6.E.2. Do not write on packet

175

Geology

You might think Earth is basically a giant ball of rock and soil. This description is partly correct. Earth is roughly spherical and has a rocky surface. But beneath this solid surface, Earth is very different.

Earth Structure and Composition

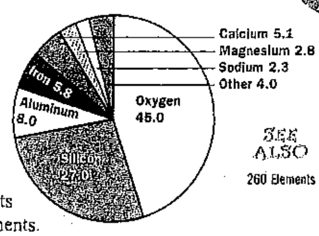
176

Research shows that Earth is made of several materials. The materials make up different layers.

Structure of Earth

177

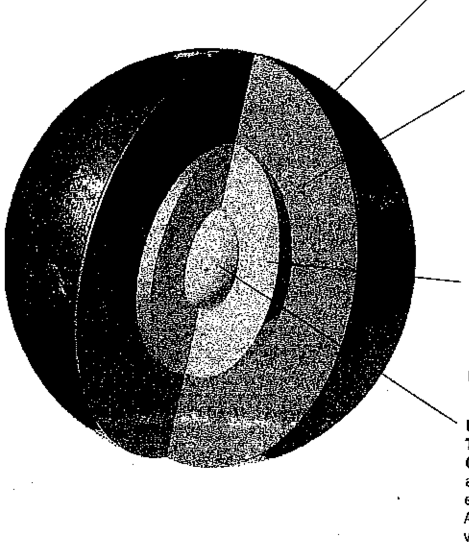
Every time you walk outdoors, you are in contact with Earth's outermost layer, the **crust**. Based on your own experience, you know that some of Earth's crust is made up of soil. Beneath this soil is a thick layer of rock. Most rocks that make up Earth's crust are made up primarily of the elements silicon and oxygen. As shown in the chart, the crust also holds small amounts of aluminum, iron, calcium, and other elements.



SEE ALSO 260 Elements

MORE

If you have ever planted a garden or dug a hole in the ground, you know that Earth's crust is made up of soil and rocks. But what would you find if you kept digging until you reached Earth's center? If you could dig a hole to the center of Earth, you would pass through four layers. From outside to inside, these layers are the **crust**, the **mantle**, the **outer core**, and the **inner core.** Each layer has its own characteristics.



CRUST
Thickness: 5–10 km beneath the oceans; 20–70 km beneath the continents.
Other Features: Mostly solid rock

MANTLE
Thickness: About 2900 km
Other Features: High temperatures (2800–3200°C) in the upper part of the mantle melt rocks, forming a substance called **magma.** Magma flows like hot and thick oatmeal.

OUTER CORE
Thickness: About 2250 km
Other Features: Made up mostly of molten (melted) iron and nickel; Temperatures between 4000–5000°C

INNER CORE
Thickness: About 1280 km
Other Features: Solid iron and nickel; Temperature estimated at 6000°C; Although the inner core is very hot, it is kept solid due to the great pressure of the layers above it.

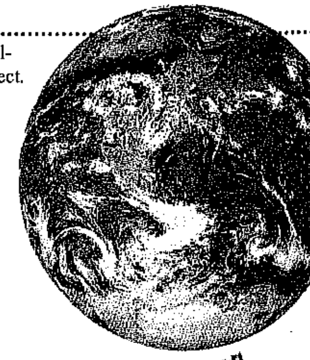
Did You Know?

If Earth were the size of an apple, the crust would be only as thick as the apple's skin.

Earth's Size and Shape

178

Earth is almost spherical, or ball-shaped, but its shape is not perfect. Earth is a little flattened at its poles and bulges a bit at its equator. For this reason, Earth's diameter from the North Pole to the South Pole is slightly smaller than its diameter from one point on the equator to an opposite point halfway around the equator.



Word Watch!

The diameter of a sphere is the length of a line that passes through its center. The distance around the sphere is its circumference.

EARTH PROFILE

Characteristic	Measurement
Diameter: North to South Pole	12,664 km
Diameter: Equator	12,756 km
Circumference: Around Poles	39,995 km
Circumference: Around Equator	40,064 km
Mass	5,882 sextillion metric tons
Volume	1,083 billion km^3
Total Surface Area	510 million km^2
Land Area	149 million km^2
Water Area	361 million km^2
Average Distance from Sun	149,573,900 km
Average Distance from Moon	384,400 km
Length of Day (one rotation on axis)	23 h, 56 min, 4.1 s
Length of Year (one revolution around sun)	365 days, 5 h, 48 min, 46 s
Axial Tilt (° tilted on axis from vertical)	23.5°

Minerals

179

A **mineral** is a naturally formed solid substance with a crystal structure, which was not formed from living things. A **crystal structure** is a definite pattern in the way that particles in a substance are arranged. A mineral has a crystal structure even if it does not have a crystal shape that you can see.

Amethyst (quartz)

Each kind of mineral has certain properties that you can use to identify it. One property of minerals is hardness. **Hardness** is the ability of a mineral to resist being scratched. A harder mineral will always scratch a softer one. German scientist Friedrich Mohs developed a system for comparing the hardness of a mineral to 10 common minerals. These 10 minerals make up Mohs' Hardness Scale. The scale is based on familiar minerals, not on exact differences in hardness. The difference in hardness between minerals 3 and 4, for example, is much less than the difference in hardness between minerals 9 and 10. Even though the scale is not exact, it is still quite useful for identifying specimens.

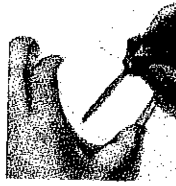
MOHS' HARDNESS SCALE FOR MINERALS

Hardness	Mineral	Common Object
1	Talc	
2	Gypsum	Fingernail (2.5–3)
3	Calcite	Copper penny
4	Fluorite	
5	Apatite	Steel blade
6	Feldspar	Glass 5–6
7	Quartz	
8	Topaz	
9	Corundum	
10	Diamond	

To remember Mohs' Hardness Scale, make up a sentence with the first letters of each mineral, like The Giant Cat Found A Foolish Quail That Couldn't Dance.

Other properties used to identify minerals include:

- **Color** A mineral may be one color or many colors. You cannot identify a mineral by color alone, but color is helpful along with other properties.
- **Luster** This property describes how a mineral reflects light from its surface. Some minerals are shiny like metal or glass (a glassy luster is called vitreous). Others have dull, waxy, or earthy lusters.
- **Streak** Streak is the color of a mineral in powder form. You can find out a mineral's streak by rubbing it across an unglazed porcelain streak plate. Each mineral makes a streak of a certain color. This color may differ from the color of the mineral.



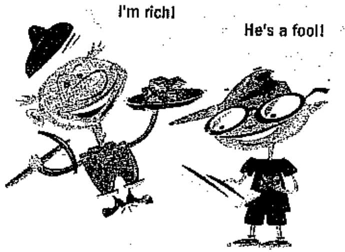
- **Crystal Shape** The atoms or ions of a mineral are arranged in a certain pattern. That pattern may result in a distinct crystal shape for the mineral. The pattern of the atoms in a mineral also affects its cleavage.
- **Cleavage and Fracture** Minerals break according to how their atoms are arranged. **Cleavage** is the tendency of a mineral to break along a flat surface where layers of atoms are attached weakly to each other. **Fracture** is the tendency of a mineral to break in a way that is not along a flat surface.

Halite

- **Specific Gravity** The specific gravity of a mineral is a comparison of its density to the density of an equal volume of water.

SEE ALSO 068 Finding Density

You can find mineral properties in a field guide. Using such guides along with observations and a few tests, you can find out if a yellow-colored mineral you find is gold or pyrite (fool's gold). A greenish-black streak tells you it is pyrite.



180 Rocks

Rocks are solid earth materials formed from a mixture of minerals and sometimes other materials. Rocks are classified into one of three groups based on how they formed. These groups are igneous rocks, sedimentary rocks, and metamorphic rocks.

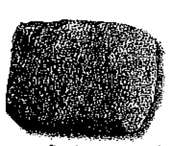
SEE ALSO 177 Structure of Earth

Igneous Rocks High temperatures deep in Earth's crust cause rocks and minerals to melt, forming a liquid called **magma.** Magma that reaches Earth's surface is called **lava. Igneous rocks** form when magma or lava cools and becomes solid. Rocks that form from quickly cooled lava, such as rhyolite, are called **extrusive** or **volcanic** and have small mineral grains. Rocks that form from slowly cooled magma, such as granite, are called **intrusive** or **plutonic** and have large mineral grains.

Granite

SEE ALSO 272 Parts of a Solution

Sedimentary Rocks Pieces of rocks, minerals, remains of living things, and dissolved minerals that come out of water (such as lime) are all kinds of **sediment.** When sediment becomes solid material, it makes a **sedimentary rock.** Sediment is moved by wind and water and piles up on land and on riverbeds, lake bottoms, and the ocean floor. New layers of sediment build up over time, pressing down on older layers underneath. Dissolved minerals, such as calcite, come out of the water and cement the grains together. In time, the pressure and cementing form a **clastic** sedimentary rock, such as sandstone, shale, and many kinds of limestone. A **chemical** sedimentary rock, such as rock salt, forms when minerals come out of solution and settle on the ocean floor. An **organic** sedimentary rock, such as chalk, forms from the remains of once-living things.

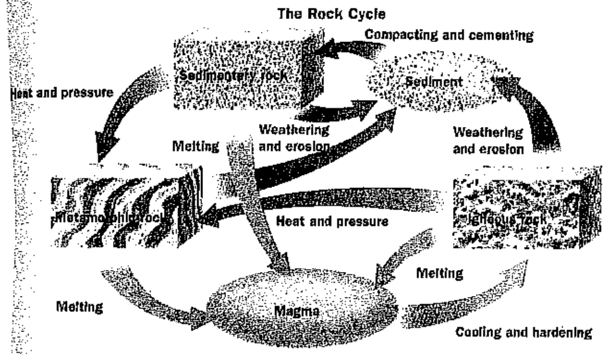


Sandstone

Metamorphic Rocks Over time, heat and pressure inside Earth squeeze and melt existing rocks. This process changes the grain size and even the minerals that make up those rocks, forming a new type of rock, called a metamorphic rock. **Metamorphic rock** is rock that has been changed in form by pressure and heat. Gneiss and slate are examples of metamorphic rocks. Gneiss many form from granite. Slate forms from shale.

Gneiss

Throughout Earth's history, rocks of each type have been changed into other types by natural forces. They have been broken, heated, pressed, and pushed around over and over again. This constant changing in the form and structure of rocks is called the **rock cycle.**



Melting	Hot temperatures deep inside Earth melt rocks, forming magma.
Cooling and Hardening	Magma that rises from deep inside Earth cools as it reaches the surface, hardening into rock. Magma also cools beneath the surface.
Weathering and Erosion	Weathering breaks apart existing rocks, forming sediment. Erosion moves sediment to new locations.
Compacting and Cementing	Pressure compacts sediments together. Water between particles evaporates, leaving minerals that cement sediments.
Heat and Pressure	Heat and pressure inside Earth melt and squeeze minerals in rocks. This changes the minerals themselves or their grain sizes.

SEE ALSO 188 Weathering, Soil, and Erosion
195 Geologic Principles

Science Alert!

The rock cycle shows many possible paths rocks can undergo to change from one form to another. A certain rock may go through all or only some stages in the rock cycle.

181 Plate Tectonics and Mountain Building

Based on your own observations, you may think of Earth as a rigid, unchanging planet. The TV news tells how parts of Earth can change suddenly from volcanoes, earthquakes, or floods. Earth is also changing slowly beneath your feet, even as you read these pages. Large parts of Earth are always on the move. Some parts move sideways, while others rise or sink.

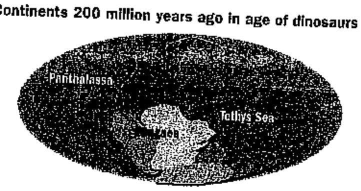
182 Continental Drift

SEE ALSO 199 Earth's Continents through Time

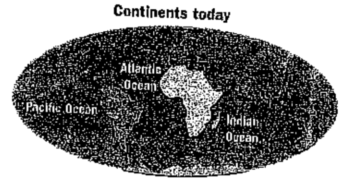
In 1912, the German scientist Alfred Wegener proposed two ideas that are now known as the theory of continental drift. The **theory of continental drift** states that Earth's continents were once joined in a single large landmass that broke apart, and that the continents have drifted to their current locations. Other scientists at the time made fun of Wegener's ideas, because no one could imagine how continents could have moved. But geologists have found a lot of evidence to support the theory of continental drift, including rocks, fossils, measurements, and ocean-floor structures. Today's **theory of plate tectonics** is a more complete picture that includes all the evidence that the continents have moved and are still moving.

One piece of evidence is that the shapes of continents fit together like puzzle pieces. Compare the shapes of South America and Africa.

Continents 200 million years ago in age of dinosaurs



Continents today



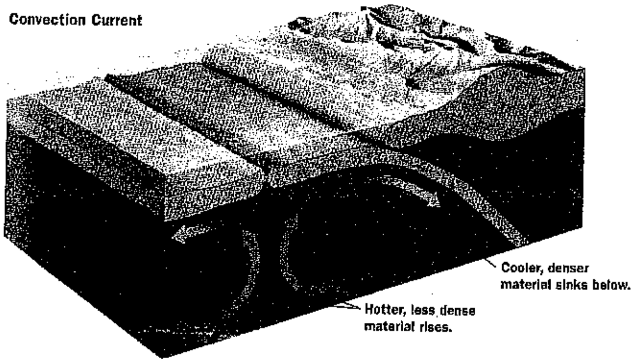
183

Lithospheric Plates

No one has been able to dig through Earth to see what it's like inside. Scientists must use indirect evidence, such as the way earthquake waves move through Earth, to form a model of Earth's interior. The best evidence supports this model: Earth's solid crust lies over a layer of melted material called the **mantle.** As material deep in the mantle is heated, it becomes less dense and rises. At the same time, material nearer Earth's surface spreads out, cools, and becomes denser. This denser material sinks below the hotter, less dense material. Uneven heating causes material in the mantle to constantly and slowly rise and fall in a **convection current.**

SEE ALSO
006 Forming a Hypothesis
177 Structure of Earth

Convection Current



As convection currents move the molten material sideways, large portions of the crust, called **lithospheric plates,** ride on top across Earth's surface. The **lithosphere** is the rocky outer shell of Earth, which is made up of the crust and the rigid upper part of the mantle.

Earth has two kinds of crust: **continental crust** and **oceanic crust.** Continents are made of continental crust, which is made up of rocks that are less dense than those of oceanic crust. Because it is less dense, continental crust rides higher on the mantle than oceanic crust.

Word Watch!

The prefix *litho-* comes from the Greek *lithos* meaning stone or rock. The root word *sphere* in this case means a layer in a ball shape.

SCI LINKS Keyword: Plate Tectonics
www.scilinks.org
Code: GSSM181

184

Plate Boundaries

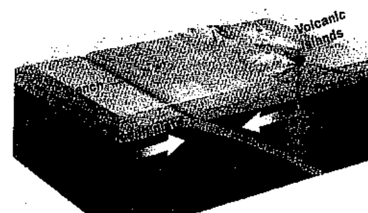
Earth's crust is made up of seven major and several minor lithospheric plates. The plates are named for the surface features that lie on top of them. The seven major plates are the: Pacific, North American, South American, Eurasian, African, Indo-Australian, and Antarctic. The edges of most plates lie beneath the oceans. **Plate boundaries** occur where the edges of plates meet. The type of boundary depends on whether the plates forming them are moving toward each other, separating, or sliding past each other.

Colliding continental plates
Makes mountains like the Himalayas

A **convergent boundary** forms where plates collide. The pressure and violence at convergent boundaries produces mountains and bands of earthquake and volcanic activity. The west coast of South America with its towering Andes mountains, volcanoes, and frequent earthquakes is the location of a convergent boundary. It is here that the Nazca Plate crunches into the South American plate.

Colliding ocean and continental plates
Makes mountains like the Andes

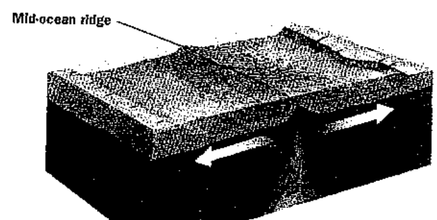
The movement of one plate under another is called **subduction.** Subduction happens at converging plate boundaries. When a plate undergoes subduction, the rocks in that plate are pushed deep into Earth where they are heated and changed into molten material. This molten material, which is under great pressure, can escape through weak spots in Earth's crust as an erupting volcano.



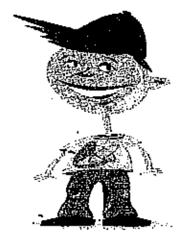
Colliding ocean plates
Makes volcanic islands like the Aleutians

A **divergent boundary** forms when two plates diverge, or move away from each other. Melted rock from the mantle can seep to the surface at divergent boundaries and form new crust. Most divergent boundaries are in the oceans. Here, they build undersea mountain ranges called **mid-ocean ridges.** The Great Rift Valley in Africa is at the edge of a divergent boundary on a continent.

As new crust forms at mid-ocean ridges, other crust is consumed at deep-sea trenches. So Earth's surface doesn't get any bigger.

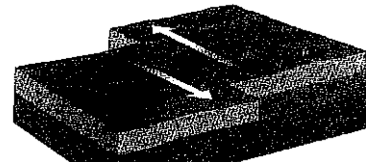


Separating plates
Makes mid-ocean ridges like Mid-Atlantic Ridge



A **transform boundary** forms where two plates slide past each other. If you live on the west coast of the United States you may have felt the effects of a transform boundary. Here, the Pacific and North American plates slide past each other in a north-south direction. The sliding causes rocks along the boundary to grind against each other from time to time, causing jolts that you feel as earthquakes.

Transform Boundary



Sliding plates
Strike-slip boundary like San Andreas Fault

Did You Know?

The transform boundary between the Pacific and North American Plates is moving Los Angeles north toward San Francisco at a rate of about 5 cm a year. At this rate, it would take the two cities about 11 million years to be side-by-side (but the rate is usually slower).

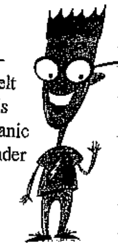
185

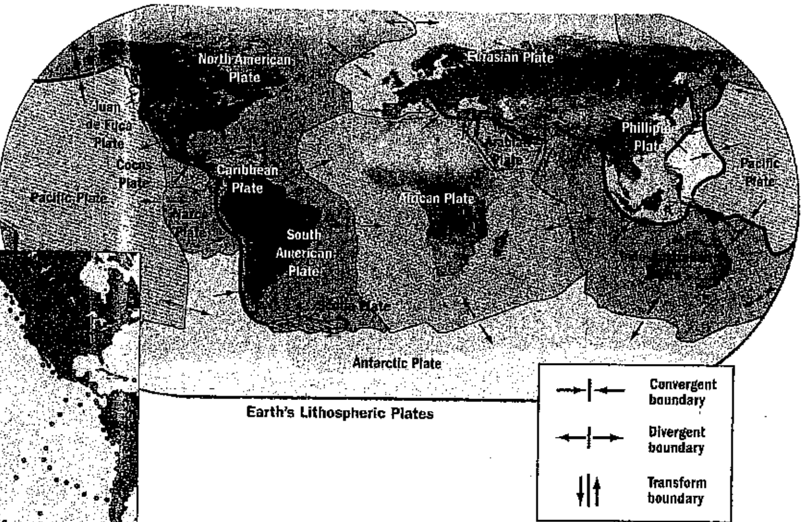
Map of Plate Boundaries

Earth's lithospheric plates make up the entire surface of Earth. Plates are constantly in motion; they move toward each other, away from each other, or slide past each other. Most earthquake and volcano activity takes place at the plate boundaries.

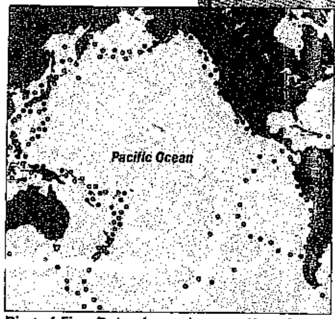
The Juan de Fuca plate is a small plate off the coast of the northwest United States. The movement of this small plate causes a lot of volcanic activity.

An interesting feature produced by lithospheric plate boundaries is the Ring of Fire. The **Ring of Fire** is a ring-shaped belt of volcano and earthquake activity in the Pacific Ocean. This belt is formed at plate boundaries where plates of dense oceanic crust (the Pacific, Nazca, and Juan de Fuca Plates), move under less dense continental plates (the North American, Eurasian, Indo-Australian, and South American Plates).





Earth's Lithospheric Plates



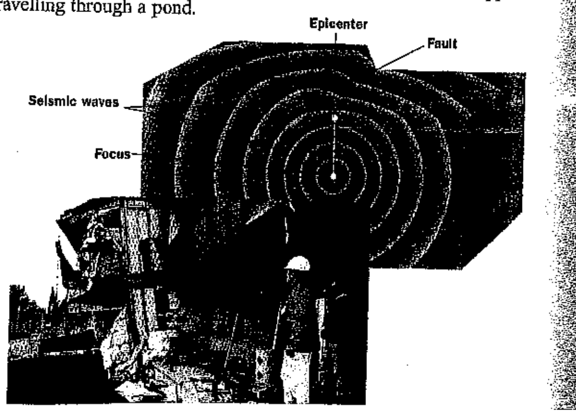
Ring of Fire: Dots show where earthquakes or volcanic activity are common.

186 Earthquakes

Press the palms of your hands flat together as hard as you can. While you are doing that, try to slide one hand past the other. Unless your hands are wet, they probably do not slide past each other smoothly. Most likely your hands stay in place until they suddenly slide a few centimeters, then stop. This is the way movement takes place in Earth's crust. Movement occurs along **faults,** which are large cracks in Earth's crust. Rocks on either side of a fault are under pressure and get locked together, just like your hands did. When too much pressure builds up, the rocks suddenly slide past each other and release the pressure. You feel the result as an **earthquake,** or violent shaking of Earth's crust.

SEE ALSO 307 Kinds of Waves

The place in Earth's crust where the pressure was released is called the **focus.** Earthquake waves, or **seismic waves,** spread out in all directions from the focus like ripples through a pond. The focus can be many kilometers down in the crust, so usually people talk about an earthquake **epicenter,** which is the spot on Earth's surface directly above the focus. Earthquakes make three kinds of seismic waves. **Primary waves** (also called P-waves) stretch and compress land as they pass through. **Secondary waves** (also called S-waves) move land side to side. **Land waves** (also called L-waves) form when P- and S-waves combine. Land waves move land up and down, like ripples travelling through a pond.



Seismic waves provide evidence for the model of Earth's layers. P-waves travel through solids and liquids, but S-waves can travel only through solids. When an earthquake occurs, both P- and S- waves reach nearby seismographs, while only P-waves reach seismographs on the other side of Earth. So there must be a liquid layer stopping the S-waves. The P-waves do not come out where you would expect, so there must be a change in density causing the P-waves to bend. The strength, or **magnitude,** of an earthquake can be measured using a seismograph. A few different scales are used to measure earthquake magnitude. You will most often hear about the **Richter scale.** The Richter scale is named for the American scientist Charles F. Richter, who invented the scale in 1935. The Richter scale has a range from 1 through 9. Each number on the scale stands for a ten-fold increase in the size of the earthquake wave. For example, a magnitude 5 earthquake has a wave that is ten times larger than a magnitude 4.

Another scale that is often used to measure earthquake magnitude is the Mercalli scale. This scale describes magnitude based on how much damage the earthquake causes.

Richter Scale

Magnitude	Earthquake Effects
1–3	Not felt; recorded on local seismographs
3–4	Felt by people; no damage
5	Felt by most people; causes slight damage near epicenter
6	Damage caused to poorly constructed buildings and other structures within about 10 km
7	Causes major damage to structures up to 100 km from epicenter
8	Very destructive; may cause loss of life over a distance of several hundred kilometers
9	Very rare; major damage to areas as much as 1000 km away

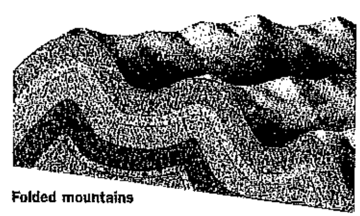
Source: Geological Survey of Canada

187 Mountain Building and Volcanoes

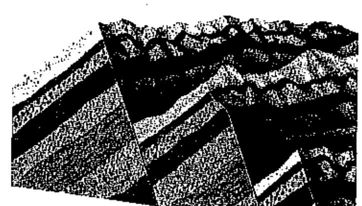
SEE ALSO 183 Lithospheric Plates 184 Plate Boundaries

A major force shaping the land is **uplift,** the lifting of land by forces in Earth's crust. Moving plates uplift land, forming mountains. Three types of mountains are folded mountains, fault-block mountains, and volcanic mountains. Each forms by a different type of plate movement.

Place a sheet of paper flat on your desk. Place a hand on one edge of the paper. Push your other hand against the free edge of the paper. What happens? A fold, or bulge, forms in the paper. Earth's crust may experience the same effect when lithospheric plates collide. In this case, the "bulge" becomes a mountain range. Mountains formed in this way are called **folded mountains.** The Rocky Mountains of North America, the Andes of South America, the Alps of central Europe, and the Himalayas of Asia are examples of folded mountains.


Folded mountains

Mountains can form when blocks of Earth's crust on either side of a fault are dropped below or pushed above the surrounding land. This happens where sections of crust are pulling apart or pushing together. At these places, large blocks of the crust are sliding up and down past each other. The taller blocks form **fault-block mountains.** Examples of fault-block mountains include the Sierra Nevadas of California, the Wasatch Range of Utah, and the Teton Range of Wyoming.

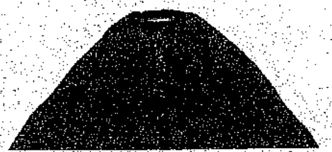

Fault-block mountains

Volcanoes, or volcanic mountains, form when material from inside Earth reaches the surface. Volcanic mountains are most common at plate boundaries. Within converging boundaries, heat and pressure melts rock into magma, which can rise through cracks in the crust. When magma is forced up onto Earth's surface, it becomes lava that hardens into rock. At diverging boundaries, where plates are pulling apart, magma rises through cracks and forms the mountains at mid-ocean ridges.

Volcanoes are classified into three types based on how they form.

Cinder cone volcano

- sudden, violent eruption
- formed from ash, cinders, dust
- cone-shaped mound
- Mount Paricutín, Mexico; Mount Isalco, El Salvador

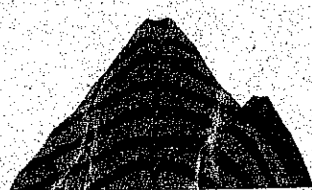


Shield volcano

- slow, gentle eruption
- formed from layers of cooled lava
- low, gently-sloped sides
- Mauna Loa, Mauna Kea in Hawaii

Composite cone volcano

- both violent and gentle eruptions
- formed from alternating layers of ash and lava
- cone-shaped mound, steep sides
- Mount Vesuvius, Italy; Mount St. Helen's in Washington State; Mount Egmont, New Zealand



188 Weathering, Soil, and Erosion

Earth's surface is constantly changing. Movements at plate boundaries build up Earth's surface, forming mountains. At the same time, two other processes wear down Earth's surface. Weathering changes Earth by breaking rocks and other matter into smaller particles called sediment. Erosion sweeps these weathered particles away.

Weathering breaks up rock into smaller pieces, much like you might do using a hammer. Unlike using a hammer, the weathering of rock in nature is a gradual process. No matter how slowly, sooner or later, every rock that is in water or air will be weathered away. There are two main types of weathering: mechanical weathering and chemical weathering.

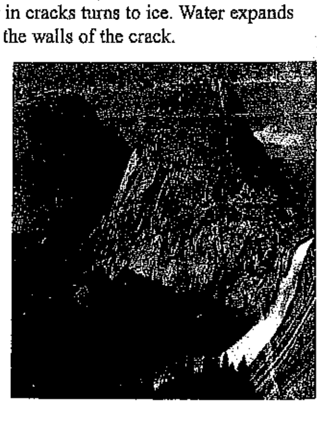
Word Watch!

Weathering means breaking rock apart by water, wind, and other agents. *Erosion* means the movement of those rock particles, often from a higher to a lower elevation.

189 Mechanical Weathering

Mechanical weathering, also called physical weathering, takes place when rocks are broken apart by a physical force.

- **Ice Wedging** When the temperature drops below the freezing point of water (0°C), water in cracks turns to ice. Water expands as it freezes, pushing apart the walls of the crack.
- **Release of Pressure** When a large mass of a rock such as granite reaches Earth's surface, the pressure on it is reduced. There is evidence that this release of pressure can cause pieces of the rock to flake off. As they start to flake, chemical weathering helps to speed the process.



- **Abrasion** Moving water and air (wind) can carry sand and other particles. When these particles strike rocks, they chip away the surface, much as you would if you rubbed a rock with sandpaper.
- **Plant Action** Plant roots can grow in cracks in rocks. As roots grow, they break apart the rock.

SciLinks Keyword: Weathering/Erosion www.scilinks.org Code: GSSM188

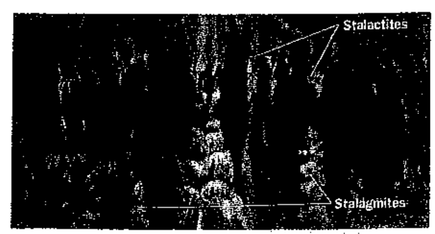
190 Chemical Weathering

Chemical weathering changes the chemical makeup of rocks and minerals. Chemical weathering can remove certain minerals from some rocks. It can also change the minerals into new substances. There are two main types of chemical weathering.

- **Oxidation** The red-brown crust called rust is iron oxide. It forms when oxygen joins chemically with iron. Oxidation is the joining of oxygen with other substances. Oxidation can weaken and crumble rocks as well as metal.
- **Dissolving by Acids** Water can dissolve minerals. Water that contains acid dissolves minerals more quickly than neutral water. One source of acid is acid rain. Acid rain can form when chemicals given off by factories, power plants, cars, and volcanoes join with water vapor in the air. This forms acids that return to Earth in precipitation such as rain and snow. Some plants and fungi also make acids as they carry out their life processes.

SEE ALSO
180 Rocks
351 Acid Rain

Carbon dioxide that mixes with water forms carbonic acid. This acid dissolves calcium carbonate in rocks such as limestone. As water containing calcium carbonate drips from cavern ceilings and dries, it leaves behind stalactites, icicle-shaped spikes of rock hanging from the ceilings. Other spikes called stalagmites form when water drips from the stalactites onto the floor and then evaporates, leaving solid minerals behind.



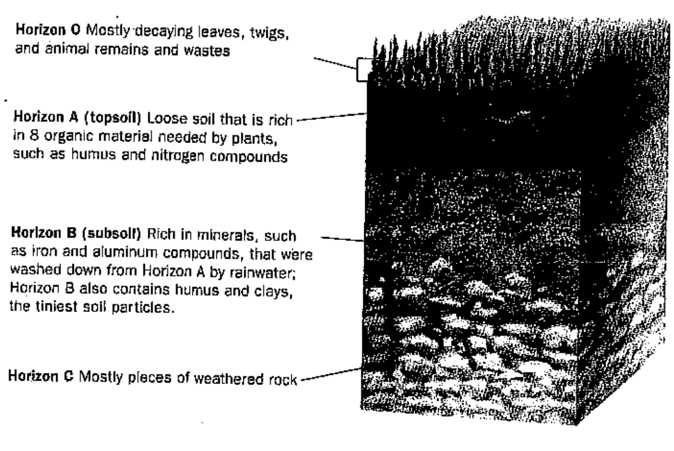
191 Soil

Soil is a mixture of rock, mineral particles, and organic matter. Weathering forms the rock and mineral particles of soil. These particles are inorganic parts of soil. Other inorganic parts of soil are the water and air that fill the spaces between soil particles.

In life and earth sciences, **inorganic** substances are those that were not formed from living things. **Organic** substances are those formed by living things.

Most organic material in soil, called **humus**, comes from decaying animals and plants. Living things, such as bacteria and fungi, break down plant and animal remains and form humus.

Soil is made up of layers called **horizons.** It takes thousands of years for a soil to mature. Mature soils have four horizons. Less mature soils have fewer horizons.



Soil horizons are home to a variety of living things. These include burrowing animals such as groundhogs and moles, and smaller animals such as snails, worms, ants, spiders, and centipedes. Many plants, fungi of all sizes, and microscopic bacteria and protists also live in soil.

SEE ALSO
156 Protist Kingdom

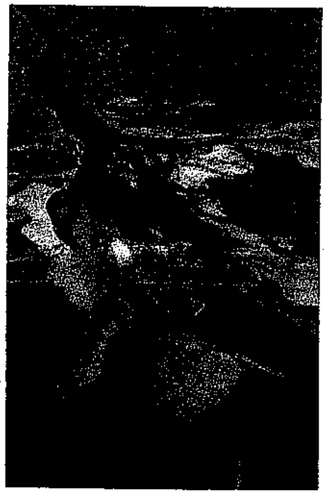
Erosion and Deposition

Weathering breaks rocks into smaller pieces. These pieces can be swept away through **erosion.** Erosion takes away land in one place and builds land in another. When moving water, ice, wind, or gravity drops a load of Earth materials in a new place, it is called **deposition.**

Streams are called by many names, such as creek, brook, and river. Scientists just use the term *stream.*

Moving Water Rainwater running off land carries away sediment, leaving behind an eroded path called a gully. Over time, as water keeps flowing in the gully, it widens and deepens to form a stream or river. Great rivers, such as the Mississippi River, deposit the sediment they carry where they enter the ocean, forming a **delta.** Moving water affects sediment at the shore, too. Ocean waves and currents carry sand off one beach, and deposit it later on another beach somewhere else.

A gully forms where moving water erodes sediment.



Rivers slow down where they enter an ocean. The slower-moving water deposits sediments, forming a delta.

SCILINKS Keyword: Weathering/Erosion www.scilinks.org Code: GSSM188

MORE

CHAPTER 10

GEOLOGY

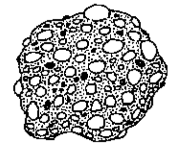
> THE PHYSICAL SETTING KEY IDEA 2:
> *Many of the phenomena that we observe on Earth involve interactions among components of air, water and land.*

The Lithosphere

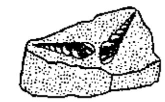
The rock at Earth's surface forms a continuous shell around Earth called the **lithosphere**. Most of the lithosphere is covered by a thin layer of water called the **hydrosphere**. Oceans, lakes, streams, and fields of ice and snow make up the hydrosphere.

Rocks are made of minerals. There are a few common minerals that are found in most rocks. **Minerals** are identified by their physical and chemical properties. Physical properties include **streak**, the color of the powdered mineral, **hardness**, the resistance to being scratched, and **luster**, the reflection of light by the mineral. The reaction of a mineral to an acid is a chemical property that is often tested.

Sedimentary rock forms from sediment. Sediment can be rock fragments or pieces of organic matter such as seashells and plant leaves. These sediments over time will get buried, compressed and cemented together. Most sedimentary rock forms on Earth's surface or near water where sediment accumulates. As sediment accumulates many plants and animals are buried and become part of the rock. The remains of these organism may become **fossils** which are very common in sedimentary rock. Fossils are useful because they indicate past life forms, climates, and environments that once existed at the location.



Conglomerate of rock fragments



Siltstone with fossils

FIGURE 2. SEDIMENTARY ROCKS

Metamorphic rock forms when pre-existing rock is exposed to intense heat and/or pressure. This usually occurs during mountain building or deep within Earth. Metamorphic rock may form when a small area of rock is in contact with hot magma.

GNEISS

FIGURE 3. METAMORPHIC ROCK

Changes in rocks are shown by the **rock cycle.** Each type of rock may be transformed or changed into another type of rock. For example, if a sedimentary rock melts and solidifies, it will change into an igneous rock.

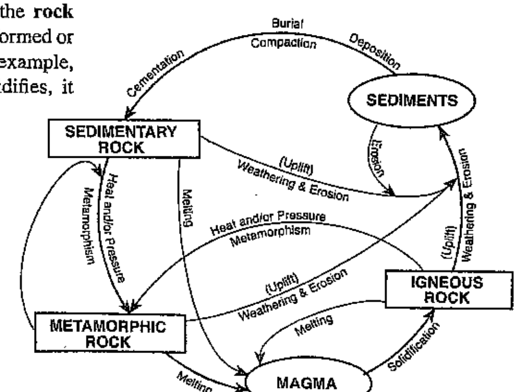


FIGURE 4. ROCK CYCLE

Rocks are classified according to how they formed. Most rocks show physical characteristics that give clues to their formation conditions. **Igneous rocks** form when hot, liquid rock material (magma or lava) cools and solidifies (hardens). This hot, liquid rock material is often found in regions of volcanic activity. If hot, liquid magma cools slowly below the surface, the igneous rock will have large mineral crystals. Igneous rocks that have small crystals formed when lava cooled and hardened rapidly on Earth's surface.

GRANITE
large mineral crystals

BASALT
small mineral crystals

FIGURE 1. IGNEOUS ROCKS

Review Questions

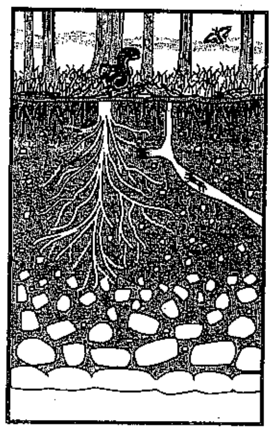
1. The layer of rock at Earth's surface is called the ____________
2. A large area of Earth's surface is covered with ____________.
3. All rocks are made of solid compounds called ____________.
4. A mineral can be identified by its ____________ and chemical properties.
5. A mineral's ____________ is the color of its powder.
6. Rocks are classified by their method of ____________
7. Place an "X" in the column for which the description is true.

	DESCRIPTION	Igneous	Sedimentary	Metamorphic
a.	Pebbles cemented together			
b.	Found in an area of volcanoes			
c.	Most common at surface near water areas			
d.	Contains fossils			
e.	Rock exposed to extreme pressure and heat			
f.	Layers of sand compacted together			
g.	Magma cooled and hardened			
h.	Made of minerals			

Weathering and Erosion

Many forces wear away Earth's surface and change its appearance. **Weathering** breaks rock into smaller pieces called **sediment**. **Soil** is made of weathered rock, organic matter, water, and air.

FIGURE 5.
SOIL PROFILE



Weathering occurs when rocks are exposed to atmospheric gases, water, and the weather. Weathering of bedrock is caused by the action of expanding ice, temperature changes, animal and plant activity, and the action of chemicals such as water or carbon dioxide. Weathering is most affected by climate. Air and water pollution have increased the rate of weathering in some locations.

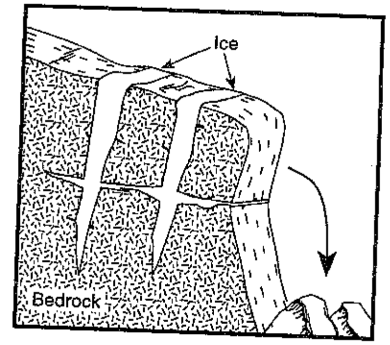


FIGURE 6. WEATHERING BY EXPANDING ICE

Erosion is the movement of sediment to a new location. The driving force behind erosion is gravity. Gravity can act directly or through agents of erosion such as moving water, wind, and glaciers. Gravity can act alone to move sediment downhill. Wind erosion occurs where soil is loose and unprotected. Wind erosion is common in dry climates and along beaches. **Glaciers** are masses of ice that move slowly downhill. As the mass of ice moves, the glacier pushes sediment ahead and carries sediment that is frozen in the ice.

AGENT	ACTION	EFFECTS ON SEDIMENTS	COMMON LOCATION
gravity	Pulls loose or wet materials down cliffs or steep slopes.	mixed sizes angular particles	hill slopes
moving water (streams, runoff, ocean currents)	Moves sediment, faster currents carry larger particles.	Particles are rounded, smoothed and sorted by size, density and shape.	worldwide the most common agent of erosion
wind	Moves loose, dry, fine sediment	Well sorted by size and density. Smallest particles can be carried long distances.	arid (dry) climates
glacier	Removes rock material off valley walls and floor. Drags sediment along bottom and in ice.	Rocks are scratched, flat sides produced. Mixed sizes, ranging from microscopic clay to boulders.	cold, humid climates

FIGURE 7. AGENTS OF EROSION

Moving water is the most common transporting agent of sediment on Earth. Rivers move sediment downstream toward the mouth of the river. At the shoreline, ocean currents and waves move sediment along the coast.

Deposition occurs when sediments are put down in place when the erosion agent stops or slows down. Erosion wears away Earth's surface and deposition builds it up.

Review Questions

8. Weathering breaks rocks into small pieces called ____________.
9. Organic plant and animal matter are found in the ____________.
10. The weathering of a rock by frost action is most common in ____________ climates.
11. The force behind all transporting agents of erosion is ____________.
12. Sediment is moved by ____________ in a desert.
13. Most sediment on Earth's surface is moved by ____________.
14. The ____________ of sediment will build up the land.

Earth's Interior

The structure of Earth's interior is known by analyzing the behavior of earthquake waves as they travel through the inside of Earth. Earth is divided into four layers: crust, mantle, outer core, and inner core. Each layer has unique ...

The **crust** is the thinnest, outermost layer, which completely surrounds Earth. It is the least dense layer. The crust is made of continental crust, which makes up landmasses, and ocean crust, which makes up the ocean floor.

The upper part of the **mantle** is a liquid-like plastic that the crust "floats" on. Beneath this the mantle is a stiff solid.

The **outer core** is above its melting point, therefore this layer is a liquid. Its composition is liquid iron. The **inner core** is very dense and very hot. It is solid iron and nickel. The elements that make up the core of the Earth are believed to be the same as those that are found in some meteorites.

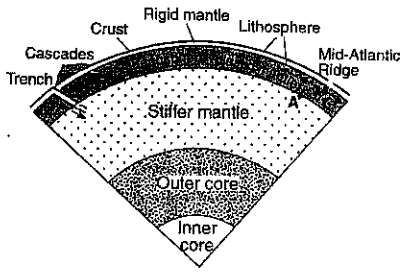
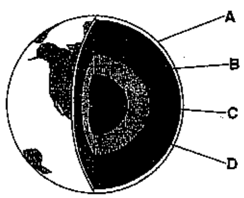


FIGURE 8. EARTH'S INTERIOR

Review Questions

15. The structure of Earth's interior was discovered by studying ______________ waves.
16. Earth's interior is divided into ______________ layers.
17. The composition of Earth's core is inferred to be the same as ______________
18. The diagram shows the four layers of Earth's interior. Select the letter described.



a. Solid iron and nickel. ______________
b. The ocean floor. ______________
c. Crust floats on its "plastic" section. ______________
d. Largest section of the interior. ______________
e. Liquid iron layer. ______________
f. The outer core. ______________
g. The mantle. ______________

Crustal Movements

There are many evidences that prove Earth's lithosphere has moved in the past. Displaced rock layers provide evidence for crustal movements. For example, marine fossil shells have been found high in the mountains, suggesting that this land was once below sea level and later uplifted. Some rock layers are observed to be **folded** (bent), tilted, or **faulted** (cracked).

Major crustal movements have affected large portions of Earth's lithosphere. The ***Theory of Continental Drift*** states that the present positions of the continents are different from those of the past. The continents were and still are moving. Evidence that the continents were once together is that the continents fit together like pieces of a jig-saw puzzle and there are similar fossils among different continents. Today, the continents have different plants and animals.

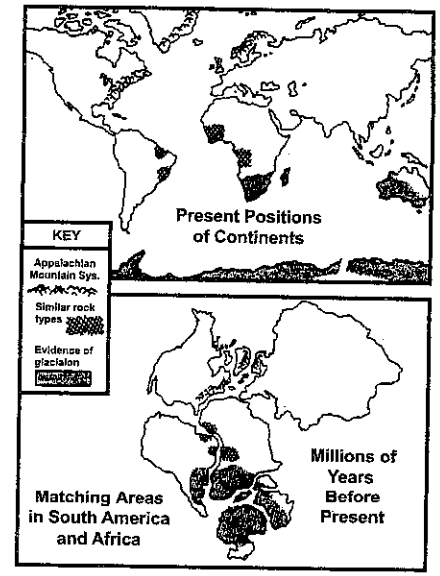


FIGURE 10. EVIDENCE FOR CONTINENTAL DRIFT

The ***Theory of Plate Tectonics*** explains that Earth's lithosphere is divided into a series of plates that "float" on the partially melted section of the upper mantle. The plates are constantly in motion due to **convection currents** in the mantle. Convection currents are caused by density differences. The flow of these convection currents move Earth's crust. Plate tectonics provides the mechanism that moves the continents.

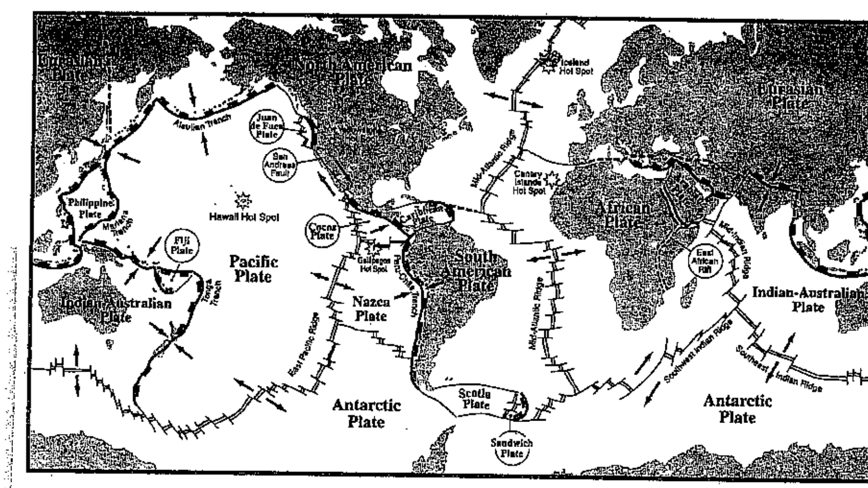
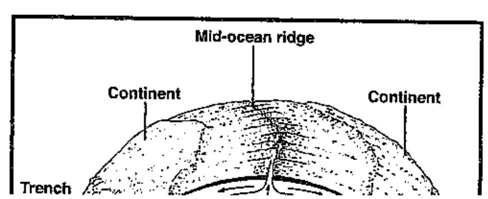


FIGURE 11. LITHOSPHERE PLATES



Crustal plates may collide or subduct and form mountains, slide past each other in fault zones, or move away from each other forming new ocean basins. The edges of plates are geologically active zones of crustal movement where earthquakes, volcanoes, and new mountains occur.

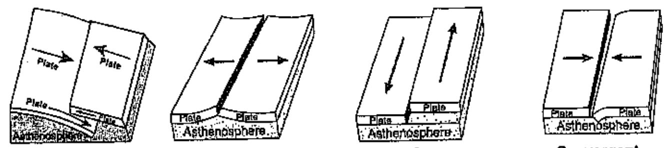


FIGURE 13. INTERACTIONS BETWEEN CRUSTAL PLATES

Review Questions

19. Folded, faulted, and tilted rock layers suggest that Earth's crust ________.

20. Evidence that the continents were once together is that their outlines appear to ________ together.

21. Another evidence that the continents were once together is that they have many of the same ________.

22. The *Theory of Plate Tectonics* describes Earth's lithosphere as being divided into separate sections called ________.

23. When two plates collide a ________ may form.

24. Volcanoes and earthquakes are common along the ________ of plates.

Earthquakes and Volcanoes

Volcanoes form in weak spots in the crust where molten material or magma comes to the surface. Lava that flows out of the volcano will harden and form new land. Ash, dust, rocks, water vapor, carbon dioxide, and other gases are thrown out of volcanoes.

Volcanoes are very hazardous. Lava will flow, setting fires and burying everything in its path. Ash can cover entire towns. Volcanoes can cause landslides and mudslides. Clouds of ash may be blown into the upper atmosphere and remain there for years. This can block sunlight and cause a colder climate.

Earthquakes are a natural shaking of Earth's crust. They can be caused by volcanic eruptions, the movement of rock along a fault, or plate movement. Earthquakes can cause damage to rock structures and buildings. Landslides may occur in areas where there are hills or loose soil.

Geologists have located the sites of volcanoes and earthquakes. They have observed that there is a pattern to where these occur. Most volcanoes and earthquakes occur at the edges of actively moving crustal plates. The most active sites border the Pacific Ocean, commonly known as the "Ring of Fire." Volcanoes and earthquakes are also common from the Mediterranean Sea to India and along the mid-Atlantic ridge.

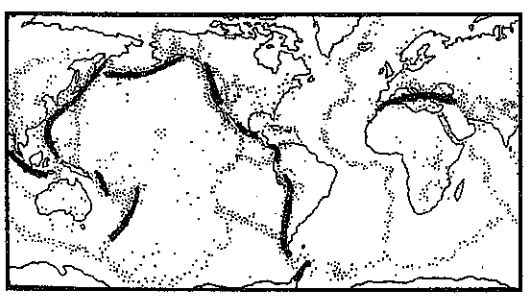


FIGURE 14.
THE DOTTED REGIONS ARE THE MAJOR EARTHQUAKE ZONES, THE SOLID LINES ARE THE MAJOR VOLCANIC BELTS

Review Questions

25. Volcanoes form in weak spots in the ________.

26. ________ can flow out of volcanoes and set fires.

27. The natural shaking of Earth's crust is an ________.

28. Volcanoes and earthquakes are common along the ________ of crustal plates.

29. The "Ring of Fire" refers to crustal activity along the edge of the ________ Ocean.

CHAPTER REVIEW

1. The layer of rock and sediment on Earth's surface is the
(1) atmosphere (2) troposphere (3) hydrosphere (4) lithosphere

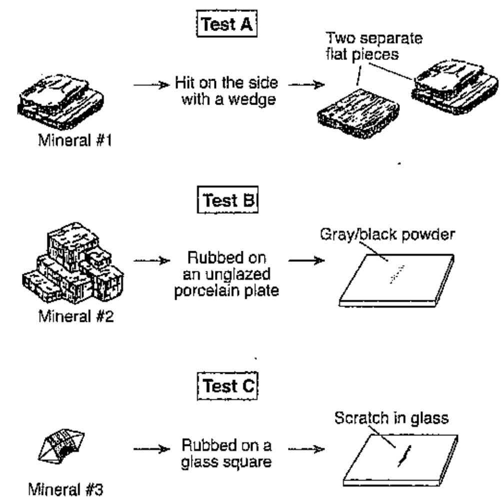
2. The hydrosphere is mostly
(1) solid rock (2) liquid rock (3) liquid water (4) gaseous water

3. Innermost layer of Earth is the
(1) inner core (2) outer core (3) mantle (4) crust

4. All rocks contain
(1) fossils (2) sand particles (3) minerals (4) air pockets

5. Rocks and minerals can be identified by their
(1) color
(2) physical features
(3) minerals
(4) mass

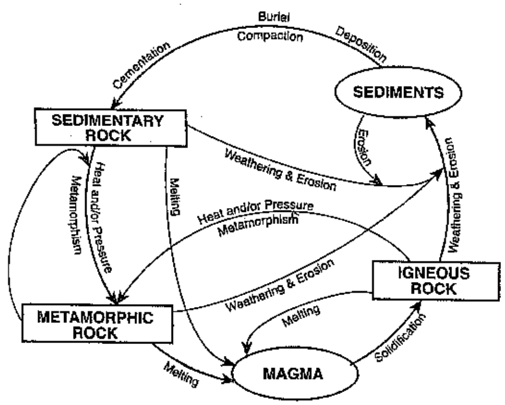
Base your answers to **questions 6-7** on the diagrams below which illustrate three physical tests used to identify minerals.



6. Which diagram illustrates the streak test?
(1) Test A (2) Test B (3) Test C

7. Which diagram illustrates the hardness test?
(1) Test A (2) Test B (3) Test C

Base your answers to **questions 8-12** on the diagram of the Rock Cycle below.



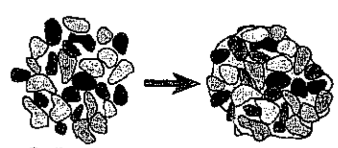
8. Igneous rocks form by the
(1) cementing together of loose rock particles
(2) cooling and hardening of liquid rock material
(3) intense heat and pressure on rocks
(4) compaction of sediment

9. Rocks that contain sand particles and fossils are classified as
(1) igneous (2) metamorphic (3) sedimentary

10. Metamorphic rock can form from
(1) magma and lava
(2) deposited clay and sand particles
(3) any type of rock
(4) igneous rocks only

11. The diagram shows the formation of a sedimentary rock. Which two processes formed the rock?

(1) heat and pressure
(2) folding and faulting
(3) compaction and cementation
(4) melting and hardening



12. Which processes change sedimentary rock into metamorphic rock?
(1) erosion and deposition
(2) melting and solidification
(3) heat and pressure
(4) evaporation and condensation

16. Which two processes cause the formation of soil ?
(1) weathering of rock and decay of organic matter
(2) weathering and faulting
(3) decay of plant matter and condensation
(4) evaporation and condensation

17. Which is an example of physical weathering?
(1) cracking of a rock by freezing water
(2) movement of sediment down a hill
(3) reaction of limestone with acid rainwater
(4) formation of a sandbar at the mouth of a river

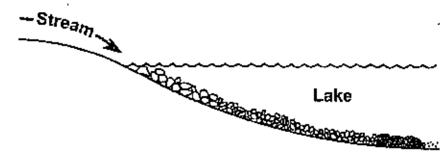
18. The main force that causes movement of loose rock material over Earth's surface is
(1) gravity (2) glaciers (3) wind (4) ocean currents

19. Most erosion on Earth is caused by:
(1) wind (2) moving water (3) glaciers (4) ground water

20. The process that breaks solid bedrock into smaller pieces is known as
(1) physical weathering
(2) chemical weathering
(3) erosion
(4) deposition

21. The movement of loose sediment and rock material is known as
(1) physical weathering
(2) chemical weathering
(3) erosion
(4) deposition

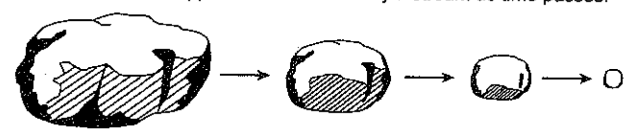
Base your answer to **questions 22-23** on the following diagram which shows a stream entering the calm waters of a large lake.



22. Which process occurs when the stream drops its sediment on the lake bottom?
(1) physical weathering
(2) chemical weathering
(3) erosion
(4) deposition

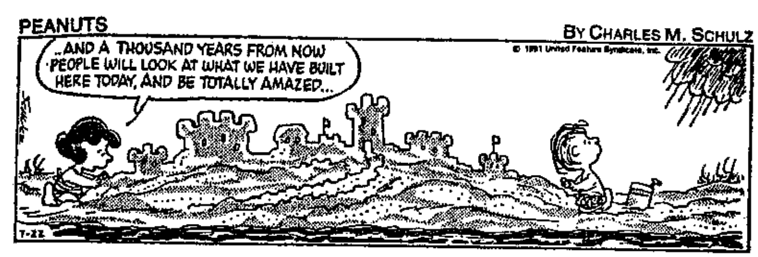
23. According to the diagram which size sediment is dropped first by the stream when it slows down?
(1) very large (2) large (3) small (4) very small

24. The diagram shows what happens to rock carried by a stream as time passes.



Which process of change is represented by the diagram?
(1) deposition
(2) metamorphism
(3) condensation
(4) weathering

25. Refer to the cartoon below.



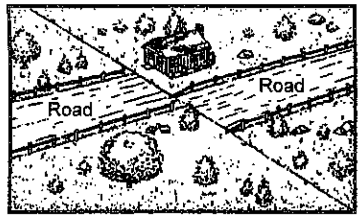
The cartoon character on the right realizes that the sand castle will eventually be
(1) folded
(2) metamorphosed
(3) eroded
(4) deposited

26. The collision between two crustal plates can cause the formation of
(1) an ocean basin
(2) a valley
(3) a mountain range
(4) an island

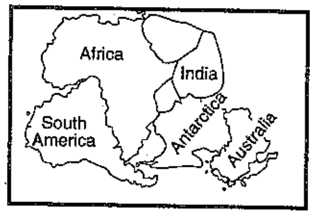
27. Fossils of organisms that lived in shallow oceans have been found high up in mountains. This is evidence of
(1) erosion
(3) weathering

28. The diagram shows land features that have been displaced by

(1) faulting
(2) folding
(3) landslides
(4) deposition



Base your answers to **questions 29-31** on the diagram below.
The diagram shows how scientists think some of the continents were connected in the past.



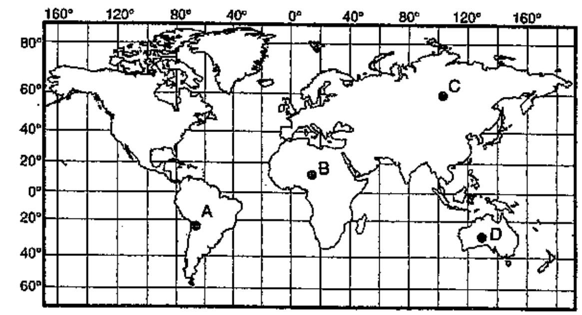
29. What evidence suggests that the continents were once joined?
(1) shapes of the continents appear to fit together
(2) same fossils of plants and animals are found on all these continents
(3) same rock structures exist where continents would have been joined
(4) all of these facts are evidence of contintental joining

30. For the past 250 million years, Africa and South America have
(1) rotated around each other
(2) moved further apart
(3) moved closer together

31. The *Theory of Plate Tectonics* suggests that the continents move because of
(1) Earth's orbiting of the Sun
(2) Earth's rotation
(3) the convection of heat energy in Earth
(4) the Moon's gravitational pull on Earth

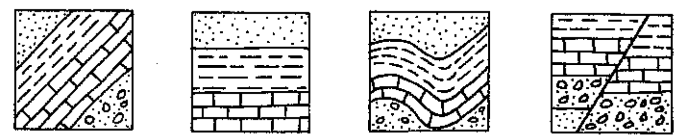
32. Which set of geologic events are found in the same geographic zones?
(1) mountain building, earthquakes, volcanoes
(2) mountain building, fossil formation, volcanoes
(3) volcanoes, earthquakes, deposition of sediment
(4) earthquakes, hurricanes, fossil formation

33. Which position is closest to a major earthquake and volcano zone?



(1) A (2) B (3) C (4) D

34. The diagrams show cross sections of exposed bedrock layers. Which cross section shows the *least* evidence of crustal movement?



(1) (2) (3) (4)

35. A student plotted the locations of a major earthquakes for the past twenty years. This map shows that most earthquakes occur
(1) near large rivers
(2) in the tropics
(3) at the edges of crustal plates
(4) in the inner core