

Chapter 22 Earth's Interior**Summary****22.1 Earth's Structure**

Geology is the study of planet Earth. Geologists are scientists who study Earth. They study what Earth is made of and the forces that change Earth's surface. Two types of forces change Earth's surface: constructive forces and destructive forces. Constructive forces build up Earth's surface. Destructive forces slowly wear away Earth's surface. These forces have been at work for billions of years. They are still changing Earth's surface today.

Earth consists of three main layers: the crust, the mantle, and the core. The layers differ in the materials they are made of. The layers also differ in density, temperature, and pressure.

The crust is the outer layer of Earth. It is thin and rocky. It consists mainly of silicates. Silicates are compounds containing silicon and oxygen. There are two types of crust: continental crust and oceanic crust.

- Continental crust makes up the continents. It consists mainly of less-dense rocks such as granite. It is relatively thick.
- Oceanic crust makes up the ocean floors. It consists mainly of more-dense rocks such as basalt. It is relatively thin.

The mantle is the layer below the crust. It is a very thick layer. The mantle consists of hot, solid rock. As you go deeper in the mantle, temperature and pressure increase. Like the crust, the mantle consists mainly of silicates. However, the mantle is denser than the crust. The mantle has three layers: the lithosphere, the asthenosphere, and the mesosphere.

- The lithosphere is the top layer of the mantle. It contains rock that is rigid, or stiff.

- The asthenosphere lies just below the lithosphere. It contains rock that is soft and can flow slowly.
- The mesosphere is the bottom layer of the mantle. It contains rock that is rigid.

The core is the layer below the mantle. It is a large sphere at the center of Earth. It consists mostly of iron. The core is extremely hot and under great pressure. The core is divided into two parts: the outer core and the inner core.

- The outer core contains liquid rock that flows. The iron in the flowing rock produces an electric current and creates Earth's magnetic field.
- The inner core is solid, even though it is extremely hot. It is under so much pressure that its particles are squeezed together in solid form.

22.2 Minerals

Most of Earth consists of rocks, and rocks consist of minerals. Minerals are inorganic solids. Inorganic means not made from living things. Minerals are also naturally occurring. This means that humans do not make them. In addition, minerals have a crystal structure. Recall that crystals are solids with their atoms arranged in a regular pattern. Minerals are also unique substances. Each mineral has its own chemical composition. There are thousands of different minerals. However, only a few minerals are common. Examples of minerals are quartz, sulfur, talc, diamond, mica, and halite.

Each mineral has a set of properties that help identify it. The properties are crystal structure, color, streak, luster, density, hardness, fracture, and cleavage.

- Crystal structure refers to the shape of a mineral's crystals. For example,

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quartz crystals are shaped like prisms. Other minerals have crystals shaped like cubes or sheets.

- Color refers to the color of the mineral itself. Some minerals have a characteristic color. For example, sulfur is always yellow. Other minerals may not always be the same color. For example, quartz can be white or violet.
- Streak is the color of a mineral's powder. You can see a mineral's streak by scraping the mineral against a certain type of plate. The powder left on the plate is the streak. The color of a mineral's streak may be different from the color of the mineral itself.
- Luster refers to how shiny a mineral is. It depends on how the mineral's surface reflects light. Minerals can have a metallic, silky, greasy, pearly, glassy, or earthy luster.
- Density is the amount of mass in a given volume of a material. The density of a mineral depends on what elements the mineral contains. For example, quartz consists of silicon and oxygen. Both of these elements have relatively low atomic masses. As a result, quartz is relatively low in density.
- Hardness measures how difficult a mineral is to scratch. A hard mineral can scratch a softer mineral, but a soft mineral cannot scratch a harder mineral. Diamond is the hardest mineral. It can scratch all other minerals. Talc is the softest mineral. It cannot scratch any other minerals.
- Fracture refers to how a mineral breaks. Quartz breaks into pieces with evenly curved surfaces. Some minerals break into pieces with jagged surfaces.
- Cleavage is a mineral's tendency to split apart along regular, well-defined planes. For example, mica splits into sheets, and halite splits into cubes.

22.3 Rocks and the Rock Cycle

Rocks are classified into three major groups based on how they form. The three groups are igneous, sedimentary, and metamorphic rocks.

Igneous rocks form from magma. Magma is a mixture of melted rock and gases. It forms underground. Lava is magma that flows out of volcanoes onto Earth's surface. When magma or lava cools and hardens, it forms igneous rock. If magma hardens underground, the igneous rock is called intrusive rock. Granite is an example of intrusive igneous rock. If lava hardens at Earth's surface, the igneous rock is called extrusive rock. Basalt is an example of extrusive igneous rock. Magma cools slowly underground. When magma cools slowly, it forms large crystals. As a result, intrusive rocks have large crystals. At Earth's surface, lava cools more quickly and forms small crystals. Therefore, extrusive rocks have small crystals.

Sedimentary rocks form from sediment. Sediment is small pieces of solid material from rocks or living things. Sediment settles to the bottom of oceans and lakes. As the sediment piles up, it puts pressure on the lower layers. Gradually, the pressure turns the sediment into rock. There are three types of sedimentary rocks: clastic, chemical, and organic.

- Clastic rocks form from broken pieces of other rocks. The pieces may be large or small. Sandstone is an example of clastic rock.
- Chemical rocks form from dissolved minerals. When the water evaporates, the minerals are left behind. Tufa is an example of chemical rock.
- Organic rocks form from the shells and bones of dead animals. The shells and bones sink to the bottom of oceans and lakes. They are pressed together over time. Limestone is an example of organic rock.

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Metamorphic rocks form from other rocks. High temperature and pressure gradually change the original rocks into new kinds of rocks. The original rocks can be any kind of rocks, including metamorphic rocks.

The rock cycle is a series of repeating processes in which rocks change from one type to another. Forces within Earth and at Earth's surface cause rocks to change form. For example, magma at Earth's surface hardens to form igneous rock. The igneous rock is gradually broken down into sediment. The sediment becomes part of sedimentary rock. The sedimentary rock is pushed deep underground. Heat and pressure change the sedimentary rock into metamorphic rock. The metamorphic rock later melts to form magma, and the rock cycle begins again.

22.4 Plate Tectonics

Plate tectonics is a scientific theory. The theory states that pieces of lithosphere move slowly on top of the asthenosphere. The pieces of lithosphere are called plates. The theory of plate tectonics explains the formation and movement of Earth's plates.

At one time, all the land surface of Earth formed a single supercontinent. Later, the supercontinent broke into pieces that moved apart. The continents are still moving. Continental drift is the process in which continents move slowly across Earth's surface.

The mid-ocean ridge is a chain of underwater mountains. It reaches into all of Earth's oceans, forming the world's longest mountain chain. There is a huge crack in the crust all along the mid-ocean ridge. On each side of the crack, pieces of ocean floor move slowly apart. This is called sea-floor spreading. As pieces of ocean floor move apart, magma from the mantle pushes up through the crack. The magma forms new crust. As the new crust moves away from the crack, it cools

and hardens. It also becomes denser. Gravity eventually causes the denser crust to sink back into the mantle. This is called subduction. It occurs in regions called subduction zones. Sea-floor spreading and subduction occur together in a continuous cycle. Sea-floor spreading creates new oceanic crust at the mid-ocean ridge. Subduction destroys old oceanic crust at subduction zones.

According to the theory of plate tectonics, continental drift and sea-floor spreading are caused by convection currents in Earth's mantle. Hot melted rock from the mantle rises at the mid-ocean ridge. The rock cools and spreads out to form lithosphere. Pieces of lithosphere later sink back into the mantle at subduction zones. Through these movements, heat flows from Earth's hot inside toward the cooler surface.

There are about 12 major plates. Most major plates contain both continental and oceanic crust. The edges of plates meet at plate boundaries. Most mountains form along plate boundaries. There are three types of plate boundaries: divergent, convergent, and transform boundaries. At each type of boundary, plates move in a different way.

- At a divergent boundary, plates move away from each other. Magma rises and forms new rock at the gap between divergent plates. The magma may form mountains, such as the mid-ocean ridge.
- At a convergent boundary, plates move toward each other. When the plates come together, the denser plate may slide under the other plate and sink into the mantle. Alternatively, the edges of the two plates may buckle and fold to form mountains.
- At a transform boundary, plates slide past each other in opposite directions. Rock is not created or destroyed at a transform boundary.

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22.5 Earthquakes

An earthquake is a movement of Earth's lithosphere. It occurs when rocks suddenly shift and release stored energy. The energy released during an earthquake is carried by waves. Earthquake waves are called seismic waves. Seismic waves can cause thousands of deaths and billions of dollars in damage.

The movement of plates explains why earthquakes occur. As plates move, they cause stress in the crust. Stress is a force that squeezes rocks together, stretches them apart, or pushes them in different directions. Stress in the crust causes faults and folds. A fault is a break in a mass of rock along which movement can occur. A fold is a bend in layers of rock. Both faults and folds tend to form along plate boundaries.

When stress builds up along a fault, an earthquake may occur. Earthquakes occur because stress forces have become greater than the rock can bear and the rock suddenly shifts. The place beneath Earth's surface where an earthquake begins is called the focus. The place on Earth's surface directly above the focus is called the epicenter. After an earthquake occurs, seismic waves move out in all directions from the focus. Earthquakes produce three main types of seismic waves: P waves, S waves, and surface waves.

- P waves are longitudinal waves. They push and pull the ground like a spring. P waves are the fastest seismic waves. They can travel through both solids and liquids.
- S waves are transverse waves. They shake the ground up and down or back and forth. S waves can travel only through solids and not through liquids.
- Surface waves are seismic waves that reach Earth's surface. Surface waves are slower than P and S waves. However, surface waves move the

ground more and cause greater damage than P and S waves.

Scientists can find the epicenter and strength of an earthquake using seismographs. A seismograph is a device that detects and records seismic waves. Information from several seismographs in different places is needed to determine where an earthquake occurred. The strength of an earthquake is measured on a scale. The most useful scale for geologists is the moment magnitude scale. This scale measures the amount of energy released by an earthquake.

Every day, earthquakes occur all around the world. Most earthquakes occur along plate boundaries because this is where many faults are found. Scientists have used data on earthquakes to learn more about the inside of Earth. For example, scientists know that Earth's outer core is liquid because S waves cannot pass through it.

22.6 Volcanoes

A volcano is a mountain that forms when magma reaches Earth's surface. The process begins deep inside Earth. Rock in the mantle melts and forms magma. The magma rises up toward the crust. The magma rises because it is less dense than the solid rock around it. Before the magma breaks through the crust, it may collect in a space underground called a magma chamber. The magma may rise to the surface through a narrow, vertical channel called a pipe. When the volcano erupts, the magma finally breaks through the surface. A vent is an opening in the ground where magma escapes to the surface. There may be more than one vent. The central vent may have a bowl-shaped pit called a crater.

Some volcanoes erupt with an explosion. Other volcanoes erupt quietly. How a volcano erupts depends on how easily the magma flows. Thin magma flows easily. It causes quiet eruptions. Thick magma resists flowing. It can clog

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a volcanic pipe so that great pressure builds up inside the volcano. When the volcano finally erupts, it explodes.

Most volcanoes occur along plate boundaries or at hot spots in the crust. At a convergent boundary, a plate sinking into the mantle causes melting. Magma forms and rises to the surface. At a divergent boundary, magma rises to fill the gap between two separating plates. A hot spot is a region where hot rock extends from deep within the mantle all the way to the surface.

There are three major types of volcanoes: shield volcanoes, cinder cones, and composite volcanoes.

- A shield volcano is a wide, flat volcano. It is produced by a quiet eruption of thin magma. Because the magma is thin, it travels a long way before it hardens.
- A cinder cone is a small volcano with steep sides. It is produced by the eruption of ash and cinders instead of magma.
- A composite volcano is a tall volcano with steep sides. It is produced by repeated explosive eruptions of thick magma and ash.

Sometimes magma does not reach the surface. Instead it cools and hardens in the crust to form intrusive igneous rock. A batholith is a large mass of intrusive igneous rock that has been forced up to Earth's surface. Batholiths often form mountain ranges. Magma also may harden in the cracks between layers of rock. If the cracks run in the same direction as the rock layers, the formation is called a sill. If the cracks run at right angles to the direction of the rock layers, the formation is called a dike. In addition, magma may harden in the pipe of a volcano. This forms a structure called a volcanic neck.

Lava sometimes erupts from many long, thin cracks in the crust. This lava may spread out over a huge area before hardening. After many years, layers of hardened lava may form a high flat area called a lava plateau.