Earth Materials—Minerals, Rocks, and Mineral Resources

TOPIC 11

How Scientists Study Minerals

Do you think every mineral has a unique chemical composition?

It is the crystal structure that is unique to each mineral and not the chemical composition. Just consider the minerals graphite and diamond, which are both composed of only carbon. It is hard to believe that two minerals with the same chemical composition could be so different: Graphite is one of the softest minerals and diamond is the hardest of the somewhat common minerals. Diamond has a brilliant luster and graphite is greasy to metallic. Graphite is used as a lubricant, while diamond is used as an abrasive. And graphite is an electrical conductor, while diamond is an insulator.

Graphite and diamond are not the only example. Calcite and aragonite are two minerals that are composed of calcium carbonate ($CaCO_3$). There are at least five minerals with the formula SiO_2, with quartz being the most common.

TOPIC 11 Earth Materials—Minerals, Rocks, and Mineral Resources

Vocabulary

bioclastic sedimentary rocks	fracture	mineral crystal
chemical sedimentary rocks	hardness	mineral resources
clastic sedimentary rock	igneous rock	organic
cleavage	inorganic	precipitation (of minerals)
contact metamorphism	intrusive igneous rock	regional metamorphism
crystal shape	luster	rock cycle
crystal structure	magma	sedimentary rocks
extrusive igneous rock	metamorphic rocks	streak
foliation	metamorphism	texture
fossil	mineral	

Topic Overview

Rocks and minerals are the source of much of the material and energy that people want or need. If you make a list of about one hundred objects you used or wanted to use today, most likely 95 to 100 percent of them come from rocks and minerals. Earth materials—minerals, rocks, and mineral resources—are of value to people in many ways. Earth materials fuel our industrial society as extracted fossil fuels. They provide the raw materials for the building of homes and other construction projects. Rocks and minerals make up Earth's solid surface—the lithosphere—that you live on. When Earth's solid surface is weathered and eroded, the end results are the landscape features that people live, work, and play on.

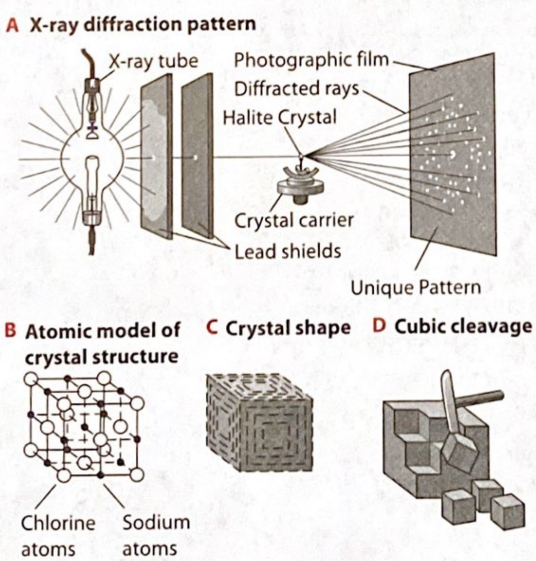


Figure 11-1. Crystal structure and properties of the mineral halite: Halite is the mineral with the formula NaCl (sodium chloride). It is the one mineral of rock salt and common table salt.

Minerals

Minerals have characteristic physical and chemical properties. Some of these properties are color, streak, luster, hardness, density, cleavage and crystal structure.

What a Mineral Is

A **mineral** is a naturally occurring, inorganic, crystalline solid having a definite chemical composition. A mineral is considered to be naturally occurring because it is formed in nature and not made by people. It is **inorganic** because it has not been made by or composed of life forms. Thus fossil fuels or a pearl from an oyster are NOT minerals.

A mineral is crystalline because its atoms have a specific arrangement. This arrangement of atoms is called **crystal structure**. Each mineral has its own distinctive crystal structure that can lead to very accurate identifications through the use of X-rays. Figure 11-1 illustrates the crystal structure of a mineral.

All minerals are solids that are composed of one or more chemical elements. The chemical composition of a mineral describes the types and ratios of elements that make up the mineral. Some minerals contain only one element and others are compounds of two or more elements. You can find the characteristics of some minerals in the Properties of Common Minerals in the *Earth Science Reference Tables.*

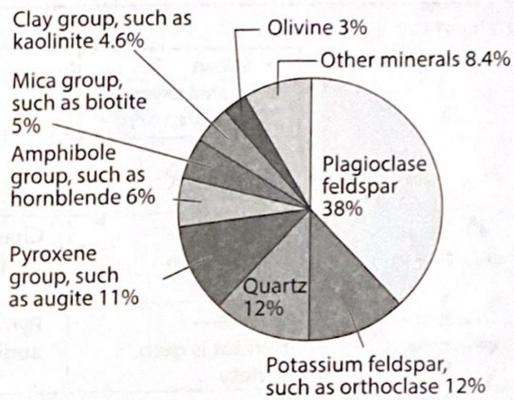


Figure 11-2. Circle graph of the most common minerals of Earth's crust: 90 percent of Earth's crust by weight is composed of eight minerals or groups of minerals—all silicates. These common minerals are called rock-forming minerals.

Relation of Minerals to Rocks

All minerals are rocks, but not all rocks are minerals nor are they all composed of minerals. A rock is any naturally formed solid that is part of Earth or any other celestial body. Though a large percentage of rocks is composed of minerals, many rocks are composed of organic or glassy materials that are not minerals. Glasses are not minerals because their atoms are not arranged in a specific pattern. The majority of rocks are made of two or more minerals—multiple-mineral rocks. Some rocks are composed of only one mineral—single-mineral rocks.

A review of the three schemes for rock identification—sedimentary, metamorphic, and igneous—in the *Earth Science Reference Tables* and Figure 11-2 indicates that only a small number of minerals are commonly found in rocks. These 20 to 30 very common minerals, found in rocks, are called the rock-forming minerals. Many of these rock-forming minerals are listed in the Properties of Common Minerals in the *Earth Science Reference Tables.*

Element Composition of Earth's Crust

The chemical element composition of Earth's crust is shown in Figure 11-3.

- The graph indicates that over 99 percent of Earth's crust and its minerals are, by volume and mass, composed of only 8 of the 90 naturally occurring elements found on Earth.
- Silicon is the second most abundant element by mass, but the element potassium is number two in crustal abundance by volume because of its lower density and higher volume.

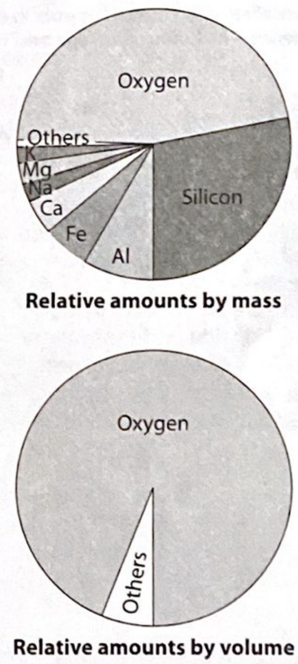


Figure 11-3. Percentages of the chief elements in Earth's crust by mass and by volume: Volume is the amount of space occupied by the atoms of each element in the solid substances of the crust. Also see Average Chemical Composition of Earth's Crust, Hydrosphere, and Troposphere in the *Earth Science Reference Tables.*

Mineral Crystal Structure

The crystal structure, or atomic arrangement of the atoms, that comprise minerals is responsible for many of their chemical and physical properties, such as crystal form, breaking pattern, and hardness. Most rock-forming minerals are silicates. Silicate minerals have a structure that results from various arrangements of a tetrahedron-shaped (4-sided) unit of oxygen and silicon called the silicon-oxygen tetrahedron. Figure 11-4 shows how each tetrahedron is composed of one atom of silicon and four atoms of oxygen. It also shows different ways the silicon-oxygen tetrahedron can be arranged resulting in different breaking patterns (cleavage and fracture).

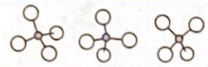
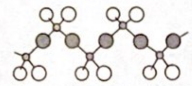
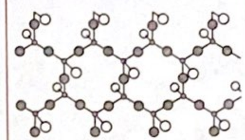
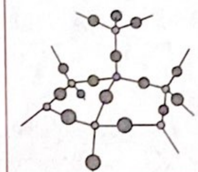
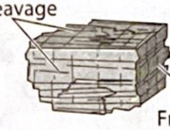
Silicate structure	Key ✧ Silicon ● Shared oxygen ○ Unshared oxygen 			
Silicate structure	Single tetrahedron	Chains of tetrahedra	Sheets of tetrahedra	A network of tetrahedra in three dimensions
Mineral example	Olivine—peridot is gem variety	Pyroxene, such as augite	Mica, such as biotite	Quartz
Cleavage or fracture type	Curved or conchoidal fracture	Two directions of cleavage into blocky or splinter shapes and fracture	One direction of cleavage into sheets and fracture	Curved or conchoidal fracture
Drawing		Cleavage  Fracture	Cleavage  Fracture	

Figure 11-4. Various arrangements of the silicon-oxygen tetrahedron in silicate minerals: The tetrahedra combine with themselves and other elements in different atomic structures. The different combinations affect the physical properties of the minerals—including cleavage and fracture patterns shown in the illustration.

> **Digging Deeper**
>
> Diamond is still the hardest mineral that a person is likely to encounter, but not the hardest in the world. Scientists have recently discovered that wurtzite boron nitride and lonsdaleite, two very rare minerals, are even harder than diamond.

Mineral Formation

Since all minerals are rocks, they form by one of two processes. Minerals form as the result of inorganic crystallization—a process of organizing atoms to form crystalline solids. Minerals also form by recrystallization of atoms from the solids, liquids, and gases associated with various rock- forming environments.

Mineral Properties and Identification

Each mineral has a characteristic set of physical and chemical properties that can be used to help identify it. The crystal structure and the chemical composition of minerals largely determine these properties. Some properties, such as color, are often caused by impurities. The mineral corundum, when pure, is colorless. However, with slight chemical impurities, corundum becomes the blue sapphire or red ruby.

The most accurate method for identifying minerals is by the use of X-ray diffraction instruments (see Figure 11-1) and other machines not available to most individuals. Therefore, simple tests and mineral identification charts are relied on. An example of a mineral identification key, or chart, Ⓡ is found in Properties of Common Minerals in the *Earth Science Reference Tables*.

Color The color of a mineral is one of its most obvious properties. However, in most cases color is not useful because many minerals have the same color. In addition, the color of many minerals varies due to impurities, and many minerals are clear or colorless when pure. In a few cases however, such as in the yellow of sulfur, the gray of graphite (pencil lead) and galena, or the brassy yellow of pyrite (fool's gold), the mineral's color is usually consistent.

Streak The color of finely crushed residue or powder of a mineral is its **streak**. When you write on a chalkboard, you observe the streak of the rock chalk. The streak of a mineral is usually quite consistent; thus streak color is much more useful than mineral color. For example, the iron ore mineral, hematite, can be various shades of silver-gray to red in color, but the streak is a consistent red.

Luster The shine from an unweathered mineral's surface, or the way a mineral looks in reflected light, is **luster**. There are two broad groups of luster—metallic and nonmetallic. Minerals with a metallic luster, such as pyrite and galena, shine like the surface of a clean stainless steel pot. Most minerals have a nonmetallic luster. There are many types of nonmetallic luster, such as the glassy luster of black hornblende and clear quartz "rhinestone," or the pearly luster of muscovite mica.

Hardness The resistance a mineral offers to being scratched is its **hardness**—the scratchability of a mineral, not how easily the mineral breaks. Diamond is the hardest mineral (see Digging Deeper on page 220), but drop an unmounted diamond on a tile floor and it will likely shatter. On the other hand, if the very soft mineral graphite is dropped, only a small amount will chip off, or cleave.

Figure 11-5 shows the Mohs hardness scale and some other common materials that are often used to determine hardness. Mohs hardness scale is arranged from the softest #1 (talc) to the hardest #10 (diamond). A quick way to determine relative hardness is to use a piece of window glass. If a mineral scratches the glass, the mineral is hard, and if it doesn't, it is soft.

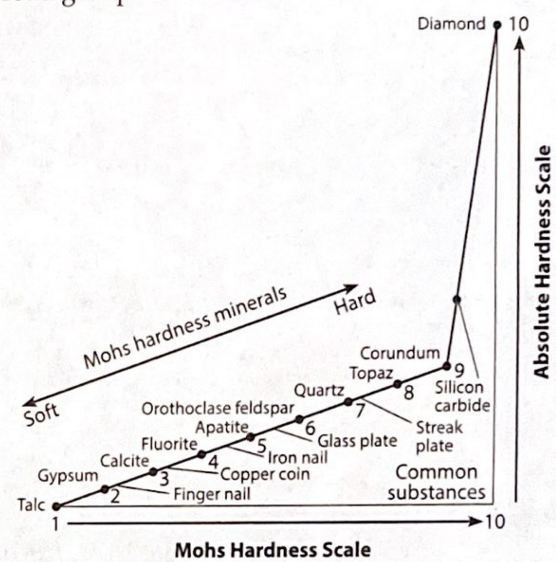


Figure 11-5. Mohs and absolute hardness scale: The differences in the hardnesses on the Mohs scale vary, as shown by the comparison to an absolute scale of hardness. Note that on the absolute scale, the difference of hardness between diamond and corundum—ruby or sapphire—is more than all the way from talc to corundum.

Density Each mineral has a specific density or a small range of densities—for those minerals that vary in mineral composition. Often in mineral studies, density is stated as specific gravity, a value without units. Specific gravity is the density of a mineral compared to the density of water. Specific gravity is a good test to distinguish gemstones, because it doesn't harm the samples like hardness or cleavage tests do. In mining and refining processes, differences in the densities of various minerals allow them to be separated. A common example is the panning of high-density gold.

Cleavage The tendency of a mineral to break along the zones of weakness and form smooth to semi-smooth parallel sides, or surfaces, is called **cleavage**. Cleavage surfaces can often be distinguished from sides without cleavage by having a shinier or more brilliant luster (smooth surfaces reflect better). If a mineral lacks preferred zones of weakness in the crystal structure, then it will demonstrate uneven breaking surfaces called **fracture.** For example, some types of fracture are irregular (earthy), fibrous (splintery), and curved (conchoidal). The curved surfaces in a type of quartz called flint make this

Memory Jogger

Recall that density is the ratio of the mass of an object to its volume. Therefore, an element that has a lower density than another element has a smaller mass per volume than an element with higher density.

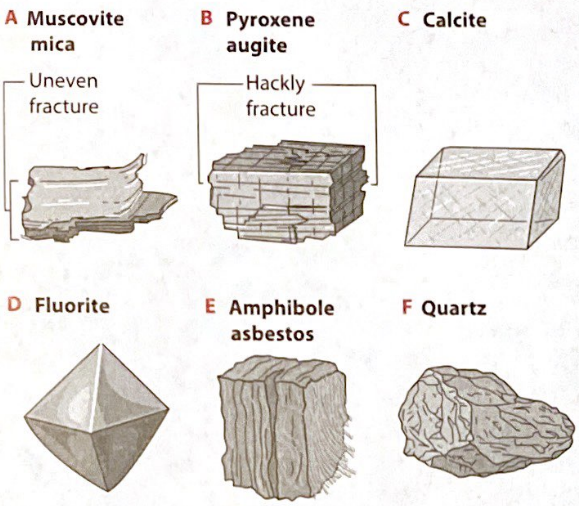


Figure 11-6. Types of cleavage and fracture: (A) shows one direction of cleavage and some uneven fracture. (B) shows two directions of cleavage and a hackly (bumpy) fracture. (C) shows three directions of cleavage. (D) shows four directions of cleavage. (E) shows fibrous fracture. (F) shows curved fracture.

material very useful in making knives and arrowheads. Often a mineral will have both cleavage and fracture on different sides, such as the silicates hornblende and the feldspars. (See Figures 11-4 and 11-6)

Crystal Structure The outward geometric shape of a mineral, the crystal form, or **crystal shape,** reflects the crystal structure—orderly arrangement of the atoms in the mineral. It is only when individual mineral grains have the room to freely grow that this crystal shape, with its smooth sides or faces, can take shape. This is the reason most mineral samples found in nature don't illustrate the crystal forms; the use of crystal form in mineral identification is limited. Another problem is that even though the internal crystal structure of minerals is unique, the outward crystal shape, such as the cubic shape of halite, galena, and fluorite, isn't unique. Also, any mineral can have many different crystal shapes.

Other Mineral Properties Besides physical properties, some chemical properties of minerals are also used for identification. One of these chemical properties is the reaction of a mineral with acid. When a small amount of dilute hydrochloric acid is placed on a mineral or rock containing calcite (CaCO3), the mineral or rock will bubble (effervesce)—giving off carbon dioxide. The mineral dolomite can be distinguished from calcite, because dolomite will bubble in acid only after the mineral is powdered.

Many other chemical and physical properties are used to identify minerals. Many of the properties only apply to a few minerals and will often be the key to a mineral's identification. For example, some minerals such as thin pieces of muscovite and biotite micas are flexible. This means that they can be bent and will snap back to their original shape. Other properties used for identification are found in Properties of Common Minerals in the *Earth Science Reference Tables.* Ⓡ

Digging Deeper

A few minerals have very fine lines—called striations—on cleavage surfaces and on the faces of their crystal form. These striations can be used to distinguish the mineral plagioclase feldspar from the potassium feldspars such as orthoclase. Striations are an outward expression of the internal arrangement of the atoms within a mineral.

Review Questions

1. A mineral CANNOT be
(1) organic
(2) crystalline
(3) a solid
(4) formed in nature

2. Which rock is usually composed of several different minerals?
(1) rock gypsum
(2) limestone
(3) quartzite
(4) gneiss

3. Only a small number of Earth's minerals are commonly found in rocks. This fact indicates that most
(1) minerals weather before they can be identified
(2) minerals have properties that are difficult to identify
(3) rocks have a number of minerals in common
(4) exposed surface rocks are mostly igneous

4. The data table shows the composition of six common rock-forming minerals.

Mineral	Composition
Muscovite Mica	$KAl_3Si_3O_{10}$
Olivine	$(FeMg)_2SiO_4$
Orthoclase	$KAlSi_3O_8$
Plagioclase	$NaAlSi_3O_8$
Pyroxene	$CaMgSi_2O_6$
Quartz	SiO_2

The data table provides evidence that

(1) the same elements are found in all minerals
(2) a few elements are found in many minerals
(3) all elements are found in only a few minerals
(4) all elements are found in all minerals

5. What are the four most abundant elements, by volume, in Earth's crust?

(1) oxygen, potassium, sodium, and calcium
(2) hydrogen, oxygen, nitrogen, and potassium
(3) aluminum, iron, silicon, and magnesium
(4) aluminum, calcium, hydrogen, and iron

6. Diamonds and graphite are both minerals that are composed of the element carbon. Diamond has a hardness of 10, while graphite has a hardness of 1. Based on your knowledge of earth science, what is the most probable cause of this difference in hardness?

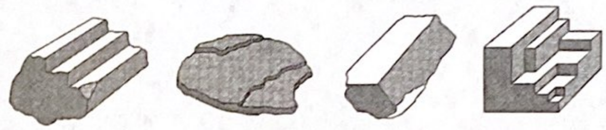
7. Minerals are composed of

(1) one or more rocks
(2) only one rock
(3) one or more chemical elements
(4) only one metal

8. The cubic shape of a mineral crystal is most likely the result of that crystal's

(1) hardness
(2) density distribution
(3) internal arrangement of atoms
(4) intensity of radioactive decay

9. The following diagrams represent four different mineral samples.



Which mineral property is best represented by the samples?

(1) density (3) hardness
(2) cleavage (4) streak

10. Minerals are identified on the basis of

(1) the method by which they were formed
(2) the type of rock in which they are found
(3) the size of their crystals
(4) their physical and chemical properties

11. A six-sided mineral crystal is a very hard mineral called

(1) hornblende (3) quartz
(2) orthoclase feldspar (4) biotite mica

12. The relative hardness of a mineral can best be tested by

(1) scratching the mineral across a glass plate
(2) squeezing the mineral with calibrated pliers
(3) determining the density of the mineral
(4) breaking the mineral with a hammer

13. What property would a mineral have if it appears like a new quarter in reflected light?

(1) a metallic luster
(2) metallic element composition
(3) magnetic
(4) a high density

14. Which property of the mineral diamond allows diamond powder to be used to shape gems for jewelry?

(1) crystal shape (3) luster
(2) cleavage (4) hardness

15. What information about a mineral is needed to determine its density?

(1) shape and volume
(2) shape and mass
(3) volume and mass
(4) volume and hardness

Rocks

A rock is any naturally formed solid on Earth or in any part of the universe. The definitions for rock and the individual rock types are not nearly as specific as those for a mineral. The reason is that rocks, except for the single-mineral ones, are mixtures of minerals, organic materials, glasses, and fragments of other rocks. A single-mineral rock is both a rock and a mineral and has a mineral's definite composition and properties.

In your study of rocks you will often have to refer to parts of the Ⓡ *Earth Science Reference Tables*. The Generalized Landscape Regions of New York State and the Generalized Bedrock Geology of New York State will allow you to see in which portions of New York State different rock types are found and the geologic ages (periods) of the rocks. The Rock Cycle in Earth's Crust diagram will allow you to quickly understand the relationships among the three major rock types and the processes that form them. The Scheme for Igneous Rock Identification, Scheme for Sedimentary Rock Identification, and Scheme for Metamorphic Rock Identification will provide you with the basic individual rock properties and how to identify most of the important rock types.

Rock Types

Rocks are classified into three categories—sedimentary, igneous, and metamorphic—based on the three methods of rock formation. Sometimes metamorphic and igneous rocks are grouped together as nonsedimentary rocks. As a group, rocks are distinguished and identified based on their composition and the texture. The **texture** of a rock is not how rough it feels, but the size, shape, and arrangement of the materials the rock is composed of. The majority of rocks are composed of individual grains of minerals called **mineral crystals.** Rocks that are made of intergrown or interconnecting mineral crystals are called crystalline.

Sedimentary Rocks

Rocks that form from an accumulation of sediments derived from preexisting rocks and/or organic materials are **sedimentary rocks**. These rocks form by various processes that occur on or within the top few kilometers of Earth's crust.

Formation of Sedimentary Rocks Most sedimentary rocks are made up of solid fragments or sediments, often called "clasts," that have been weathered or eroded from older rocks. After formation, erosional agents, such as running water, glaciers, wind, ocean waves, currents, and gravity transport sediments to new locations under water or on land. Most sedimentary rocks form under large bodies of water, such as lakes, seas, and oceans, where the sediments are usually deposited in horizontal layers. Some methods of formation of sedimentary rocks are cementation, compaction, chemical action, and organic processes.

Cementation Often the clasts, such as sand, silt, and pebbles, are cemented together in a process called cementation. This happens as the sediments lose water and the dissolved minerals in the pores of sediments precipitate out, forming crystalline mineral material. Minerals, such as calcite, quartz, and hematite, are the common cements that glue the solid sediments together. Cementation can happen alone or in combination with other processes to form the clastic sedimentary rocks, such as siltstone and conglomerate. A **clastic sedimentary rock** is one that is largely composed of solid sediments, such as the sand in sandstone, or the tiny pieces of clay in shale.

Digging Deeper

Most precipitation of minerals occurs at the bottoms of lakes, seas, and oceans; but it also happens in soil, in caves—forming rock "icicles"— around mineral springs, and in homes—forming a rock film on water glasses and shower stalls.

Compaction Crustal movements and the weight of overlying water and sediments compress, or compact, sediments. This causes a reduction in volume due to the loss of pore space and water. The process is called compaction. While some sedimentary rocks, such as shale and bituminous coal, may form only by compaction, most of the clastic or fragmental rocks form due to compaction and cementation.

Chemical Action All natural liquid water on Earth contains dissolved minerals. In water, these dissolved minerals are called by various names—hardness in drinking water and salts in the sea—but they are all minerals that have been dissolved by chemical weathering. When these dissolved minerals precipitate, or drop out from the water, they often form a crystalline mass of intergrown or interconnected mineral crystals called a **chemical sedimentary rock or evaporites**. This **precipitation** of minerals is the result of evaporation, saturation with dissolved minerals, or changes in temperature. Chemical sedimentary rocks or evaporites, are composed of interconnected crystals of just one mineral.

Organic Processes When dissolved minerals are withdrawn from water by life forms, it is termed chemical—not mineral—precipitation. **Organic** means anything related to living organisms or to things that were alive. Any rock made by living organisms or mostly composed of materials from life forms is an organic, or **bioclastic sedimentary rock.** When a clam makes a shell, a coral makes a skeleton, or you make bones and teeth, chemicals are precipitated from water. Some organic sedimentary rocks, such as the limestone of a coral reef, are formed directly by chemical precipitation.

Characteristics of Sedimentary Rocks Some features that distinguish sedimentary rocks from igneous and metamorphic rocks include the following:

- Most sedimentary rocks are clastic—composed of fragments called sediments, or clasts.
- The clasts or sediments are usually rounded particles because they have been moved by running water, wind, waves, or ocean currents.
- The clasts or sediments are often sorted into a small range of sizes because of horizontal sorting.
- Some sedimentary rocks are organic and thus contain fossils. A **fossil** is any evidence of former life.
- One of the most distinguishing characteristics of sedimentary rocks is the beds or strata—parallel layers of the sediments in the rock. These beds are often seen in hand specimens, but are even more obvious outside where sedimentary rocks are exposed at Earth's surface in places such as road cuts or stream valleys.
- Sedimentary rocks often contain features that indicate they formed at Earth's solid surface. Some features might be mud cracks, rain drop impressions, or ripple marks that formed on the top of a sand dune or at the bottom of the ocean. Other features might be fossils that indicate an earlier Earth's surface.
- The chemical sedimentary rocks are not composed of sediments or clasts, but are composed of interconnected mineral crystals of one mineral variety.

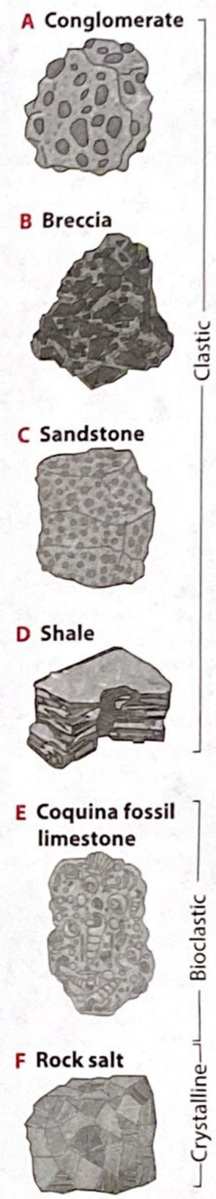


Figure 11-7. Some characteristics of sedimentary rocks: In diagrams A, B, and C the dark shading is sediment and the light color is the cement. (A) has unsorted sediments, mostly larger than sand, cemented together. (B) has sediments similar to conglomerate that are angular, not rounded. (C) has sorted sand-size sediments cemented together. (D) has compacted and sometimes cemented clay-sized sediments. (E) is an organic rock composed of shells cemented together. (F) is a chemical sedimentary rock of intergrown mineral crystals of the mineral halite.

Figure 11-8. Layers in a sedimentary rock: Layers—called beds or strata—result from changes, often minor, in the types of sediment deposited at different times.

Identifying Sedimentary Rocks The more common clastic, or fragmental, sedimentary rocks are distinguished largely on the basis of their sediments—clay, silt, sand, or larger sediment sizes. If the sediments of a conglomerate are mostly rounded, the rock is regular conglomerate. If the sediments are mostly angular the rock is breccia. In basic rock identification, it makes no difference what type of mineral or rock fragments are in a clastic rock—texture is the main factor used for classification and identification. For example, if a rock is composed of sand-sized sediments, the rock is sandstone. Refer to the chart Scheme for Sedimentary Rock Identification in the *Earth Science Reference Tables.* Ⓡ

This chart also shows that nonclastic rocks are predominantly composed of one mineral. Therefore, you treat most of them as if they are minerals. Bioclastic limestone is composed of $CaCO_3$, so it will easily fizz in dilute hydrochloric acid. If the rock only fizzes after some of it is powdered, then the rock is likely dolostone. Other examples of nonclastic rocks are rock salt, composed of the mineral halite, and rock gypsum, composed of the mineral gypsum.

Digging Deeper

To measure sand or larger sediments in a rock, a ruler can be placed on or next to the rock. If you can't easily see the sediments, but the rock feels gritty to a fingernail, then it is most likely siltstone. You can use a magnifying glass or microscope to see silt-sized sediments. If you can't see the sediments under a normal microscope, or if the rock does not feel gritty, it is likely shale.

Igneous Rocks

Rocks that form when natural, molten (liquid) rock-forming material cools and turns into a solid are **igneous rocks.** Liquid rock material beneath Earth's solid surface is called **magma.** When magma comes out onto or above Earth's solid surface, it becomes lava. If Earth was largely molten in its earliest stages of formation, then igneous rocks were the first rocks to form on Earth.

When magma solidifies beneath Earth's solid surface, it forms rocks called **intrusive** (plutonic) **igneous rocks.** The bodies, or masses, of these rocks can range from finger size up to the size of one or more of our states, such as Vermont. These bodies are called intrusions. Figure 11-9 illustrates many of the types of intrusions from the thin dikes and sills, common as light and

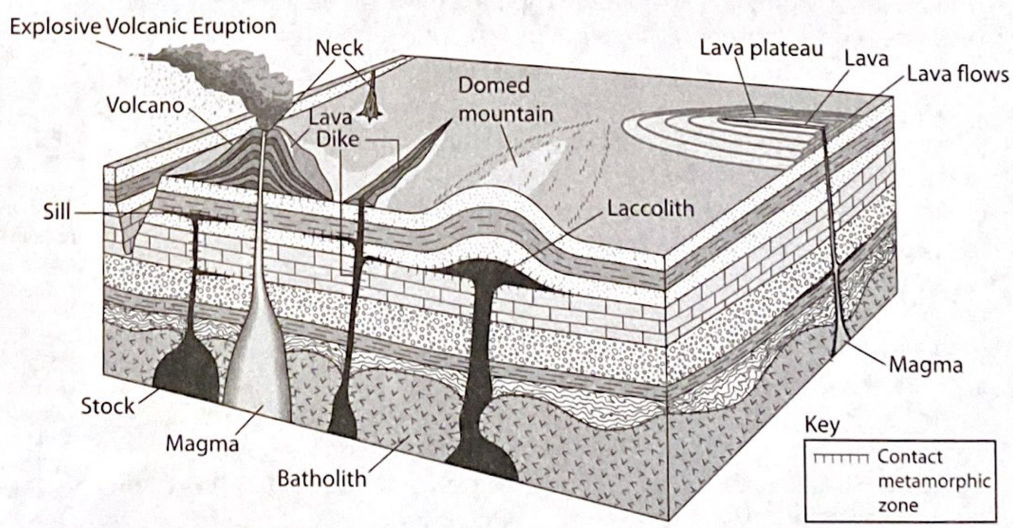


Figure 11-9. Examples of igneous intrusions and extrusions: The types of intrusions are batholith, stock, laccolith, sill, and dike. (Except for sill, you need not know the names of the various types of intrusions.) Note that both the volcano and the laccolith intrusion have formed mountains.

dark streaks in eastern New York State road cuts, to massive batholiths. It is believed that most intrusions form, within Earth's solid outer layer—the lithosphere.

When lava solidifies on or above Earth's solid surface, the result is **extrusive igneous rock.** Extrusive, or volcanic rocks, form landscape features called extrusions. The two most common extrusions are lava flows and volcanoes. (See Figure 11-9.)

Formation of Igneous Rocks All igneous rocks are the result of solidification—the change from a liquid to a solid. Most igneous rocks are produced as a result of the type of solidification called crystallization. Crystallization results when molten lava or magma cools and forms a solid composed of intergrown mineral crystals—a crystalline rock. Some igneous rocks that form at or above Earth's surface cool so fast that mineral crystals don't have a chance to form. The result is a type of solid called glass. In glass there is no pattern or arrangement of the atoms, therefore the substance is non-crystalline.

Crystal Sizes and Glasses The size of the crystals in an igneous rock depends on the conditions in which the rock formed. The immediate cause of the difference in the size of the crystals, or lack of crystals, is the time in which the cooling takes place. Generally, the longer the time of cooling, the larger the crystals become. However, the cooling time itself depends on the temperature and pressure of the environment, and the composition of the magma or lava. Generally, molten rock low in silica (SiO_2) content or high in water content will take longer to cool. The pressure and temperature deep within the lithosphere are very high, and therefore magma cools slowly—over many thousands of years. The result is rocks with large or coarse crystals easily visible to the human eye.

The temperature and pressure at or near Earth's surface are much lower, and the lava there cools much more quickly, forming fine-grained rocks with small crystals, not easily seen with the unaided human eye. If the cooling is very fast (usually seconds to hours), a glassy rock with no or few mineral crystals forms. Most lava flows and volcanoes are composed of rocks with small mineral crystals or no crystals in them.

Textures of Igneous Rocks Texture in igneous rocks depends on the size of mineral crystals, the presence of glass and rounded pores (vesicles). These features are related to the cooling time of magma or lava and the rock-forming environment. (See Figure 11-10). Rocks with crystals easily seen by the unaided eye are coarse-textured intrusive rocks like granite and gabbro, and almost always form within the lithosphere. Medium textured rocks like diabase have barely visible crystals. Pegmatite intrusive rocks have a very coarse texture and can have meter sized crystals.

Associated with lava flows and volcanoes, most of the extrusive igneous rocks have a fine texture of crystals smaller than one millimeter in size. To clearly see mineral crystals in fine-textured rocks, such as basalt and rhyolite, magnification is required. Many of the extrusive igneous rocks of lava flows and volcanoes have rounded openings in them caused by lava solidifying around trapped expanding gases. The rocks with these openings are said to have a vesicular texture. These openings or pockets are like the pores in the foam produced when you shake up a carbonated

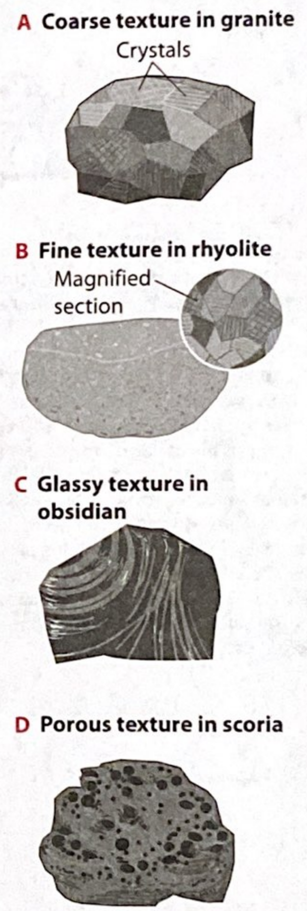


Figure 11-10. Textures of igneous rocks: (A) Slow cooling of magma results in coarse-sized crystals easily visible to the unaided eye. (B) Fast cooling of lava at Earth's surface results in fine-sized crystals not easily visible without magnification. A magnified section resembles the texture in (A). (C) If lava cools very rapidly, a rock with a glassy texture of no minerals will form. (D) In fine—or glassy—textured rocks or extrusive igneous rocks, there is often a mixed, porous vesicular texture. The pores are due to expanding gas forming bubbles in the lava as it solidified.

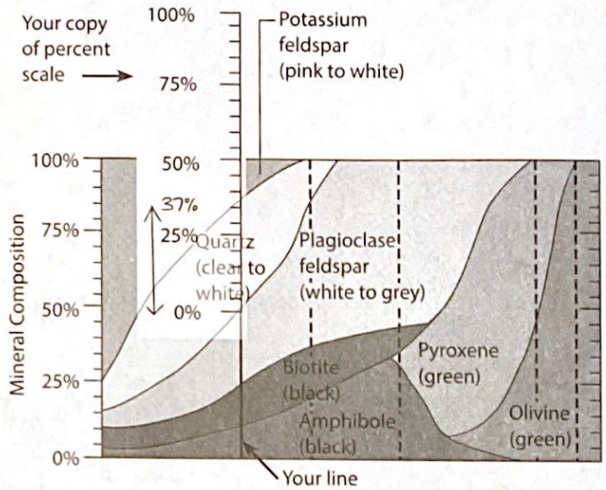


Figure 11-11. How to use the Scheme for Igneous Rock Identification in the *Earth Science Reference Tables* to measure the percent of mineral composition: Refer to the identification scheme in the *Earth Science Reference Tables* as you proceed. To obtain a percent for a particular part of the chart, do the following: (1) Copy the scale from the left side of the chart. (2) Draw a vertical line on the chart in pencil through the "t" in the word "quartz," as shown. (3) To compute the mineral composition of quartz, place your copy of the percent scale on the chart along your drawn line, as shown. (4) Align the 0% of your copy of the scale with the bottom of the quartz portion of the chart and read the percent at the top part of the mineral. The art shows quartz at about 37%. (5) Repeat this procedure for each of the other minerals. The values for the other minerals are: amphibole 10%, biotite 13%, plagioclase feldspar 24%, and potassium feldspar 14%. Usually you can obtain answers within 2–3 percent of the actual value.

soft drink. Basalt with many pores is called vesicular basalt. Volcanic glass with many pores is called pumice or scoria depending upon color and composition. In pumice the vesticular texture is often due to gases expanding in lava during an explosive volcanic eruption.

Identification of Igneous Rocks Igneous rocks are identified largely on the basis of texture (very coarse, coarse, medium, fine, glassy, or vesicular) and percent mineral composition. In the coarse-grained rocks you can often identify the minerals easily because they are visible to the unaided eye. You match the percents of what you observe in the rock with the chart of percent by volume of the surface of a rock. With a strong enough microscope the same thing can be done with the fine-textured rocks. For aid in using the percent mineral composition chart see Figure 11-11.

When microscopes are not available, both rock density and rock color can be a guide to the mineral composition. Refer to the Scheme for Igneous Rock Identification in the *Earth Science Reference Tables.* Ⓡ This scheme shows a method of classifying and identifying igneous rocks. The color of an igneous rock is more like shade, or tone—it is the overall lightness or darkness of the total rock—not the actual color. Light-colored rocks are on the left side of the scheme and dark-colored rocks are on the right. Nonvesicular igneous rocks range from 2.7 g/cm^3 for low-density rocks (on the left side) to approximately 3.4 g/cm^3 for high-density rocks (on the right side). Thus both density and color hint at mineral composition when the minerals can't be seen, or if identification of the minerals is uncertain.

The percent mineral composition divides igneous rocks on the diagram into vertical columns of igneous rock families usually named for the coarse-grained member. An example would be the granite family, which includes granite, pegmatite, rhyolite, vesicular rhyolite, pumice, and some obsidian. The left, or granite side, of the chart is also the felsic side, which indicates a high aluminum (Al) and silicon (Si) content compared to the peridotite and dunite side on the right, which is mafic. Mafic rocks are higher in iron (Fe) and magnesium (Mg) and lower in silicon and aluminum. Note that all the minerals listed on this chart are silicates, with the oxygen-silicon tetrahedron as the basic component of the minerals' atomic structure.

Metamorphic Rocks

Rocks that form from changes in previously existing rocks due to heat, pressure, and/or mineral fluids without weathering or melting are **metamorphic rocks.** The previously existing rocks can be sedimentary, igneous, or other metamorphic rocks. The process of forming metamorphic rocks is called **metamorphism.** The changes that produce metamorphic rocks occur within the lithosphere, usually many kilometers deep. The changed rocks resulting from metamorphism are often less porous and more dense than the original rocks. They also have larger mineral crystals, and often have a layering of mineral crystals called **foliation.**

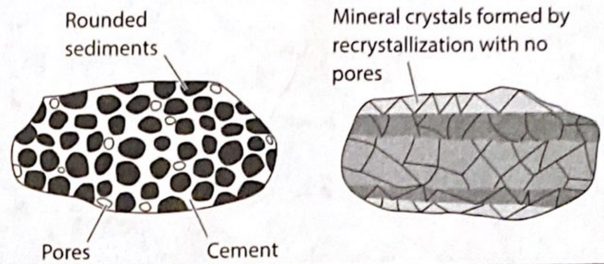


Figure 11-12. Metamorphic rock formed from sedimentary rock by recrystallization: Under the influence of heat and pressure, minerals in this clastic sedimentary rock combine by recrystallization to form mineral crystals of a coarse-texture (banded) crystalline rock. Recrystallization increases the rock's density by reducing the pore spaces.

Formation of Metamorphic Rocks When metamorphism occurs the previously existing rocks, called parent rocks, are usually recrystallized. (See Figure 11-12.) Recrystallization is the process of increasing the size of the mineral crystals or rock clasts and/or changing the mineral composition without melting. Under high heat and pressure conditions deep within the lithosphere, atoms can move small distances and become rearranged with changes in mineral composition without true melting, resulting in recrystallization. The various types of metamorphism are described in the sections that follow.

Contact Metamorphism When older rocks come in contact with the magma of an intrusion or lava of an extrusion, the heat and mineral fluids of the liquid rock alter the older rock in a process called **contact metamorphism.** Figure 11-13 shows the details of contact metamorphism. In a contact metamorphic zone there is a progression from igneous rocks, to metamorphic rocks, to the parent rocks, often without clear separations. At contact metamorphic zones, metamorphic rocks, such as hornfel, some marbles, and some quartzites are formed. Because there is mostly heat and not much directional pressure, the rocks formed by contact metamorphism usually don't have foliation.

Regional Metamorphism Sections of the lithosphere called plates may be hundreds of kilometers in width and tens of kilometers in depth. During the convergence (collision) of these plates, rocks are subjected to the high temperatures and pressures associated with a great thickness of overlying rocks and sediments and the pressures resulting from the collisions. The colliding plates often result in mountain building. The closer an area is to the boundary of colliding plates, the greater the increase in temperature and pressure. This increase in temperature and pressure transforms older rocks to a series of metamorphic rocks in a process called **regional metamorphism.** The rocks formed by regional metamorphism are often highly folded (bent) and faulted. The Taconic Mountains and the Hudson Highlands show features of regional metamorphism. Figure 11-14 illustrates the rock types and features formed by regional metamorphism.

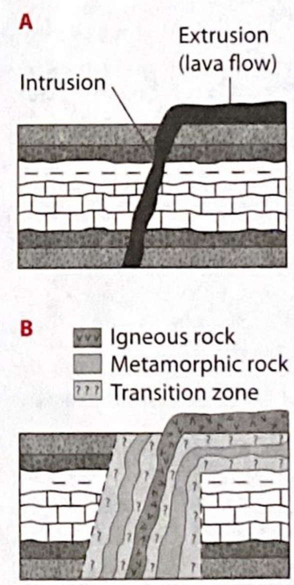


Figure 11-13. Transition of rock types in contact metamorphic zones: (A) Molten rock flows up through a crack in sedimentary rock to the surface, forming an intrusion below the surface and an extrusion (lava flow) on the surface. (B) At the contact zone, between the original local rock and the intrusion or extrusion, there is a blending of rock type from sedimentary, through metamorphic to igneous.

Textures of Metamorphic Rocks Metamorphic rocks have two major types of textures—foliated and nonfoliated. Foliated rocks have layers of mineral crystals that have formed by recrystallization under directional pressures associated with regional metamorphism. These rocks are composed of two or more minerals and are made of interconnected mineral crystals. The three types of foliations are shown in Figure 11-15.

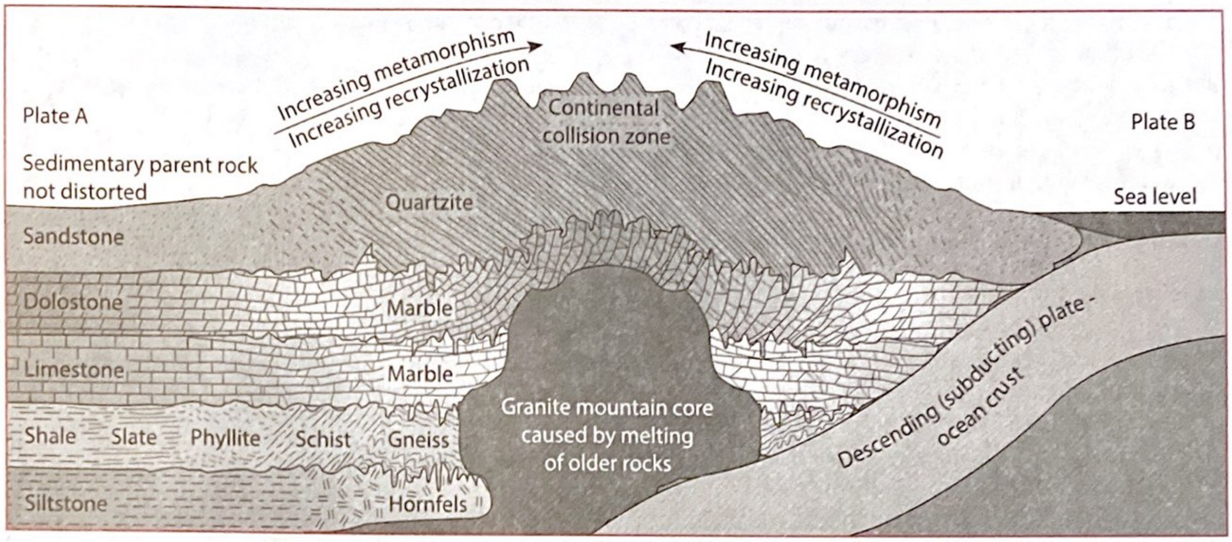


Figure 11-14. Conditions and rocks of regional metamorphism: This extremely ideal view shows two continents that have collided producing a young mountain range. The rocks become increasingly more deformed towards the center of the continents' zone of collision. As heat and pressure increase towards the collision zones, older sedimentary rocks progressively recrystallize into metamorphic rocks. With shale as the parent rock, a series of metamorphic rocks are formed as heat and pressure increases—shale → slate → phyllite → schist → gneiss. In the center of the mountain range, the heat and pressure have become so great that the rocks melted to form a granite intrusion of igneous rock.

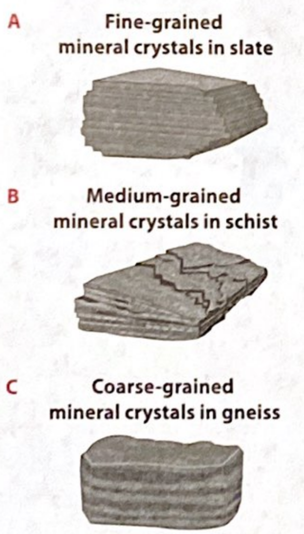


Figure 11-15. Foliation in metamorphic rocks: There are three types of foliations. Metamorphic foliations are very thin in the variety shown in diagram A. The slightly thicker foliations have mineral crystals that are reasonably visible with various minerals blending together in one foliation as in diagram B. Extreme recrystallization in diagram C has resulted in a separation (segregation) of minerals into broad bands of different color-sometimes called banding.

Nonfoliated metamorphic rocks are not layered because the minerals are not flat, or sheet-like, and/or the rocks were not subjected to a directional pressure. These rocks are composed of interconnected mineral crystals. Two single-mineral, crystalline rocks are quartzite, whose parent rock was pure quartz sandstone, and marble, whose parent rock is either limestone or dolostone.

Identification of Metamorphic Rocks Similar to sedimentary and igneous rocks, metamorphic rocks are classified and identified based on composition and texture. If the rock has foliations that are thin, if it breaks into smooth layers, and if the mineral crystals are not easily visible, the rock is slate, or phyllite (if the surface is shiny). If the rock is foliated, the mineral crystals are just clearly visible, and the rock has a high-mica mineral content, then the rock is schist. If the rock has coarse foliations—banded—and the mineral crystals are easy to see and distinguish, then the rock is gneiss. Refer to the Scheme for Metamorphic Rock Identification in the *Earth Science Reference Tables*. Ⓡ

In the nonfoliated metamorphic rocks the composition of the rock is usually the key to identification and classification.

- A rock that looks something like sedimentary conglomerate, but whose crystallized pebbles are stretched out and broken through, is probably a meta-conglomerate.
- A grainy single-mineral rock that easily scratches glass—because the quartz mineral content is much harder than glass—is quartzite.
- Grainy single-mineral metamorphic rocks that don't scratch glass are likely marble.
- Marble will fizz in dilute hydrochloric acid either directly or after powdering depending on if the parent rock is limestone or dolostone.

- Hornfels are very difficult to identify unless you know the specimen was collected next to an intrusion or under an extrusion.
- Anthracite coal is usually shiny black with a curved/conchoidal fracture.

Environment of Rock Formation

The type of environment in which a rock formed is inferred from its composition, structure, and texture. Four examples follow:

Large thick areas of rock salt in western New York State led to the inference that there was a large area of salty water in the past that has evaporated. This in turn suggests that the same could happen today in isolated seas of salt water exposed to a hot dry climate, such as the Mediterranean Sea.

The bent and twisted rock structure of surface metamorphic rocks in the Adirondack Mountains of northern New York State suggests that this region once experienced one or more mountain-building periods. See Landscape Regions of New York State and Their Characteristics in the Appendix. The rock structure also suggests that much uplift and erosion has occurred to expose rocks that formed deep beneath the surface.

If the sediments in a clastic sedimentary rock are sharp and angular, such as those in breccia, it can be inferred that the rock was formed near where weathering produced the sediments. This is because any long-distance transporting would have rounded the sediments.

A piece of igneous rock from a lava flow that has many large mineral crystals mixed with fine-grained crystals may indicate that solidification of magma had begun below the surface to produce the larger crystals. Then the lava with the large crystals erupted onto Earth's surface where the rest of the liquid solidified into rock.

The Rock Cycle

The **rock cycle** is a model used to show how the rock types— sedimentary, igneous, and metamorphic— are interrelated. It also shows the process that produces each rock type. Two examples of the rock cycle are Figure 11-16 and the Rock Cycle in Earth's Crust in the *Earth Science Reference Tables*. Some of the major concepts about the rock cycle are described in the following paragraphs.

Rocks Change Types Any rock type can change into any other rock type. Thus a specimen of any rock type can have materials in it that were once part of any other rock type. Examples include the solid sediments in sedimentary rocks, inclusions of older rocks in igneous rocks, or distorted fossils and sediments in metamorphic rocks.

No Preferred Direction of Movement There is no preferred direction of movement of material in the rock cycle for any one mass of chemical elements. Any one piece of mass can stay in one place for any

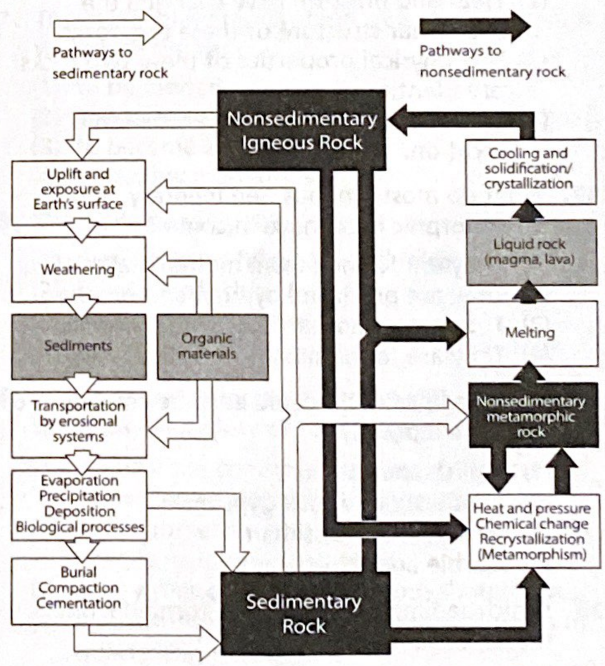


Figure 11-16. The rock cycle: Some of the processes by which one type of rock can be changed to another.

length of time, or it can follow any one of the paths of the rock cycle. As an example, there are sedimentary rocks over 3 billion years old that have remained largely unaltered. On the other hand a newly formed rock from a volcano can be eroded off by a hiker's boot, blown into evaporating water of a mineral spring, and become a sediment in a sandstone.

No Exact Point of Separation There is often no exact point of separation between the rock types. One example is the progression from igneous rock, to contact metamorphic rock, to the older intruded rock associated with contact metamorphism. (See Figure 11-13.) In areas of regional metamorphism there are zones many miles wide where identification of the rock type is debatable. Whether the rock is sedimentary shale or metamorphic slate, slate or schist, schist or gneiss, and even metamorphic gneiss or igneous granite is questionable.

Driving Forces The input of energy from Earth's interior, insolation from the sun, impacting meteorites, and gravity are the driving forces of the rock cycle. These forces create the processes of uplift, erosion and weathering, pressure, and melting.

Review Questions

16. When dilute hydrochloric acid is placed on the sedimentary rock limestone and the metamorphic rock marble, a bubbling reaction occurs with both. What would this indicate?

(1) The minerals of these rocks are similar.
(2) Heat and pressure have changed the molecular structure of these two rocks.
(3) The physical properties of these two rocks are identical.
(4) The two rocks originated at the same location.

17. What do most igneous, sedimentary, and metamorphic rocks have in common?

(1) They are formed from molten material.
(2) They are produced by heat and pressure.
(3) They are composed mostly of minerals.
(4) They are found mostly in distinct layers.

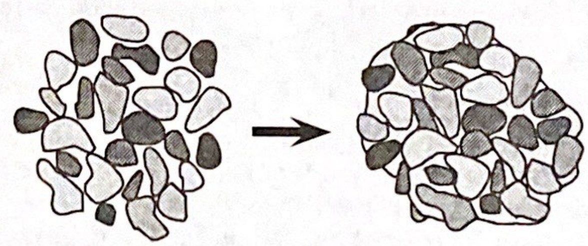
18. Which pair of rocks could each be composed of only one mineral?

(1) dunite and rock salt
(2) peridotite and rock gypsum
(3) dolomite and obsidian
(4) marble and schist

19. Which sedimentary rocks are formed from mostly organic matter?

(1) rock salt and shale
(2) bituminous coal and limestone
(3) dolostone and rock gypsum
(4) sandstone and conglomerate

Base your answers to questions 20 and 21 on the following diagram which represents the formation of a sedimentary rock (sediments are drawn actual size).



20. The formation of which sedimentary rock is shown in the diagram?

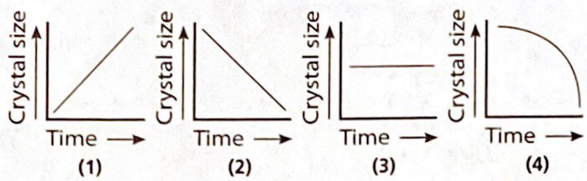
21. Which two processes formed this rock?

(1) folding and faulting
(2) melting and solidification
(3) compaction and cementation
(4) heating and application of pressure

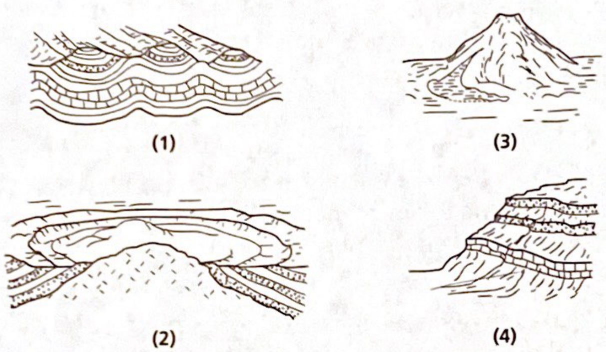
22. Which would most likely occur during the formation of igneous rocks?

(1) compression and cementation of sediments
(2) recrystallization of unmelted material
(3) solidification of molten materials
(4) evaporation and precipitation of dissolved sediments

23. Which graph best shows the relationship between the size of the crystals in an igneous rock and the length of time it has taken the rock to solidify?



24. Which diagram below shows an area in which fine-grained igneous rocks are most likely to be found?



25. The green sand found on the shores of the Hawaiian Island volcanoes most probably consists of the mineral

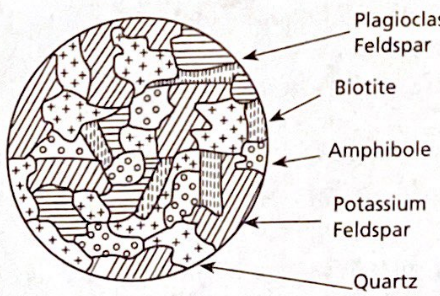
(1) quartz (3) biotite mica
(2) olivine (4) potassium feldspar

26. Generally as the percentage of felsic minerals in a rock increases, the rock's color will become

(1) darker and its density will decrease
(2) lighter and its density will increase
(3) darker and its density will increase
(4) lighter and its density will decrease

27. The diagram below represents a cross section of a coarse-grained igneous rock (drawn to true scale). This rock is most likely

(1) rhyolite (3) basalt
(2) scoria (4) granite



28. After collecting samples of igneous rocks, a student wishes to classify them as either intrusive or extrusive. Which characteristic of the samples might be the most useful to use?

29. A fine-grained rock has the following mineral composition: 50 percent potassium feldspar (orthoclase), 26 percent quartz, 13 percent plagioclase feldspar, 8 percent biotite mica, and 3 percent of the amphibole hornblende. The rock would most likely be

(1) granite (3) gabbro
(2) rhyolite (4) basalt

30. Metamorphic rocks form as the direct result of

(1) precipitation from evaporating water
(2) melting and solidification of magma
(3) erosion and deposition of soil particles
(4) heat and pressure causing changes in existing rock

31. What is the main difference between metamorphic rocks and most other rocks?

(1) Most metamorphic rocks contain only one mineral.
(2) Many metamorphic rocks have an organic composition.
(3) Many metamorphic rocks exhibit foliation and distortion of structure.
(4) Most metamorphic rocks contain a high amount of oxygen and silicon.

32. The regional metamorphism of a sandstone rock will cause the rock

(1) to be melted
(2) to recrystallize into smaller rock fragments
(3) to become denser
(4) to occupy a greater volume

33. Slate is formed by the

(1) deposition of feldspars and micas
(2) foliation of schist
(3) metamorphism of shale
(4) folding and faulting of gneiss

34. Which rock is composed of materials that show the greatest variety of rock origins?

(1) a limestone composed of coral fragments cemented together by calcium carbonate
(2) a conglomerate composed of pebbles of granite, siltstone, and gneiss
(3) a very fine-grained basalt with sharp edges
(4) a sandstone composed of rounded grains of quartz and feldspars

35. What ancient environment is the most likely inferred by the large rock salt deposits in the Syracuse, New York area?

36. Which statement about a large bedrock exposure of granite and gneiss is most likely correct?

(1) a number of volcanoes is nearby
(2) the granite and gneiss are the result of lava flows
(3) the rocks were never under water
(4) a great deal of erosion has taken place at this location

37. Which statement about inorganic rocks is true?

(1) all inorganic rocks are formed from other rocks
(2) all inorganic rocks except igneous rocks are formed from other rocks
(3) all inorganic rocks except metamorphic rocks are formed from other rocks
(4) all inorganic rocks except igneous and metamorphic rocks are formed from other rocks

Mineral Resources

Except for energy from the sun and the few things people might use from meteorites and similar objects, all things that people need come from Earth. These things, such as water to drink, air to breathe, plants to eat and use for lumber, and animals to provide clothing and milk products, are types of natural resources.

Earth materials—including minerals, rocks, and fossils fuels—are grouped together as **mineral resources.** In a lifetime, each person in the United States, on the average, is responsible for the consumption of some $3\frac{1}{2}$ million pounds of minerals, rocks, and mineral fuels that are extracted from the crust of Earth.

New York State has over 2,200 active mines that produce approximately 1.1 billion dollars of non-fuel resources. Of this, about 98% is from cement (made from limestone, gypsum, and shale), construction sand and gravel, crushed stone, salt, and the mineral wollastonite.

Memory Jogger

You may know that an ore is a rock or mineral deposit that can supply enough of a needed material to make it worthwhile to mine or drill for it from Earth's crust. Most minerals are mined to obtain one or more of the chemical elements the mineral contains.

Mineral Resources Are Nonrenewable

Some types of natural resources are renewable—which means they are replaced, or can be replaced, by Earth or sun processes at rates similar to the rates at which humans use them. Renewable natural resources include drinking water, trees, soil, oxygen, fish, and electromagnetic energy from the sun. Mineral resources are nonrenewable natural resources. This means that once the minerals are extracted—by mining or drilling—they are gone and will not be replaced at rates comparable to human life spans. Thus, there is a limited supply of the mineral resources, such as oil, gold, copper ore, sulfur, pure white marble, and other similar resources.

Rock Properties and Humans

Humans often use rocks because of the characteristics of the whole rock. Some examples include the following:

- Slate is impermeable and cleaves along foliations to produce thin flat pieces that can be used for roofing and chalkboards.
- Basalt and diabase resist crushing, so they are used as a base under roads and railroad tracks.
- Coal can burn releasing much heat energy.
- The natural pore space and low density of pumice make it useful for building insulation.
- Granite and quartzite are very resistant to weathering because of their nonporous composition, thus they are used as building stone.

Rock Properties and Land Usage

The type of rock that underlies the landscape of an area has many effects on how people use the land. Some examples follow:

- Limestones and dolostones often weather to produce nonacidic soils which are useful for certain crops; but often, underground water can dissolve these rocks producing caves that collapse forming dangerous depressions called sinkholes.
- Regions having much shale are often low in topography with a rolling landscape of gentle slopes. These topographic features are the result of the fact that shales usually weather and erode easily. This low rolling topography makes it easy to build homes and other human constructions such as roads. The high populations and many transportation facilities of the Hudson-Mohawk Lowlands of eastern New York State are often built on shale.
- Certain rock types withstand tremendous weight without crumbling or flowing under pressure. These types of rocks, such as gneiss and granite, occurring near Earth's surface allow for the safe construction of high-rise buildings, such as in New York City.

Mineral Properties and Humans

The physical properties of a mineral often determine how people use the mineral. Some examples of minerals and their useful properties are listed below:

- Quartz, when put under even minor amounts of pressure, will vibrate in a very regular fashion, which makes it ideal to use in the inexpensive yet very accurate quartz watches.
- Many minerals with a high hardness are used in jewelry and as abrasives in sandpapers and drilling operations. Diamond, corundum (ruby when red and sapphire when blue), the garnets, and quartz (amethyst when purple and citrine when golden yellow) are used in great volumes in the jewelry and abrasive industries. Mines in the Adirondack Mountains of New York State are one of the largest producers of garnet in the world.
- Graphite is soft and has a black streak that makes it very useful as a main ingredient of pencil "lead." The lead is largely graphite, not the element lead.
- Talc is very soft and has one direction of cleavage, which makes it feel smooth or greasy. For these reasons it is used in cosmetics and many baby and foot powders. Portions of the Adirondack Mountains have talc mines.
- Hematite's red color has proven to be useful to humans for many thousands of years. It is the red color of cave paintings, many cosmetics, and most red paints.
- The use(s) of many minerals is listed in the chart "Properties of Common Minerals" in the *Earth Science Reference Tables.* ®

Global Distribution of Mineral Deposits

Many of the more important elements required by our society are found in ores located outside of the United States. As the population of the United States and the rest of the world continues to grow, demand for the limited

Figure 11-17. Locations of mineral ores of some important chemical elements used in the United States: The map shows that the United States must import much of the rock and mineral sources of aluminum, nickel, tin, tungsten, and zinc.

rock and mineral resources becomes more and more competitive. At present the United States has to import almost 100 percent of the ores for aluminum, tungsten, cobalt, manganese, and graphite—plus over 50 percent of the ores for tin, zinc, nickel, and chromium. These materials are crucial for the production of much of our advanced industrial and military equipment. (See Figure 11-17.)

Fossil Fuels

Fossil fuels—which include oil (or petroleum), natural gas, coal, and oil shale—are the result of compaction and organic chemical changes in large deposits of organic sediments. These sediments are the remains of dead plants and animals.

Figure 11-18A indicates that at present three nonrenewable fossil fuels provide 90 percent of our energy needs. At present the United States can

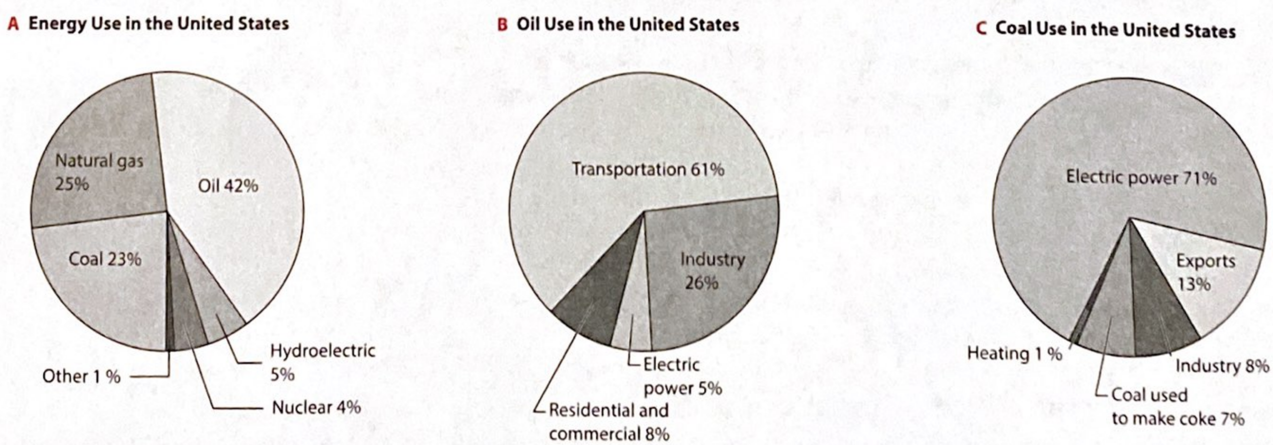


Figure 11-18. Circle graphs of sources of energy and uses of two fossil fuels in the United States.

provide a large proportion of our coal and natural gas demands, though our reserves are dwindling fast. Almost 60 percent of the oil used in the United States is imported. New York State produces small amounts of oil and natural gas, but has no commercial coal deposits. In recent years over 54 million cubic feet of natural gas and 300,000 barrels of oil were produced from 13,000 wells in New York State.

Review Questions

38. Which geological resource in New York State resulted from glaciation?

(1) oil shale and anthracite coal
(2) sand and gravel deposits
(3) gold and silver ores
(4) calcite and gypsum crystals

39. Rocks and minerals are natural resources that are mined in New York State. State *one* negative impact that should be considered before mining these natural resources.

Base your answers to questions 40 through 43 on the following chart. The chart shows information about selected mineral and energy resources.

Group	Mineral Resource	Uses
Elements	Gold	coins, jewelry, investment, electrical conductors, dental fillings
	Copper	electrical wiring, plumbing, coins
	Graphite	lubricants, pencil "lead"
Mineral Compounds	Hematite (ore of iron)	construction, motor vehicles, machinery parts
	Halite	food additive, melting of ice, water softeners, chemicals
	Feldspar	abrasives (sandpaper), jewelry
Fuels	Coal	heating, electric generation plants, plastics and other synthetic chemicals
	Petroleum	automobile fuel, lubricants, plastics and other synthetic chemicals, medicines, heating

40. Name two resources that would last longer if people used public transportation.

41. What is the primary source of all the resources listed in the chart?

(1) recycled and discarded waste materials
(2) deposits within Earth's crust
(3) substances extracted from ocean water
(4) meteorites that came from outer space

42. Which of the minerals listed in the chart does NOT have a metallic luster?

(1) gold
(2) copper
(3) graphite
(4) halite

43. Which of the materials from the chart is NOT a mineral or NOT made of minerals?

(1) copper
(2) hematite
(3) halite
(4) coal

44. Which home-building material is made mostly from the mineral gypsum?

(1) plastic pipes
(2) window glass
(3) drywall panels
(4) iron nails

45. Which statement about the minerals plagioclase feldspar, gypsum, biotite mica, and talc can best be inferred?

(1) These minerals have the same chemical and physical properties.
(2) These minerals have different chemical properties, but they have similar physical properties.
(3) These minerals have different physical and chemical properties, but they have identical uses.
(4) The physical and chemical properties of these minerals determine how humans use them.

46. Which of the minerals listed below contain only one element?

(1) graphite
(2) hematite
(3) halite
(4) garnet

47. Wood and coal are both organic natural resources. Explain why coal is considered a fossil fuel, while wood is not.

Practice Questions *for the* New York Regents Exam

Directions
Review the Test-Taking Strategies section of this book. Then answer the following questions. Read each question carefully and answer with a correct choice or response.

Part A

1 Which of the following pairs of rocks usually contains only one mineral?
(1) rock gypsum and marble
(2) sandstone and conglomerate
(3) quartzite and schist
(4) dunite and gabbro

2 Which of the following properties is most useful in mineral identification?
(1) hardness
(2) color
(3) size
(4) texture

3 Which property of minerals is illustrated by the peeling of biotite mica into thin flat sheets?
(1) fracture
(2) cleavage
(3) a low hardness
(4) a weak streak

4 The main difference between sedimentary, metamorphic, and igneous rocks is the
(1) means by which they are located
(2) conditions under which they are formed
(3) minerals of which they are composed
(4) location in which they are found

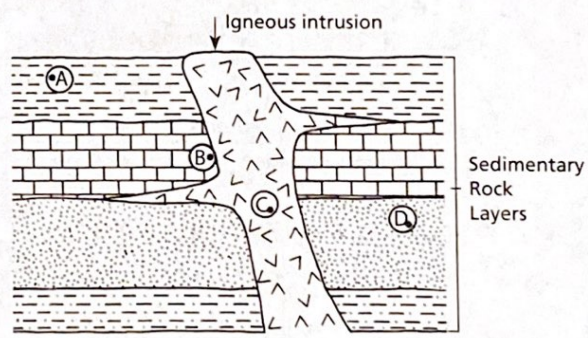
5 Which rock was formed by the compaction and cementation of particles 0.07 centimeters in diameter?
(1) conglomerate
(2) sandstone
(3) shale
(4) siltstone

6 Dolostone and rock gypsum are formed by the processes of
(1) melting and solidification
(2) evaporation and precipitation
(3) erosion and deposition of clastic fragments
(4) weathering and metamorphism

7 Which would most likely cause molten rock material to become glassy igneous rock?
(1) cooling over a long period of time
(2) cooling under high pressure
(3) cooling on Earth's surface
(4) cooling at great depth within the crust

8 An igneous rock, which has crystallized deep below Earth's surface, has the following approximate composition: 70 percent pyroxene (augite), 15 percent plagioclase feldspar, and 15 percent olivine. What is the name of this igneous rock?
(1) granite
(2) rhyolite
(3) gabbro
(4) basalt

Use the following diagram to answer questions 9 and 10. The diagram shows an igneous rock intrusion in sedimentary rock layers.

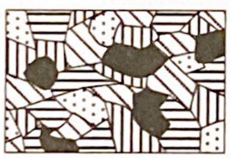


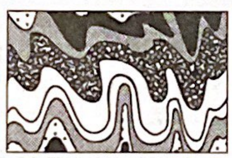
9 At which point would there most likely be contact metamorphic rock?
(1) A
(2) B
(3) C
(4) D

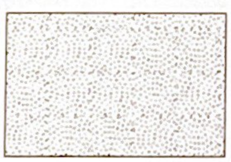
10 Which rock type would most likely be located at the contact between rocks C and D?
(1) metaconglomerate
(2) gneiss
(3) marble
(4) quartzite

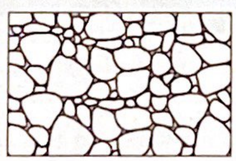
11 In which parts of New York State would you most likely find large amounts of bedrock formed by regional metamorphism?
(1) Atlantic Coastal Plain and Newark Lowlands
(2) Hudson Highlands and Adirondack Mountains
(3) Tug Hill Plateau and Allegheny Plateau
(4) Erie-Ontario Lowlands and the Catskills

12 Which actual-size diagram best represents a sample of the metamorphic rock gneiss?


(1)


(3)


(2)


(4)

13 Which type(s) of rock can be the source of deposited sediments?
(1) igneous and metamorphic rocks, only
(2) metamorphic and sedimentary rocks, only
(3) sedimentary rocks, only
(4) igneous, metamorphic, and sedimentary rocks

14 A certain igneous rock is composed of large mineral grains. This suggests that the rock formed
(1) on the surface, under high pressure, and at a rapid rate of cooling
(2) on the surface at high temperature, and at a slow rate of cooling
(3) deep underground under high pressure, at high temperature, and at a rapid rate of cooling
(4) deep underground under high pressure, at high temperature, and at a slow rate of cooling

15 Which characteristic would indicate that a rock was formed from sediments deposited in shallow water near shore rather than in deep water?
(1) hardness
(2) dark color
(3) a large grain size
(4) a large amount of cement

Part B

Base your answers to questions 16 and 17 on the diagram below and the *Earth Science Reference Tables*. The diagram shows the elements found in four minerals.

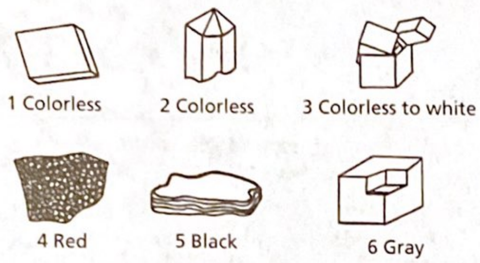
	O	Si	Al	Fe	Ca	Na	C
Quartz	■	■					
Feldspar	■	■	■		■	■	
Olivine	■	■		■	■		
Diamond							■

■ = element present

16 Which of the minerals in the diagram has the greatest variety of elements in it? [1]

17 Which of the elements listed in the diagram is second in abundance, by mass, in Earth's crust? [1]

Follow these directions for questions 18 through 23. The following numbered diagrams represent mineral specimens. Using these diagrams, write the name of the mineral which is best described by each of the statements. (If a mineral has cleavage, the diagram illustrates it.)



18 Diagram 1 is a mineral that easily bubbles when exposed to dilute acids. [1]

19 Diagram 2 is a very hard mineral that has a curved fracture. [1]

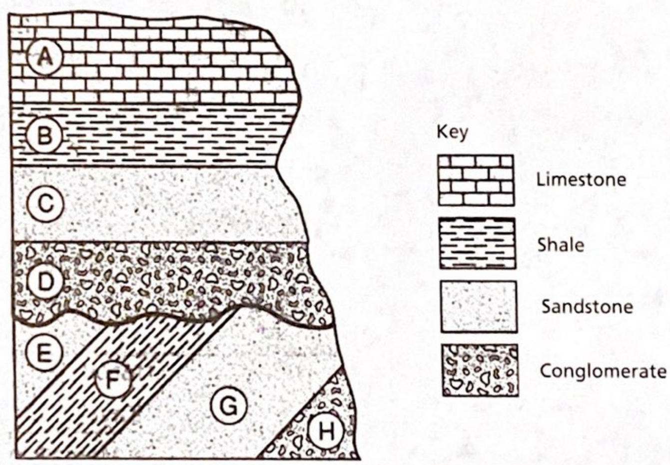
20 Diagram 3 shows intergrown crystals of this salty tasting mineral. [1]

21 Diagram 4 is an ore of iron with a red streak. [1]

22 Diagram 5 is a soft mineral with cleavage that forms thin flexible sheets. [1]

23 Diagram 6 is an ore of lead that is soft and has a metallic luster. [1]

Base your answers to questions 24 through 28 on the following diagram. The diagram represents a profile view of exposed rock layers. The layers are labeled A through H.



24 State the range of particle sizes of the sediments that formed rock layer C. [1]

25 State two ways in which the composition of rock layer A differs from the composition of rock layer B. [2]

26 State a method by which rock layer A could have formed. [1]

27 Based on information in the diagram, state a reason why you would choose to use rock from layer A instead of rock from layers C or D for a tombstone or statue. [1]

28 State the name of the sediment that was compacted to form rock unit B. [1]

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29 Describe two conditions that can result in the metamorphosis of a rock. [2]

30 If an igneous rock layer is composed of vesicular andesite, identify three types of minerals that could be found in sand weathered from the rock layer. [1]