8 Beneath Earth's Surface

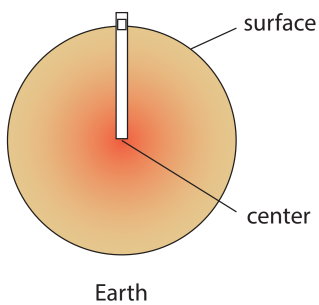
READING

In "Mapping Locations of Earthquakes and Volcanoes," you learned that earthquakes and volcanoes tend to occur in patterns around the globe. Why do all those earthquakes and volcanoes occur in certain places and not randomly across the planet? To answer these questions, it helps to know more about the structure of the Earth's interior.

GUIDING QUESTION

What is beneath Earth's surface?

Imagine taking a glass elevator to Earth's center. What would you see?



MATERIALS

For each pair of students

1 calculator

For each student

1 Student Sheet 8.1, "Beneath Earth's Surface"

1 Student Sheet 8.2, "Scaled Drawing of Earth's Interior"

1 clear metric ruler

PROCEDURE

Follow your teacher's instructions for filling out Student Sheet 8.1 to prepare you for this activity.

READING

Listen as your teacher reads aloud.

Stop when you see this yellow pencil and close your book.

Write down the main ideas you just heard.

Early scientists used evidence from volcanic eruptions to learn about what lies beneath Earth's surface. Over the past 100 years, scientists have learned more about Earth's interior using technology and new methods for gathering data. For example, scientists have learned a lot from analyzing and interpreting data gathered from earthquakes. During an earthquake, energy is transmitted in all directions from the center of the earthquake. The waves that transmit energy as a result of an earthquake are called *seismic waves*. There are different types of seismic waves, and they move through different materials at varying speeds. In general, seismic waves move faster through denser solids than they do through less-dense solids. Not all types of seismic waves can travel through liquids; these different behaviors give scientists clues about the structure of Earth's interior.

Scientists use seismometers to measure the seismic waves transmitted from earthquakes. By analyzing and comparing seismic-wave data from many earthquakes, scientists have been able to determine the state—solid or liquid—and the properties of materials that make up Earth's interior.

Scientists have used seismic-wave data and other evidence to explain that Earth has three main layers: a crust, a mantle, and a core. Information about each of these layers of Earth is presented in the table below:

LAYERS OF EARTH	APPROXIMATE DEPTH BELOW SURFACE (km)	STATE	MATERIAL	TEMPERATURE (°C)
Crust	5–40 on average	Solid	Many kinds of rocks	0–700
Mantle	40–2,800	Mostly solid. (Varies with temperature and pressure.)	Iron, magnesium, and silicate compounds	700–2,800
Outer Core	2,800–5,200	Liquid	Iron and nickel	2,800–6,000
Inner Core	5,200–6,400	Solid	Iron and nickel	Over 6,000

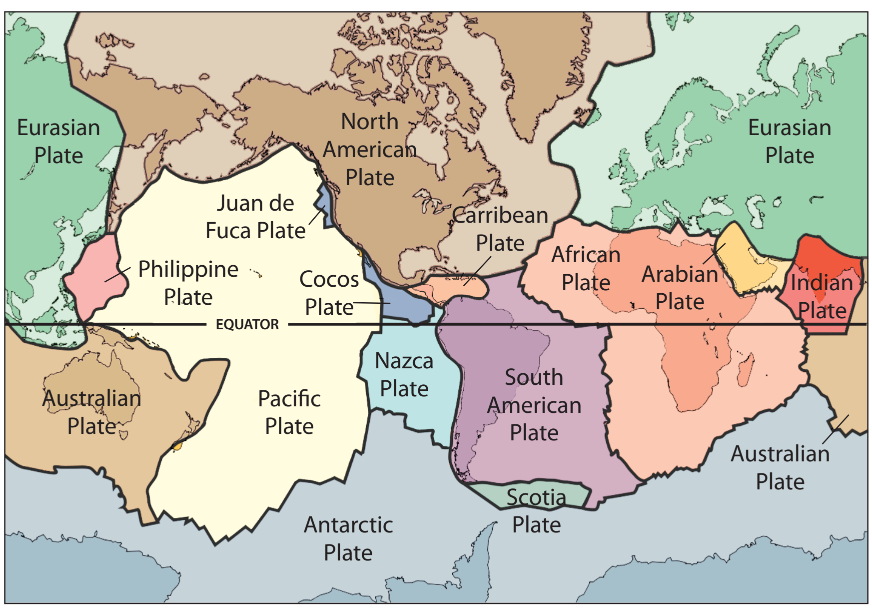
The crust is the outermost layer of the Earth. Below Earth's crust is the mantle. The mantle is almost 3,000 km thick, which is about the same as the distance from New York City to Denver, Colorado. Just as the land from New York to Colorado is not all the same, neither is the mantle. The uppermost part of the mantle is relatively cold compared with what is below it. Thus, it remains in a hard, solid state. Because the upper mantle and the crust are solid, geologists refer to the combination of these hard, solid layers as the **lithosphere** (*litho* means "stone" in Greek).

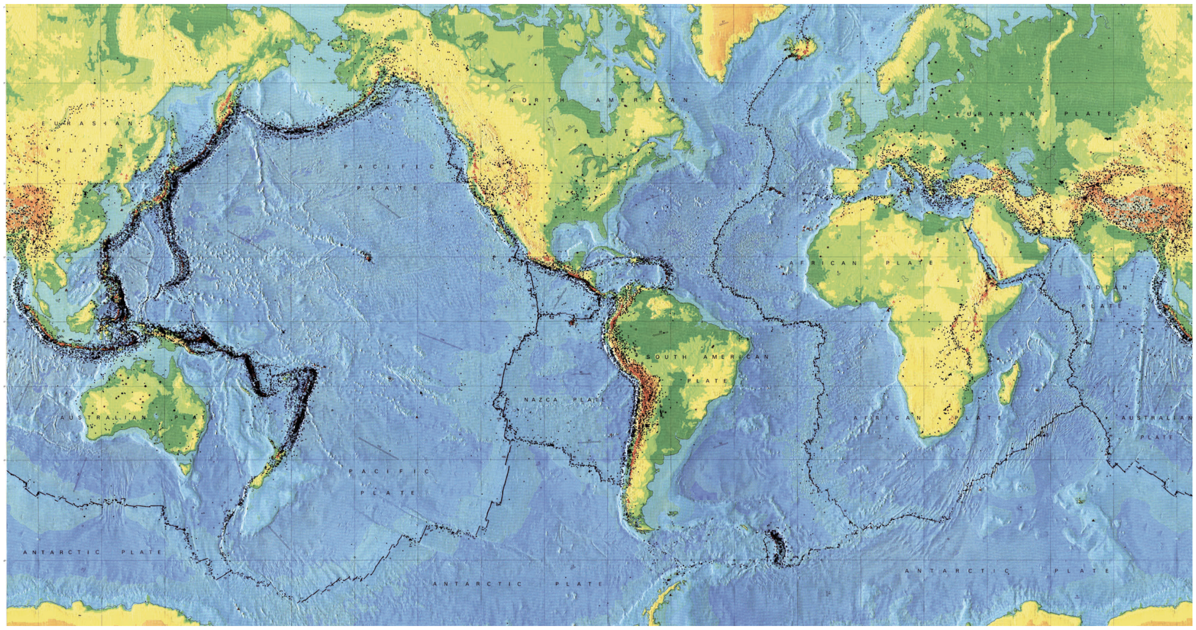
The lithosphere is approximately 100 km thick, on average. Earth's lithosphere is broken into pieces of various sizes called **lithospheric plates**, also referred to as Earth's plates. Places on the surface where two or more of Earth's plates meet are called **plate boundaries**. At plate boundaries, plates can move toward each other, move away from each other, or slide past each other. Volcanoes and earthquakes commonly appear on or near plate boundaries and are related to that motion.

Geologist installing seismometers to measure seismic waves from earthquakes

Just below the lithosphere, between the depths of 100 km and about 250 km, lies a layer of the mantle called the **asthenosphere** (ah-STHEEN-o-sfeer) (from Greek, where *a-* means "without," and *stheno-* means "strength"). The asthenosphere is a layer of solid rock that can flow and change shape. This weak, soft layer beneath the harder lithosphere allows the lithospheric plates to continuously move around very slowly. The movement of the lithospheric plates and their interactions at plate boundaries leads to the pattern of earthquakes and volcanoes on Earth's surface.

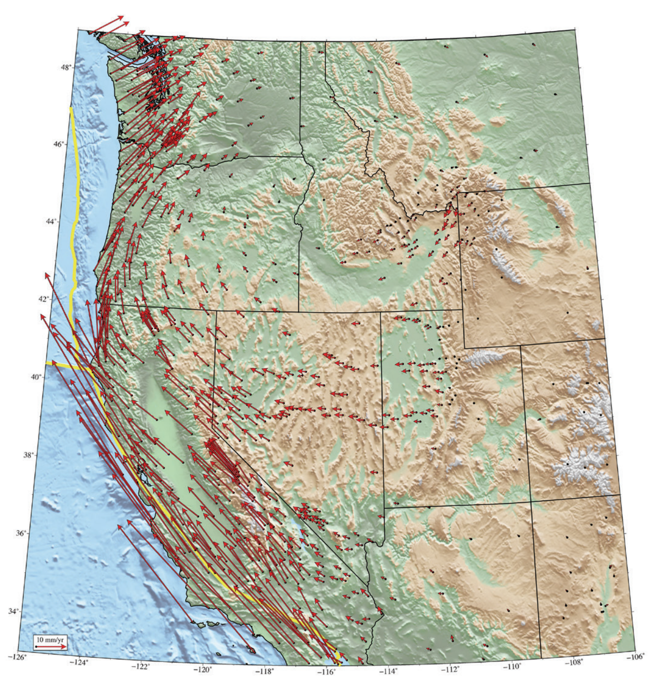
Map of Earth's Lithospheric Plates





Map of recent earthquakes and existing volcanoes on Earth. Black dots mark the locations of individual earthquakes and volcanoes.

One way that geologists study and monitor lithospheric plate movement is by using GPS technology. Data from GPS stations fixed in the lithosphere indicate the general direction Earth's plates are moving as they shift on top of weak, soft asthenosphere. The GPS data represented on the map below shows the direction and rate of plate movement in the western United States.



ANALYSIS

1. Which layer or layers of Earth
   a. are the hottest?
   b. are at Earth's center?
   c. are completely solid?
   d. contain the asthenosphere?
2. Copy the five words and phrases shown below:

   outer core

   lithosphere

   upper mantle

   solid

   crust

   a. Look for a relationship among the words. Cross out the word or phrase that does not belong.
   b. Circle the word or phrase that includes all the other words.
   c. Explain how the word or phrase you circled is related to the other words in the list.

   Your teacher will give you Student Sheet 8.2, "Scaled Drawing of Earth's Interior." Use it and the information from the reading to answer Analysis items 3 and 4.

3. On Student Sheet 8.2, answer Parts a–g to create a scaled drawing of Earth's layers. If you have colored pencils available, you may want to color in the different layers.
   a. Record the distance in kilometers from Earth's surface to its center.
   b. To make an accurate drawing, you first need to determine the scale, which tells how many kilometers each centimeter on your drawing will represent. On Student Sheet 8.2, use a clear metric ruler to measure and record the distance from the circle, representing Earth's surface, to its center in centimeters. Measure to the nearest 0.1 cm, and record this measurement in the table.
   c. Calculate the scale by dividing the actual distance to the center of Earth in kilometers by the distance you measured in centimeters on the drawing. Record your scale in the table.

d. In the table on Student Sheet 8.2, record the lowest depth of each Earth layer in kilometers. Then, use your scale and a calculator to determine the scaled depth of each location in centimeters.

e. Use the ruler to measure the depth of each layer from Earth's surface.
Hint: Save the crust–mantle boundary for last.

f. Label each layer with its name, state of matter, and temperature. If you don't have room to record the data on the drawing, write it next to the drawing, draw a box around the data, and draw an arrow to point from the box to the appropriate layer.

g. Calculate the scaled depths of the lithosphere and the asthenosphere. Draw one dotted line on your diagram to indicate the lower boundary of the lithosphere and another dotted line to indicate the lower boundary of the asthenosphere. Label the lithosphere and asthenosphere. Write the state of matter of each layer.

4. Scientists recommend storing nuclear waste deep underground. Use the model you created on Student Sheet 8.2 and the information about each layer to predict the best depth in Earth's interior for nuclear waste storage.

   a. In which layer of Earth do you think nuclear waste should be stored?

   b. Place an "X" on that layer on your copy of Student Sheet 8.2.

   c. Explain your reasoning for the prediction you made.

   d. How does the "X" you put on Student Sheet 8.2 compare with your initial thinking on Student Sheet 8.1?

EXTENSION 1

To learn more about how seismic waves interact with the layers of Earth, visit the *SEPUP Third Edition Geological Processes* page of the SEPUP website at *www.sepuplhs.org/middle/third-edition* for links with further information about the different types of waves and how they help scientists learn about Earth's interior. Be sure to check out the Animations tab.

EXTENSION 2

New discoveries can change our thinking. Learn about Inge Lehmann, an important geologist who used seismic-wave data to figure out that Earth's inner core is solid. Visit the *SEPUP Third Edition Geological Processes* page of the SEPUP website at *www.sepuplhs.org/middle/third-edition* for links with further information about her story.