Section 3

Integrating Earth Science

Magnetic Earth

Reading Preview

Key Concepts

- How is Earth like a bar magnet?
- What are the effects of Earth's magnetic field?

Key Terms

- compass
- magnetic declination
- Van Allen belts
- solar wind
- magnetosphere
- aurora

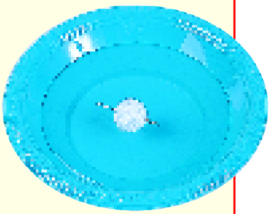
Target Reading Skill

Building Vocabulary Using a word in a sentence helps you think about how best to explain the word. After you read the section, reread the paragraphs that contain definitions of Key Terms. Use all the information you have learned to write a meaningful sentence using the Key Term.

Lab zone Discover Activity

Can You Use a Needle to Make a Compass?

1. Magnetize a large needle by rubbing it several times in the same direction with one end of a strong bar magnet. Push the needle through a ball of foam or tape it to a small piece of cork.
2. Place a drop of dishwashing soap in a bowl of water. Then float the foam or cork in the water. Adjust the needle until it floats horizontally.
3. Allow the needle to stop moving. Note the direction it points.
4. Use a local map to determine the direction in which it points.



Think It Over

Observing In what direction did the needle point? If you repeat the activity, will it still point in the same direction? What does this tell you about Earth?

When Christopher Columbus sighted land in 1492, he didn't know what he had found. He was trying to find a shortcut from Europe to India. Where he landed, however, was on an island in the Caribbean Sea just south of the present-day United States. He had no idea that such an island even existed.

In spite of his error, Columbus had successfully followed a course west to the Americas without the help of an accurate map. Instead, Columbus used a compass for navigation. A **compass** is a device that has a magnetized needle that spins freely. A compass needle usually points north. As you read, you'll find out why.

◀ Columbus navigated across the Atlantic Ocean using a compass similar to one of these.

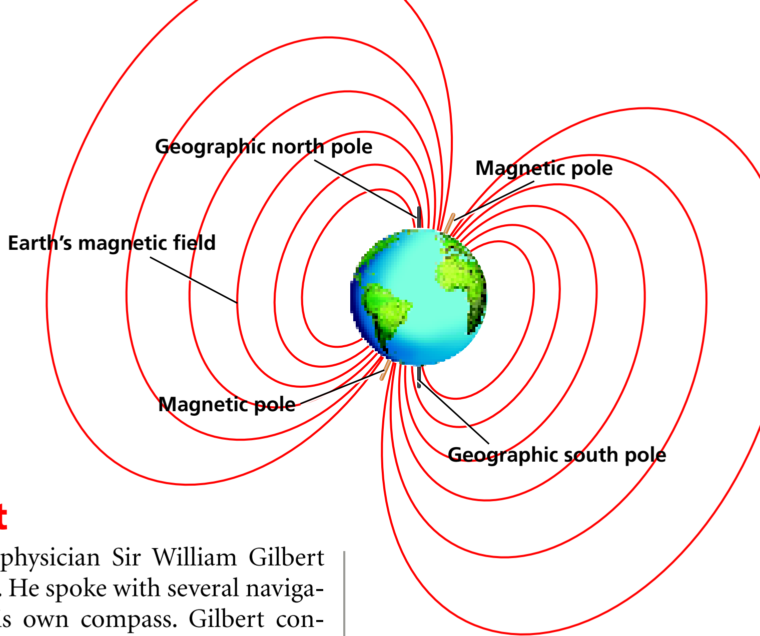


FIGURE 12
Earth's Magnetic Field
The magnetic field lines show the shape of Earth's magnetic field.
Observing *What magnetic properties does Earth have?*

Earth as a Magnet

In the late 1500s, the English physician Sir William Gilbert became interested in compasses. He spoke with several navigators and experimented with his own compass. Gilbert confirmed that a compass always points in the same direction, no matter where it is. But no one knew why.

Gilbert hypothesized that a compass behaves as it does because Earth acts as a giant magnet. Although many educated people of his time laughed at this idea, Gilbert turned out to be correct. **Just like a bar magnet, Earth has a magnetic field surrounding it and two magnetic poles.**

The fact that Earth has a magnetic field explains why a compass works as it does. The poles of the magnetized needle on the compass align themselves with Earth's magnetic field.

Earth's Core Gilbert thought that Earth's center, or core, contains magnetic rock. Scientists now think that this is not the case, since the material inside Earth's core is too hot to be solid. Also, the temperature is too high for the material to be magnetic. Earth's magnetism is still not completely understood. But scientists do know that the circulation of molten material in Earth's core is related to Earth's magnetism.

Earth's Magnetic Poles You know that Earth rotates on its axis, around the geographic poles. But Earth also has magnetic poles. These magnetic poles are located on Earth's surface where the magnetic force is strongest. As you can see in Figure 12, the magnetic poles are not in the same place as the geographic poles. For example, the magnetic pole in the Northern Hemisphere is located in northern Canada about 1,250 kilometers from the geographic North Pole.

Discovery CHANNEL SCHOOL™

Magnetism

Video Preview
▶ Video Field Trip
Video Assessment

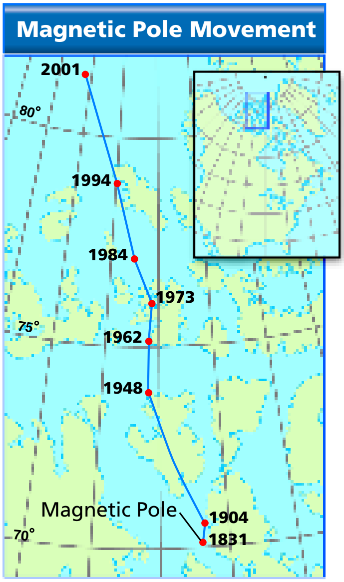


FIGURE 13
The location of Earth's magnetic poles does not stay the same.

Magnetic Declination If you use a compass, you have to account for the fact that Earth's geographic and magnetic poles are different. Suppose you could draw a line between you and the geographic North Pole. The direction of this line is geographic north. Then imagine a second line drawn between you and the magnetic pole in the Northern Hemisphere. The angle between these two lines is the angle between geographic north and the north to which a compass needle points. This angle is known as **magnetic declination**. So, magnetic declination differs depending on your location on Earth.

The magnetic declination of a location on Earth today is not the same as it was 10 years ago. The magnetic declination of a location changes. Earth's magnetic poles do not stay in one place as the geographic poles do. Figure 13 shows how the location of Earth's magnetic pole in the Northern Hemisphere has drifted over time.

Earth's Magnetic Field

You learned that a material such as iron can be made into a magnet by a strong magnetic field. **Since Earth produces a strong magnetic field, Earth itself can make magnets out of ferromagnetic materials.**

Earth as a Magnet Maker Suppose you leave an iron bar lying in a north-south direction for many years. Earth's magnetic field may attract the domains strongly enough to cause them to line up in the same direction. When the domains in the iron bar align, the bar becomes a magnet. This can happen to some everyday objects. So even though no one has tried to make metal objects such as file cabinets in your school into magnets, Earth might have done so anyway!

Math Analyzing Data

Movement of Earth's Magnetic Poles

Earth's magnetic poles move slowly over time. The data in the table show the position of Earth's magnetic north pole in specific years.

1. **Interpreting Data** What is the trend in the speed of the pole's movement?
2. **Calculating** What is the total distance the pole has traveled over the time shown?
3. **Predicting** Using this data, predict the average speed of the pole's movement between 2001 and 2010. Explain.

Magnetic North Pole Movement

Year of Reading	Distance Moved Since Previous Reading (km)	Average Speed (km/yr)
1948	420	9.5
1962	150	10.7
1973	120	10.9
1984	120	10.9
1994	180	18.0
2001	287	41.0

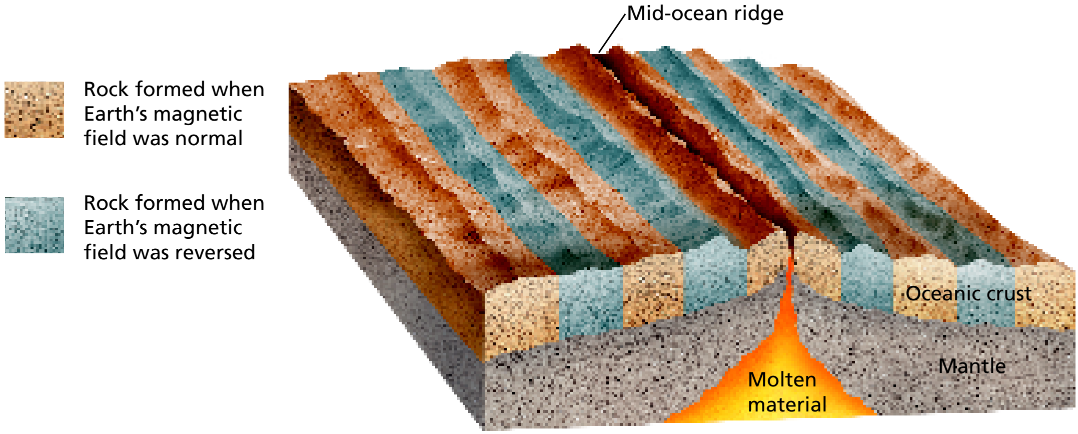


FIGURE 14
Earth's Magnetic Stripes
When molten material hardens into the rock of the ocean floor, the direction of Earth's magnetic field at that time is permanently recorded. **Applying Concepts** *How can scientists use this rock record to study changes in Earth's magnetic field?*

Earth Leaves a Record Earth's magnetic field also acts on rocks that contain magnetic material, such as rock on the ocean floor. Rock is produced on the ocean floor from molten material that seeps up through a long crack in the ocean floor known as a mid-ocean ridge. When the rock is molten, the iron it contains lines up in the direction of Earth's magnetic field. As the rock cools and hardens, the iron is locked in place. This creates a permanent record of the magnetic field.

As scientists studied such rock, they discovered that the direction and strength of Earth's magnetic field have changed over time. Earth's magnetic field has completely reversed direction every million years or so.

The different colored layers in Figure 14 indicate the directions of Earth's magnetic field over time. Notice that the patterns of bands on either side of the ridge are mirror images. This is because the sea floor spreads apart from the mid-ocean ridge. So rocks farther from the ridge are older than rocks near the ridge. Scientists can determine when the rock was formed by looking at the rock's magnetic record.

Why does Earth's magnetic field change direction? No one knows. Scientists hypothesize that changes in the motion of molten material in Earth's core may cause changes in Earth's magnetic field. But scientists cannot explain why changes in the molten material take place.

Reading Checkpoint **What evidence shows that Earth's magnetic field changes?**

Lab zone Skills Activity

Measuring

1. Use a local map to locate geographic north relative to your school. Mark the direction on the floor with tape or chalk.
2. Use a compass to find magnetic north. Again mark the direction.
3. Use a protractor to measure the number of degrees between the two marks.

Compare the directions of magnetic and geographic north. Is magnetic north to the east or west of geographic north?

Lab zone **Try This Activity**

Spinning in Circles

Which way will a compass point?

1. Place a bar magnet in the center of a sheet of paper.
2. Place a compass about 2 cm beyond the north pole of the magnet. Draw a small arrow showing the direction of the compass needle.
3. Repeat Step 2, placing the compass at 20 to 30 different positions around the magnet.
4. Remove the magnet and observe the pattern of arrows you drew.

Drawing Conclusions What does your pattern of arrows represent? Do compasses respond only to Earth's magnetic field?

The Magnetosphere

Earth's magnetic field extends into space. Space is not empty. It contains electrically charged particles. **Earth's magnetic field affects the movements of electrically charged particles in space.** Those charged particles also affect Earth's magnetic field.

Between 1,000 and 25,000 kilometers above Earth's surface are two doughnut-shaped regions called the **Van Allen belts.** They are named after their discoverer, J. A. Van Allen. These regions contain electrons and protons traveling at very high speeds. At one time it was feared that these particles would be dangerous for spacecraft passing through them, but this has not been the case.

Solar Wind Other electrically charged particles in space come from the sun. Earth and the other objects in our solar system experience a solar wind. The **solar wind** is a stream of electrically charged particles flowing at high speeds from the sun. The solar wind pushes against Earth's magnetic field and surrounds the field, as shown in Figure 15. The region of Earth's magnetic field shaped by the solar wind is called the **magnetosphere**. The solar wind constantly reshapes the magnetosphere as Earth rotates on its axis.

Although most particles in the solar wind cannot penetrate Earth's magnetic field, some particles do. They follow Earth's magnetic field lines to the magnetic poles. At the poles, the magnetic field lines dip down to Earth's surface.

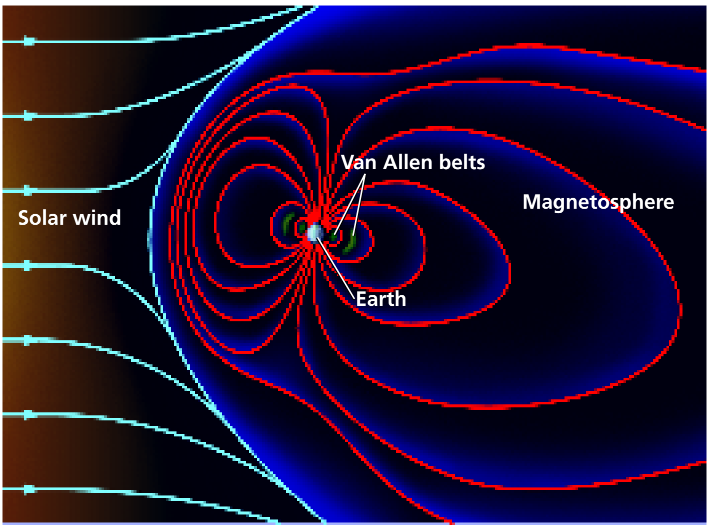


FIGURE 15
Earth's Magnetosphere
The solar wind causes Earth's magnetic field to stretch out on the side of Earth not facing the sun.
Relating Cause and Effect
What shapes the magnetosphere?

FIGURE 16
Aurora
A band of colored light called an aurora occasionally appears in the night sky near the magnetic poles.

Auroras When high-speed, charged particles get close to Earth's surface, they interact with atoms in the atmosphere. This causes some of the atoms to give off light. The result is one of Earth's most spectacular displays—a curtain of shimmering bright light in the atmosphere. A glowing region in the atmosphere caused by charged particles from the sun is called an **aurora**. In the Northern Hemisphere, an aurora is called the Northern Lights, or aurora borealis. In the Southern Hemisphere, it is called the Southern Lights, or aurora australis.

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Reading Checkpoint What causes an aurora?

Section 3 Assessment

Target Reading Skill Building Vocabulary Use your sentences to help answer the questions.

Reviewing Key Concepts

1. a. **Reviewing** How are Earth and a bar magnet similar?
   b. **Describing** How do Earth's magnetic properties explain how a compass works?
   c. **Interpreting Diagrams** Look at Figure 12. How do the positions of the geographic and magnetic poles compare?
2. a. **Identifying** What are two effects of Earth's magnetic field?
   b. **Explaining** How can scientists use rocks to learn about Earth's magnetic field?
   c. **Relating Cause and Effect** What causes the part of Earth's magnetic field called the magnetosphere to exist?

Lab zone At-Home Activity

House Compass With a family member, explore your home with a compass. Use the compass to discover magnetic fields in your house. Try metal objects that have been in the same position over a long period of time. Explain to your family member why the compass needle moves away from north near some objects.