally, in 1963, Drummond Matthews and Fred Vine of Cambridge University (and Canadian geologist Lawrence Morley, working independently) used measurements of the magnetic orientation of the sea floor to show a regular pattern of magnetic striping that was similar on both sides of the ridge. The mirror image pattern of magnetization (Figure 3) on the sea floor supported the theory that new ocean floor was being created at the mid-ocean ridges, and then slowly moving away from the ridge on both sides.

LEARNING TIP

Check your understanding. Use Figure 3 to describe to a partner how magnetic reversals were used to argue that the sea floor is spreading.

To find out more about the reversal of Earth's magnetic field, listen to the audio clip at **www.science.nelson.com**

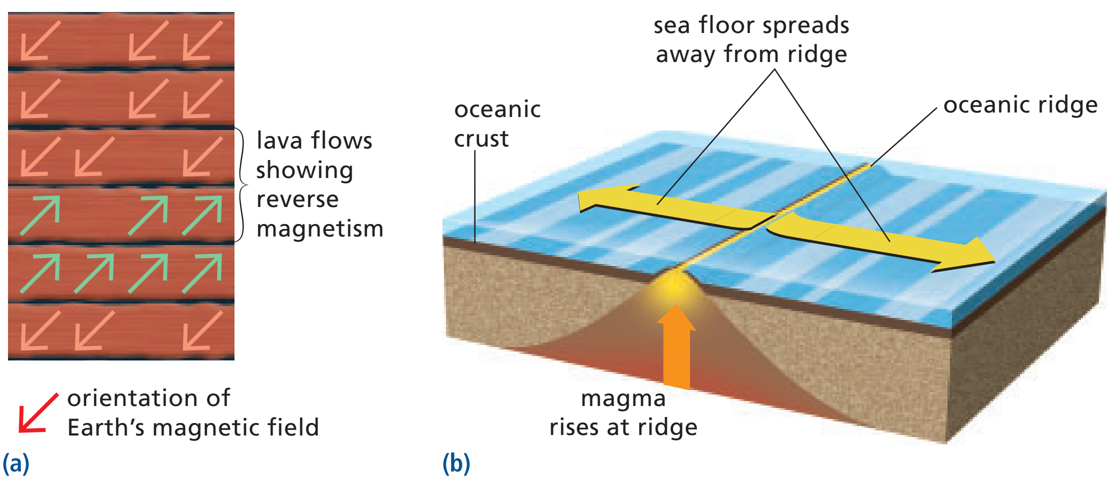

Figure 3 (a) By examining successive layers of ancient lava flows, we can see that Earth's magnetic field reversed many times, about every 500 000 years. (b) This is shown dramatically in the alternating bands of magnetic orientation, shown in different shades of blue, that radiate outward from the Mid-Atlantic Ridge.

Observations of the features of the ocean floor, radioactive dating of the ocean floor rock, patterns of magnetic striping in the rock, and radioactive decay providing an energy source to drive the process, all provided compelling evidence of sea-floor spreading. Earth's lithosphere was shown to be in motion.

17.3 CHECK YOUR Understanding

1. Describe the landscape of the ocean floor.
2. (a) What is the Mid-Atlantic Ridge?
   (b) What is the relationship between an ocean ridge and an ocean trench?
3. What new technologies allowed scientists to confirm that the sea floors are spreading?
4. Hess hypothesized that new sea floor was produced at ocean ridges.
   (a) Why are deep ocean trenches important to his hypothesis?
   (b) What would happen to the dimensions of Earth if the sea floor did not descend into the mantle at ocean trenches?
5. Which layers of Earth are involved in sea-floor spreading?
   A. crust and core
   B. core and mantle
   C. crust and asthenosphere
   D. lithosphere and asthenosphere
6. (a) List the sources of heat within Earth.
   (b) How does this heat contribute to mantle convection?
7. How do convection currents in the mantle contribute to sea-floor spreading?
8. Why does the sea floor bulge up at a spreading ridge?
   A. Rising mantle pushes up on the crust.
   B. Magma piles up as it rises from the mantle.
   C. Heated crust is less dense, so it floats higher.
   D. Friction curls up the edges of the crust as it moves.
9. Explain how the magnetic orientation of lava layers demonstrates reversals of Earth's magnetic field.
10. Describe how each of the following was used to argue that the sea floor is spreading.
    (a) magnetic reversals
    (b) age of rocks
    (c) mid-ocean ridges
    (d) deep ocean trenches
11. What evidence shows that the rock further from ocean ridges is older than rock closer to the ridges?
12. The colour coding in Figure 4 shows the age of the sea floor around the Juan de Fuca spreading ridge.

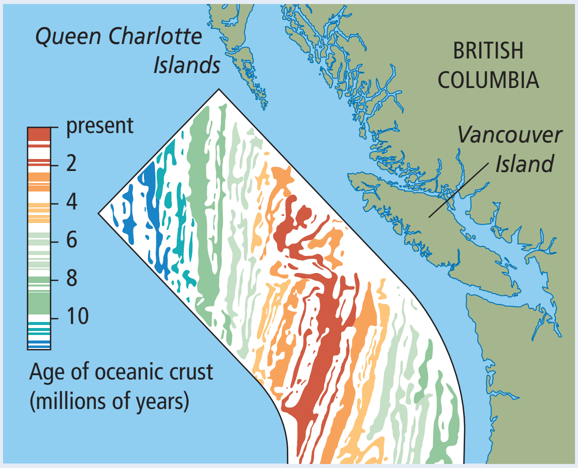

Figure 4

    (a) Which colour represents the current location of the spreading ridge?
    (b) The white regions indicate rocks with reversed magnetic polarity. Explain how the age and polarity of the rock suggests the ocean floor on either side of the ridge has moved.
    (c) In what direction is the sea floor spreading? How do you know?