The Earth System

The Geosphere

Key Concepts
- How do materials in the geosphere differ?
- Why does the geosphere have a layered structure?

Before You Read

What do you think? Read the three statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you’ve read this lesson, reread the statements to see if you have changed your mind.

<table>
<thead>
<tr>
<th>Before</th>
<th>Statement</th>
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<td>4. The inside of Earth is mostly solid rock.</td>
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<td>5. Rocks make up minerals.</td>
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Minerals

In science, the term mineral has a specific definition. A mineral is naturally occurring, inorganic, and solid, and it has a crystal structure and a definite chemical composition. Quartz is a mineral. Quartz formed naturally, was never living, is solid, has a crystal structure, and has a chemical composition of two oxygen atoms for each silicon atom.

Mineral Properties

Minerals have unique physical properties, such as color, that scientists use to identify them. Mineral properties include luster and streak. Luster is the way a mineral’s surface reflects light. Some minerals reflect a lot of light and appear shiny. Other minerals do not reflect a lot of light and appear dull. Streak is the color of a mineral’s powder. Scientists observe streak by scratching a mineral across a tile of unglazed porcelain. Although the color of a mineral often varies, its streak is always the same.
Hardness, Cleavage, and Fracture  Hardness is another physical property of minerals. Certain minerals are harder than others. The Mohs scale ranks minerals on a scale of 1 to 10 based on their relative hardness. Talc, the softest mineral, has a hardness of 1. Diamond, the hardest mineral, has a hardness of 10. Scientists determine the hardness of a mineral by how easily another mineral or a common object scratches it.

Hardness affects how easily a mineral breaks. **Cleavage** is the tendency of minerals to break along smooth, flat surfaces. The mineral calcite exhibits cleavage. When calcite breaks, it has defined edges. **Fracture** is the tendency of minerals to break along irregular surfaces. Quartz exhibits fracture because it does not break along a flat plane.

Mineral Interactions  Some minerals tend to break apart and combine with other substances. Other minerals are more stable and durable. Calcite and quartz are two common minerals that display this difference. On the Mohs scale, calcite has a hardness of 3, and quartz has a hardness of 7. Calcite dissolves in water more easily than quartz. This increases its interactions with other materials. Quartz does not dissolve easily or break apart as easily as calcite.

Rocks  You might know that a rock is a naturally occurring solid comprised of minerals and other materials. Scientists classify rocks according to how they form.

**Rock Types**  The three main types of rocks are igneous (IG nee us), metamorphic, and sedimentary. Igneous rock forms when molten rock material cools and hardens. This can happen deep inside Earth as magma cools, or when molten material called lava flows onto Earth’s surface and cools.

Metamorphic rock forms when high temperatures and extreme pressure act on sedimentary, igneous, or other metamorphic rocks. High temperatures and pressure alter the texture or the chemical composition of the rocks and form new metamorphic rocks.

Rock fragments called sediment make up sedimentary rock. Sedimentary rocks form when water, wind, ice, or gravity erode sediment and deposit it in layers. Over time, the weight from upper layers of sediment compresses lower layers. Sediment compacts and cements together, forming sedimentary rock.

**Think it Over**

2. **Apply**  What can you learn from comparing the rankings of two minerals on the Mohs scale?

**Reading Check**

3. **Identify**  What properties could you use to identify an unknown mineral?

**Reading Check**

4. **Name**  What are the three main types of rocks?
Interactions The formation of sedimentary rocks involves interactions among the geosphere, the atmosphere, the hydrosphere, and the biosphere. Recall that weathering breaks rock into small pieces. Physical weathering occurs when physical processes break down rock. For example, tree roots can grow in cracks in a rock, eventually breaking the rock. Chemical weathering results from chemical reactions on rock surfaces. Many of these chemical reactions include water.

Soil

Have you ever grown a garden? If so, you have used one of the most important materials in the geosphere—soil. Soil is the loose, weathered material in which plants grow. If you were to dig into the ground, you would see that soil has a layered structure. The layers form as Earth’s processes slowly transform rock into soil.

How Soil Forms At Earth’s surface, interactions among rocks, water, air, and organisms form soil. Soil formation begins when rocks weather into sediment. Water dissolves minerals and other materials from the sediment, and they become part of the developing soil. Animals and plants also affect soil formation. They weather sediment and create open spaces for air and water.

Wastes from organisms add nutrients to soil. Nutrients also enter soil when organisms die and their bodies decay. The organic matter makes soil more fertile and gives it a dark color. It takes hundreds to thousands of years to build thick layers of soil. Each layer has different properties.

A-Horizon The A-horizon is the part of the soil that you are most likely to see when you dig a shallow hole in the soil with your fingers. Organic matter from the decay of roots and the action of soil organisms often makes this horizon excellent for plant growth. Because the A-horizon contains most of the organic matter in the soil, it is usually darker than the other horizons.

B-Horizon When water from rain or snow seeps through pores in the A-horizon, it carries clay particles. The clay is then deposited below the upper layer, forming a B-horizon. Other materials also accumulate in B-horizons.

C-Horizon The layer of weathered parent material below the B-horizon is called the C-horizon. Parent material can be rock or sediments.
**Soil Interactions** Soil contains minerals, water, air, and organisms, all in close contact. Therefore, interactions among all Earth systems take place in soil. Recall that plants need phosphorus and carbon to grow. Plants cannot get phosphorus from the air, but they can obtain it from soil or from water in the soil. A major part of the organic matter in soil is carbon that plants obtain from the atmosphere through photosynthesis. Soil plays a major role in the phosphorus and carbon cycles.

**Structure of the Geosphere**

What do you think you would see if you could look inside the solid Earth? You would see layers similar to those in the figure below. The geosphere has three main layers: the crust, the mantle, and the core. Each layer has a different density. Recall that density is a measure of the mass of a material divided by its volume. The densest layer of the geosphere is the center, or core. The least-dense layer is the outer crust. The density of the thick mantle varies.

**Key Concept Check**

7. Differentiate How do materials in the geosphere differ?

**Visual Check**

8. Identify Highlight the layers of the geosphere that are solid.
Formation of Earth's Layers  Scientists hypothesize that Earth's layers formed early in the planet's history. Ancient Earth was much hotter than it is today. Thermal energy melted some of the rock. Then, gravity pulled denser materials through the melted rock toward Earth's center, forming layers.

Makeup of Earth's Layers  In addition to different densities, the layers of the geosphere have different compositions. Most of the geosphere is made of rock, but some of it is made of metal.

How do scientists know about the density and makeup of Earth's deep inner layers? Humans have never seen them. Scientists gather data by analyzing earthquake waves. As the waves travel through Earth, they change speed and direction as they pass through materials with different densities. Scientists use data about the waves to map Earth's interior.

Earth’s Crust  The rocky cliffs you see exposed along the sides of a highway are part of Earth’s crust. The crust is the thin outer layer of the geosphere. It is made of brittle rocks. These rocks are made of elements that combine and form minerals. Approximately 90 elements occur naturally in Earth’s crust. Just eight of these elements make up about 98 percent of the crust. The most common element in Earth’s crust is oxygen, followed by silicon, aluminum, iron, calcium, sodium, potassium, and magnesium. The following figure shows the two types of crust. One type is under the oceans. The other type makes up the continents. Oceanic crust is denser than continental crust.
**Oceanic Crust** The crust under the oceans is about 7 km thick. Oceanic crust is made of the dense igneous rocks basalt and gabbro. These rocks are rich in the dense minerals iron and magnesium. This makes oceanic crust denser than continental crust.

**Continental Crust** The crust that makes up continents is thicker than oceanic crust. Continental crust has an average thickness of about 40 km. Under large mountains, continental crust is as much as 70 km thick.

Continental crust is not made of the same kinds of rocks as oceanic crust. Continental crust is made of igneous, metamorphic, and sedimentary rocks. Rocks in the continental crust are rich in silicon and oxygen. These elements are less dense than iron and magnesium. This makes continental crust less dense than oceanic crust.

**Earth’s Mantle**

Beneath Earth’s crust is the mantle. *The mantle is the thick, rocky middle layer of the geosphere.* The mantle has the largest volume of any layer of Earth. Much of the mantle is made of the rock peridotite (puh RIH duh tite). Peridotite contains even more iron and magnesium than basalt and, therefore, is denser. The layers of Earth’s mantle are shown in the figure below.

**Reading Check**

11. **Contrast** How do oceanic crust and continental crust differ?

12. **Define** What is the mantle?

13. **Name** the layers of the lithosphere.
The Lithosphere Rocks in the uppermost mantle are more brittle than in the rest of the mantle and are similar to rocks in the crust. So the crust and the uppermost mantle are sometimes described as one layer, even though they have different compositions. The crust and the uppermost mantle form a brittle outer layer called the lithosphere.

Most of the rock below the lithosphere is solid. But high temperatures in the mantle make rock soft enough to flow. This is similar to the way a warm wax candle can bend instead of breaking. The mantle flows slowly, moving about as fast as your fingernails grow.

The Asthenosphere At a depth of about 100 km is an especially soft layer of the mantle. This weak, partially melted layer of the mantle is called the asthenosphere (as THEN uh sfirh). Less than 2 percent of the rock in the asthenosphere is melted. This small amount of molten rock makes the asthenosphere weaker than the rest of the mantle.

Earth’s Core The dense, metallic center of Earth is called the core. Note that the core is metallic and not rocky like the other layers of the geosphere.

Why is the core different than the other layers of the geosphere? Remember that, early in Earth’s history, the densest materials in the geosphere sank to the center. Therefore, the core is made mainly of iron with some nickel and traces of other elements.

Earth’s core is divided into two layers. One layer is liquid. The other layer is solid.

Outer Core Due to the high temperatures near the center of Earth, the outer layer of the core is liquid. As Earth spins on its axis, this molten iron flows. Scientists hypothesize that the movement of liquid iron in the outer core produces Earth’s magnetic field. Earth’s magnetic field is similar to the magnetic field of a huge bar magnet.

The magnetic field, shown in the figure on the next page, protects Earth from charged particles from the Sun. You have interacted with Earth’s magnetic field if you have ever used a compass to find a direction. The metal needle in the compass aligns with Earth’s magnetic field.
**Inner Core** Inside the outer core is a sphere of solid metal. Temperatures in this inner core are extremely hot, as high as 4,300°C. Despite the scorching heat, the metal in the inner core is not melted. The high pressure from the masses of all Earth’s layers compresses the inner core, making it solid.

*Reading Check*

17. **Summarize** What is the structure of the geosphere?

*Visual Check*

18. **Name** Which layer, the inner or outer core, produces Earth’s magnetic field?
1. Review the terms and their definitions in the Mini Glossary. Write a sentence explaining the difference between luster and streak.

2. Sequence the three major layers of the geosphere and state one fact about each.

3. Which soil layer do you think is the best for growing plants? Why?