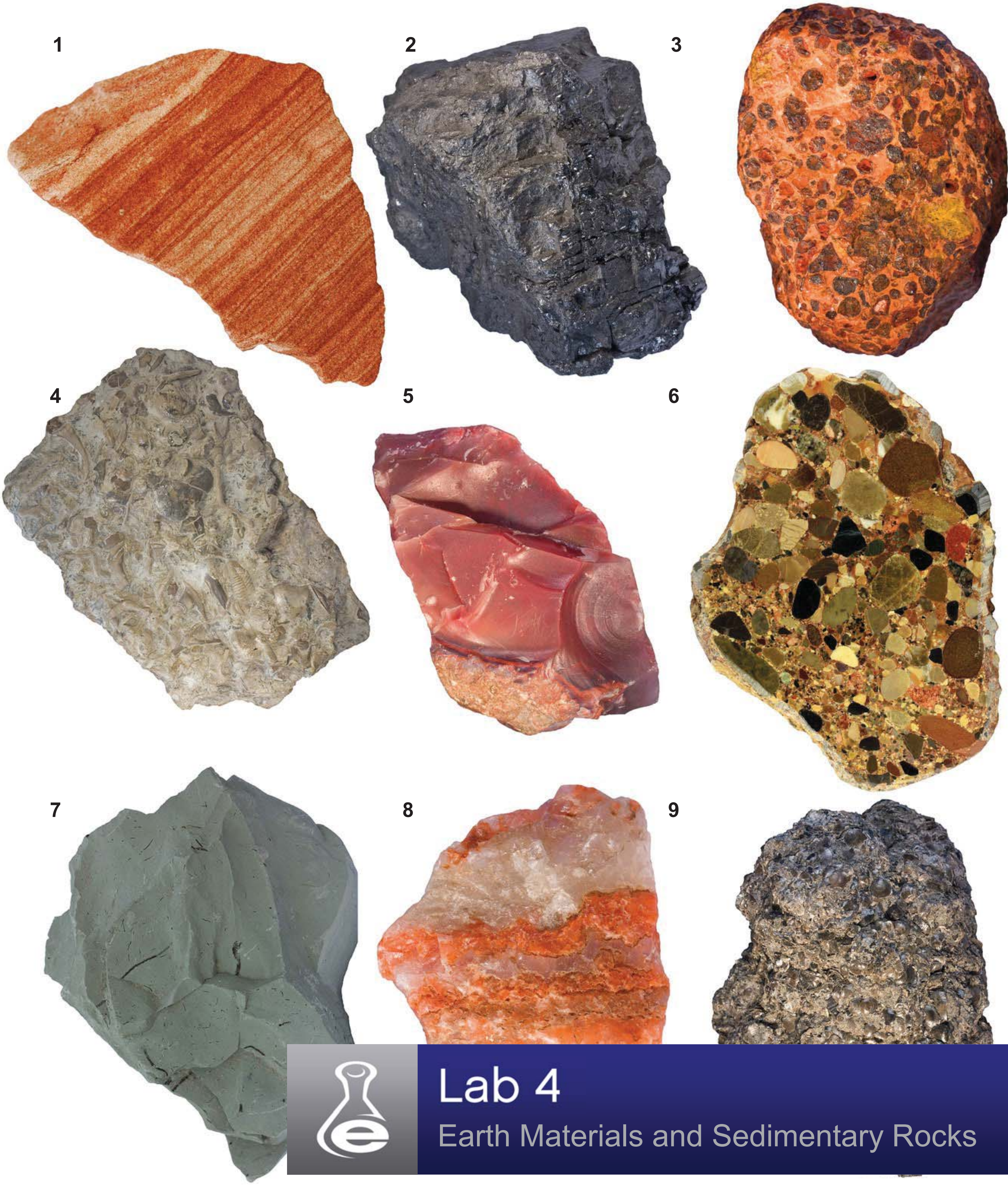

Lab 4

Earth Materials and Sedimentary Rocks

1 Sandstone, 2 Coal, 3 Bauxite, 4 Limestone, 5 Chert, 6 Conglomerate 7 Clay 8 Sylvite (rock salt) 9 Phosphorite

Lab 4 Earth Materials and Sedimentary Rocks

Learning Objectives

- Identify the relationship between minerals and rocks
- Classify common sedimentary minerals
- Develop a method for classifying sedimentary rocks

Introduction

In order to understand how geologic time is preserved in rocks, one must be able to distinguish between the materials that make up the Earth. These materials form the foundation on which the rock record is preserved, and their formation and alteration leave clues about our world's past. For example, many minerals form in distinct pressure and temperature zones, while other minerals primarily form in specific environments, such as shallow seas or deserts. Using this knowledge, geologists use rocks and minerals to gain insight into past environments.

Minerals

Minerals are naturally occurring inorganic solids and are the building blocks of most rocks. That is, they form naturally, are not made from plants or animals, and are neither liquid nor gas. All minerals have a definite chemical composition, which means each mineral is made of specific chemical elements (Figure 1). Calcite, a mineral made of calcium, carbon, and oxygen, has the chemical formula $CaCO_3$. Minerals are classified according to their physical properties, including color, luster, crystal symmetry, cleavage, streak, hardness, and chemical reactivity.

***Figure 1*: Quartz, a mineral with the chemical composition SiO_2, is a common mineral in the Earth's crust.**

Knowledge Check:

☑ *Coal is made of carbon and hydrogen, and forms from the compression of deceased organisms. Is coal a mineral?*

Mineral Identification

Crystal Symmetry

Determining a mineral's **crystal symmetry** (Figure 2) is one way of identifying a mineral. Crystals grow through different processes. In magma, atoms arrange in orderly patterns as the rock cools. Crystal symmetry structures are a useful starting point for mineral identification because each mineral has a definite crystal structure when it has room to grow. For example, quartz forms a hexagonal prism, and halite, which is cubic, forms a perfect cube. If a mineral does not have room to grow, it may not exhibit crystal symmetry on a macroscopic scale (Figure 3).

Mineral hand samples reflect their inner symmetry by their atomic structure. Minerals that commonly develop prisms have a **prismatic/columnar** symmetry (or habit). Minerals that grow in flat plans are **tabular**, and minerals with no visible structure are called **massive**.

***Figure 2:* Crystal symmetry in halite (left) and quartz (right).**

Coloration

You can also classify minerals by **color**. For example, the mineral malachite is always green. Azurite is usually blue (Figure 4) and sulfur is usually yellow. Notice the use of "usually"? A mineral's color can change if it has been altered by weathering, exposed to heat, has some impurities, or possesses other properties that don't change the mineral's basic make-up.

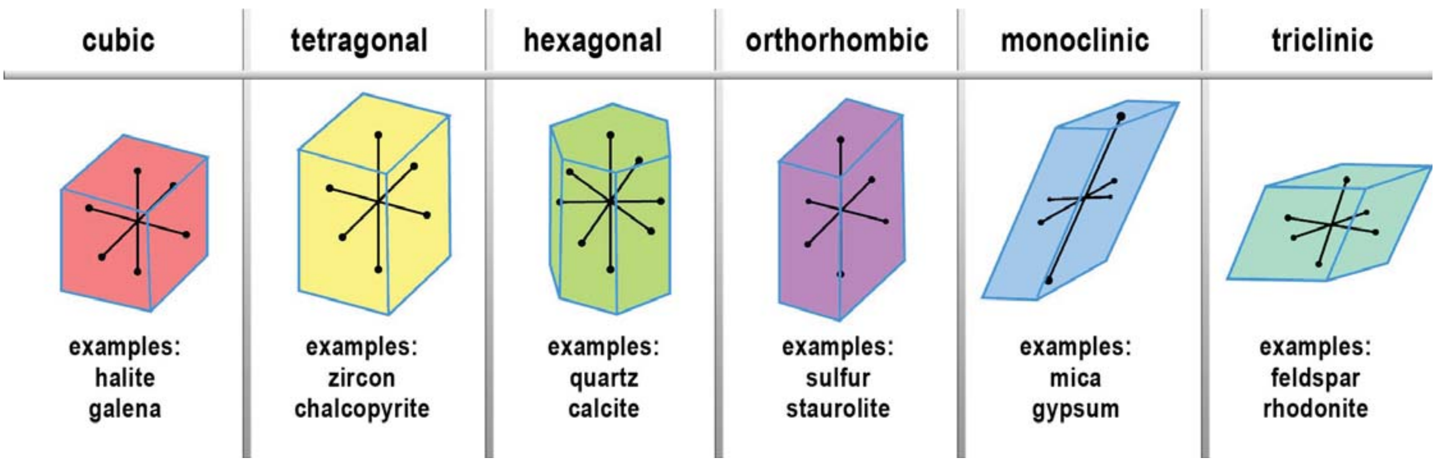

***Figure 3:* Crystal symmetry.**

Blue azurite is presented in Figure 4. However, the green color is malachite, which shows an identification complication: the existence of different minerals in one rock. Besides one mineral being different colors, different minerals can be the same color. Three minerals, for example, look like the mineral gold in color.

Pyrite (Figure 5), a mineral commonly mistaken for gold, also has the same gold-like appearance of chalcopyrite. Further, weathered biotite mica also can be mistaken for gold, which brings up another identification problem: exposure to weather can affect a mineral's surface color.

Surfaces also can be dark, pale, dull, shiny, streaked, speckled, banded, and other descriptors. So, while surface color is an easy property for which to look, geologists also use additional properties to identify minerals.

Figure 4: ***Blue azurite and green malachite (minerals) together in a rock.***

Luster

The way the surface interacts with or reflects light - **luster** - is another way to distinguish minerals. A geologist first looks to see whether a mineral has a metallic (i.e., looks like metal such as silver, gold, or copper) or non-metallic luster. They then check to see if a mineral is dull (clay-like), pearly, silky, waxy, adamantine (sparkly), resin (similar to tree sap), or vitreous (glassy). Of course, unlike determining mineral color, figuring out luster isn't always easy. About 70 percent of minerals have a vitreous luster, notably silicates, carbonates, phosphates, sulfates, halides, and hydroxides.

Figure 5: ***Pyrite, FeS_2, is the most common sulfide mineral.***

Knowledge Check

☑ *How is color different from luster?*

Cleavage

Cleavage, the look of a mineral when it evenly breaks, is another identification clue. Cleavage is displayed when a mineral splits leaving parallel planes. These breaks occur where a rock is weak within the crystalline structure, and therefore reveals internal structure. Cleavage can be measured by quality, smoothness, roughness, or number of cleavage planes. If there is more than one plane, the angles between cleavages are helpful in diagnoses. Not all minerals have cleavage. Instead they may have **fractures** (rough, uneven breaks in the structure). Therefore, this can be a tricky identification property.

Figure 6: ***Fluorite has a vitreous (glassy) luster.***

Streak

The streak - the mark a mineral leaves when rubbed on a tile of unglazed white porcelain - is often used in mineral identification. A streak color may be similar to the mineral's apparent color; or, it may be unexpected. For example, fluorite can have a few different colored crystals, but it leaves a white streak. Additionally, black hematite streaks red.

Hardness

A mineral's hardness - its bonding strength between atoms - has long been used in identification. Frederick Mohs devised a scratch test in 1822 to determine a mineral's hardness that is still used today. The softest mineral rates 1 on the scale, and the hardest rates 10. Each mineral on the scale can only scratch another mineral lower on the scale (Table 1). For example, calcite can scratch a fingernail or a sample of gypsum or talc. In addition, a copper penny, a steel nail, or a sample of apatite can scratch calcite.

Table 1: Mohs Hardness Test

Hardness	Test	Index Mineral
1	Scratch with a fingernail	Talc
2	Scratch with a fingernail	Gypsum
3	Scratch with a copper plate	Calcite
4	Scratch with a knife	Fluorite
5	Scratch with a steel nail	Apatite
6	Scratches glass	Feldspar
7	Scratches glass	Quartz
8	Scratches glass	Topaz
9	Scratches glass	Corundum
10	Scratches glass	Diamond

Other Characteristics

Some minerals may have other, unique, identifying characteristics. Magnetite, for example, is magnetic. Sulfur and pyrite have a rotten egg smell. Calcite and aragonite effervesce (i.e., fizz) when exposed to hydrochloric acid (or higher pH acids such as acetic or citric acid). This occurs because CO_2 (carbon dioxide) is released.

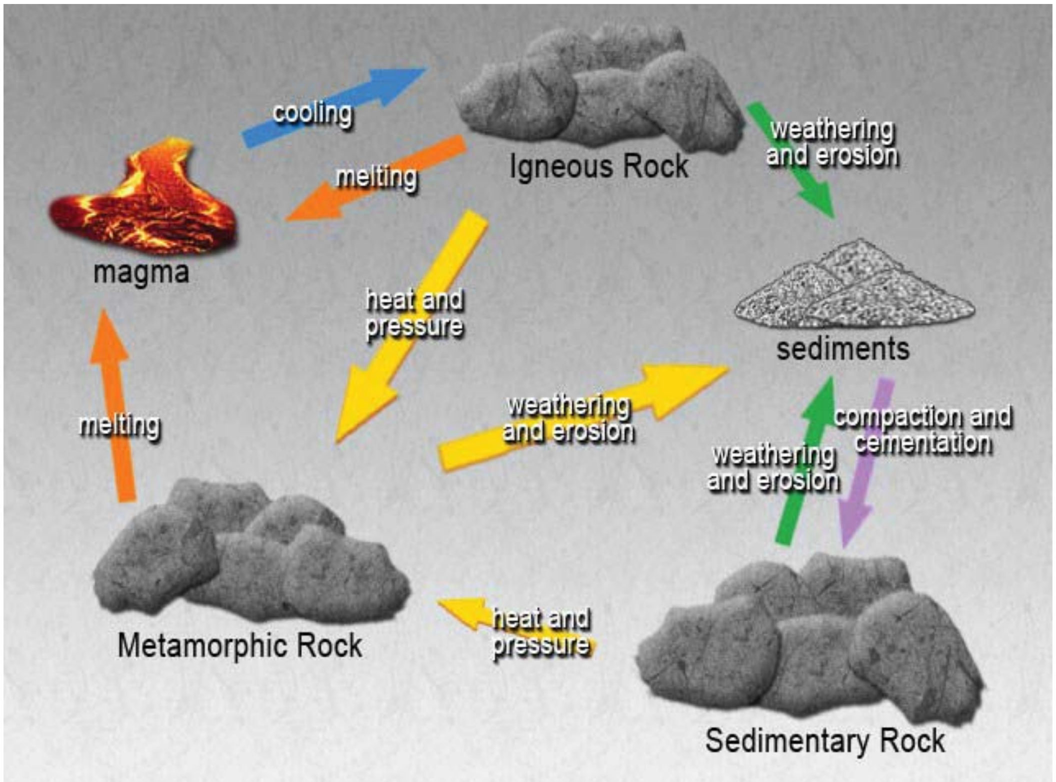

Figure 7: ***The rock cycle.***

Rocks

There are three main rock types, differentiated by their origin. **Igneous rocks** are formed from magma or lava, a mix of molten (melted) rock and gases generated within the Earth. When magma or lava cools, igneous rocks are formed.

Sedimentary rock formation generally begins when rocks (of any type) are broken down, transported, and deposited in a new location. The breakdown and transport of rocks can occur by agents such as wind or water. Once rock is broken down, it is called **sediment.** The sediment is deposited in combination with shells, bones, and plants and eventually forms layers of material (which contributes to fossil formation). The overlying material compresses the lower layers and naturally cements them together in a process known as **lithification**. The final product of lithification is a sedimentary rock!

Metamorphic rock is formed when heat and pressure cause existing rocks (of any type) to deform. Mineralogical structures within the rock change their crystalline structure and can also deform. Partial melting may take place. For example, marble is a metamorphic rock that forms when limestone, a sedimentary rock, is subjected to heat and pressure.

On Earth, rocks are continually broken down and reformed in a pattern known as the rock cycle (Figure 7). Rock cycle processes alter geologic environments by continually creating and altering the environment we see today.

Sedimentary Rocks

The deposition process which forms sedimentary rocks provides an excellently preserved record of historical environments and events. For this reason, sedimentary rocks play a significant role in historical geology. Like minerals, sedimentary rocks are classified by their physical characteristics. Since sedimentary rocks are composed of sediment particles, these particles (also called **clasts**) define the sedimentary rock type (Figure 8). Important sedimentary rock characteristics include clast size, composition, and shape. Clast composition distinguishes the three types of sedimentary rocks: biogenic, chemical, and clastic.

Figure 8: ***Sandstone is a clastic sedimentary rock. The Devil's Marbles, Australia.***

Knowledge Check:

☑ *What differentiates the three types of sedimentary rocks?*

Biogenic Sedimentary Rocks

Biogenic, also called **biologic or bioclastic,** sedimentary rocks are formed from deceased organisms. The remains of these organisms often accumulate on the seafloor, and are then compressed and cemented. One common biogenic sedimentary rock is limestone (Figure 9), which is made from the minerals calcite and aragonite. Limestone can be a variety of colors, but is generally white or grey, and relatively hard. Chert, another biogenic rock, is formed from silica-rich shells. Chert is primarily composed of quartz, and breaks in curved, irregular patterns like glass. Flint, another silica rich rock often associated with chert, is known for being used in arrowheads. Bituminous coal is also a biogenic sedimentary rock. It is a dark black (or brown), somewhat shiny rock that is burned for energy.

Figure 9: ***Limestone is a common biogenic sedimentary rock.***

Figure 10: ***Halite, a chemical sedimentary rock.***

Chemical Sedimentary Rocks

If you left a glass of lemonade sitting on the counter for a week, you would find that some of the water from the lemonade evaporated. If left undisturbed for long enough, you would find sugar that was once dissolved at the bottom of the glass. Similarly, as water evaporates from the ocean, salt is left behind. Rocks that are formed form this process are often called **evaporites,** because they are formed from evaporation. Evaporites are composed only of one mineral, and their rock name is often simply the mineral name; gypsum, sylvite, and halite are several examples.

The process of forming an evaporite from dissolved minerals is known as **precipitation**. Precipitation can occur with evaporation (which creates a saturated solution), or can occur when a solution becomes **saturated** independent of evaporation. Have you ever made lemonade and seen a layer of sugar sitting at the bottom of your glass? This layer of sugar cannot dissolve because the solution is saturated; the water is holding as much sugar as possible. Minerals such as calcite precipitate from saturated solutions. This type of precipitation forms chemical limestone, which is often found in caves.

Knowledge Check:

☑ *Chemical sedimentary rocks are formed by what process?*

Clastic Sedimentary Rocks

Clastic sedimentary rocks are primarily composed of quartz, feldspar, and clay minerals. An individual clast is a rock fragment. Unlike biogenic and chemical sedimentary rocks (Figure 10), clastic sedimentary rocks are classified by clast size and shape. Clast (or particle) size is often called grain size and assigned a sediment name. For example, very large clasts are called boulders, large clasts are called pebbles, and smaller clasts are called gravel.

Knowledge Check:

☑ *How are clastic rocks classified?*

Clast shape, also known as roundness, also classifies clastic rocks. Roundness refers to how similar a clast is to a sphere. Clast roundness is classified by the terms in Figure 11.

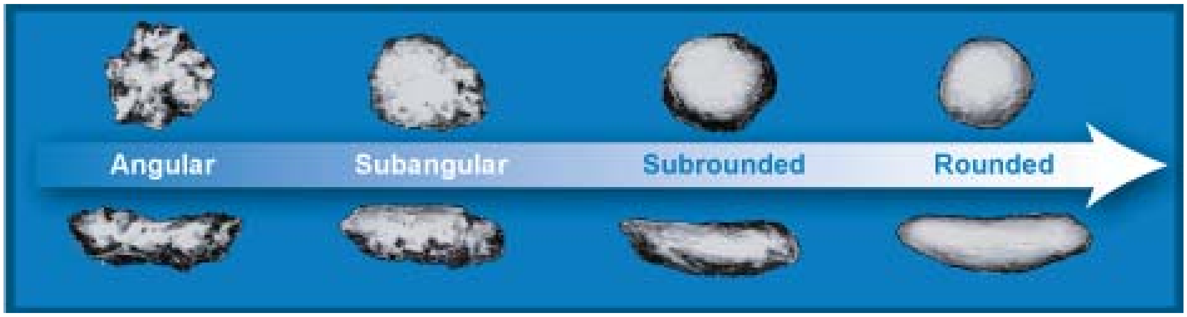

Figure 11: ***Roundness of clasts.***

Clasts become more rounded as they undergo more abrasion. For example, if a boulder falls off a cliff and shatters into pieces, these pieces will have sharp edges. The clasts will be angular, and if incorporated into a sedimentary rock, the rock would be called a breccia. However, if these clasts are picked up by a stream and carried for some time, their edges may become rounded as they bump against rocks in the stream bed. The clasts are now subangular. The longer the rocks sit in the stream, the more rounded their edges will become. If these rounded particles become cemented with fine sediment in the bottom of the stream, the rock formed will be a conglomerate.

Sedimentary rock type is based on the environment of rock formation. Therefore, sedimentary rocks reveal information about past environments. For example, the presence of an evaporite may indicate a dry environment where water was evaporating and leaving behind minerals (e.g., the Utah Salt Flats). Chert suggests that organisms with silica-rich shells were once present and therefore the area may previously have been covered by a sea or ocean. The presence of a clastic sedimentary rock indicates the role of a weathering agent such as a stream or river. Therefore, being able to classify sedimentary rocks is an essential skill in reconstructing the past.

Up Close...

What is the difference between sedimentary rocks created today and ancient sedimentary rocks? Modern sedimentary rocks contain more than just rock fragments; they also contain plastic fragments. Scientists recently classified a new type of sedimentary rock, one lithified with shells, rock fragments, and plastics. These plastics enter the ocean through various pathways. In one instance nearly twenty years ago, a shipment of rubber ducks were swept overboard in the Pacific ocean, contributing to nearly 5.8 million tons of waste that reaches the oceans every year.

Lab 4 Earth Materials and Sedimentary Rocks

Pre-Lab Questions

1. What is the relationship between minerals and rocks?

2. What characteristics are used to classify minerals? Identify at least three.

3. Develop a method to classify sedimentary rocks. Be sure your process is clearly outlined and could be reproduced by an outsider.

Experiment 1: Common Sedimentary Mineral Identification

Because all rocks are composed of minerals, a solid foundation in mineral identification is useful when classifying sedimentary rocks. Often, geologists are asked to identify rock formations in the field. In this situation, only the physical appearance is used to determine mineral and rock names. In this experiment, you will examine hand samples of several minerals that are common in sedimentary rocks. You will record your observations and compare them to a reference table in order to identify the minerals.

Materials

1 mL 4.5% Acetic Acid ($C_2H_4O_2$)

Copper Plate (H = 3.5 on Mohs Scale)

Glass Plate (H = 5.5)

- Mineral A
- Mineral B
- Mineral C
- Mineral D
- *Mineral E
- Mineral F

Steel Nail (H ≈ 6.5)

Streak Plate

*Save this mineral for the Environment of Deposition Lab (if your lab kit includes this lab)

Procedure:

1. Record the color, luster, and crystal symmetry of each mineral sample in Table 2. Remember, minerals may have more than one color or luster. Be sure to record all observations.
2. Test the streak of each mineral by scratching each mineral against the streak plate.
3. Test the hardness of each mineral using the Mohs Hardness Scale. To do this, begin by trying to scratch the mineral with your fingernail. If your fingernail does not scratch the mineral, the mineral has a hardness greater than 2.0. If your fingernail does not scratch the mineral, keep testing the mineral using the copper plate, glass plate, and steel nail. Use Table 1 on page 57 for reference. Record your findings in Table 2.
4. You may want to test other properties such as effervescence as noted in Table 3. Only a drop or two of acetic acid on a mineral is necessary to observe if the mineral effervesces.
5. After all of the minerals have been tested and results have been recorded, compare your findings to Table 3 to determine the name of the mineral.

   Note: If your lab kit contains the Environment of Deposition Lab, do not discard Mineral E and keep it in the properly labeled bag it came in. You will use it again for the Environment of Deposition Lab.

Table 2: Sedimentary Mineral Classifications

Mineral	Color	Luster	Streak	Hardness	Other	Crystal Symmetry	Mineral Name
A							
B							
C							
D							
E							
F							

Table 3: Common Sedimentary Minerals and their Properties

Mineral	Color	Luster	Streak	Hardness	Other	Crystal Symmetry
Dolomite	White, grey, pink	Vitreous, pearly	White	3.5		Rhombohedral
Gypsum	Colorless, white, grey	Vitreous, silky, waxy	White	2	Also classified as a rock	Monoclinic
Potassium Feldspar	Pink, white, grey	Vitreous	White	6		Triclinic
Quartz	Yellow, white, grey	Vitreous	Colorless	7.0		Hexagonal
Halite	Colorless, white, pink	Vitreous	White	2.0	Tastes salty, also classified as a rock	Cubic
Calcite	Colorless, white	Vitreous, pearly	White	3.0	Effervesces with acid	Trigonal hexagonal

Experiment 2: Sedimentary Rock Identification

Classifying sedimentary rocks in field investigations gives insight into past environments. In this experiment, you will use your knowledge about sedimentary rocks to identify hand samples of sedimentary rocks.

Materials

Hand Lens

*Sedimentary Rock Specimens:

- Unknown Rock G
- Unknown Rock H
- Unknown Rock I
- Unknown Rock J
- Unknown Rock K
- Unknown Rock L

*Save these rocks for the Environment of Deposition Lab (if your lab kit includes this lab)

Procedure:

1. Examine each rock specimen with a hand lens. Note the shape and grain size of the clasts (If applicable). Record your observations in Table 5.
2. Examine and record the mineral composition, and any other applicable observations in Table 5. **Note**: In many cases the minerals will not be visible to the untrained, naked eye. You may find it easier to identify the rock before attempting mineral ID.
3. Assign a name to each rock in Table 5 using Table 4.

   Note: If your lab kit contains the Environment of Deposition Lab, do not discard your rocks and keep them in the properly labeled bags they came in. You will use them again for the Environment of Deposition Lab.

Table 4: Common Sedimentary Rocks

Rock Type	Particle Size	Composition	Comments	Rock Name
Clastic	Very Coarse — Coarse > 2.0mm	Any rock (quartz, feldspars most common minerals)	Rounded clasts	Conglomerate
			Angular clasts	Breccia
Clastic	Coarse — Medium 0.06—2.0mm	Quartz, feldspars	Feels sandy, some grains may be present	Quartz Sandstone
Clastic	Fine 0.004—0.06mm	Clays, quartz	Feels gritty, some grains visible through hand lens	Siltstone
Clastic	Very Fine < 0.004mm	Clays, quartz	May be foliated, no visible grains	Shale
Chemical	Varies	Halite	No visible grains, tastes like salt, has three perfect right angles	Halite
		Gypsum	Softer than fingernail, can be pink, white, or clear	Gypsum
		Dolomite	Reacts with dilute acid only when powdered	Dolostone
Chemical or Biogenic	Microcrystalline	Quartz and/or quartz based fossils	Exhibits sharp edges and breaks in glass like patterns, smooth to the touch	Chert
Biogenic	Varies	Calcite and calcite based fossils	Small fossils or fossil impressions may be present, reacts with dilute acid	Fossiliferous Limestone
		Carbon-based material	Plant remains may be visible, black-brown color	Bituminous Coal

Table 5: Sedimentary Rock Classifications					
#	Clast Shape	Grain Size	Other Observations	Mineral Composition	Rock Name
	(If Applicable)				
G					
H					
I					
J					
K					
L					

Post-Lab Questions

1. Which of the samples were clastic? Among these samples, which of these experienced the most abrasion during transport? Explain your reasoning.

2. Were any of the samples chemical sedimentary rocks? Explain your reasoning.

3. How does mineral composition affect a rock's properties? For each rock, note the color and hardness of the minerals composing the rock, if possible. How do these values compare to the overall color and hardness of the rock (Table 6, Experiment 2)?

4. Briefly describe how each rock was formed. If several rocks were formed by the same process, note which rocks were formed by this process, and only explain the process once.