**Introduction**

To understand most geologic processes, we must understand rocks. And to understand rocks we must first understand minerals, which are the components of rocks. Minerals differ from each other in chemical composition and atomic arrangement, and these factors produce distinctive physical properties that enable minerals to be identified. In this chapter you will learn how to determine or identify the most useful properties.

**What Is a Mineral?**

A mineral is a naturally occurring compound or chemical element made of atoms arranged in an orderly, repetitive pattern. Its chemical composition is expressed with a chemical formula Both chemical composition and atomic arrangement characterize a mineral and determine its physical properties. Most minerals form by inorganic processes, but some, identical in all respects to inorganically formed minerals, are produced by organic processes (for example, the calcium carbonate in clam shells). A few naturally occurring substances called mineraloids have characteristic chemical compositions, but are amorphous; that is, atoms are not arranged in regular patterns. Opal is an example.

The precise chemical composition and internal atomic architecture that define each mineral also directly determine its outward appearance and physical properties. Thus, in most cases, general appearance and a few easily determined physical properties are sufficient to identify the mineral.

**Physical Properties**

Color, luster, streak, hardness, cleavage, fracture, and crystal form are the most useful physical properties for identifying most minerals. Other properties—such as reaction with acid, magnetism, specific gravity or density, tenacity, taste, odor, feel, and presence of striations—are helpful in identifying certain minerals.

**Color**

Color is the most readily apparent property of a mineral, but BE CAREFUL. Slight impurities or defects within the crystal structure determine the color of many minerals. For example, quartz can be colorless, white, pink, purple, green, gray, or black. Color generally is diagnostic for minerals with a metallic luster but may vary quite a bit in minerals with a nonmetallic luster. Check the other properties before making identification.

**Luster**

Luster describes the appearance of a mineral when light is reflected from its surface Is it shiny or dull? Does it look like a metal or like glass? Most minerals have either a metallic or nonmetallic luster. As you will see, the first thing you must determine before a mineral can be identified in is whether its luster is metallic or nonmetallic. Minerals with a metallic luster look like a metal, such as steel or copper.They are opaque, even when looking at a thin edge. Many metallic minerals become dull looking when they are exposed to air for a long time (like silver, they tarnish). To determine whether or not a mineral has a metallic luster, therefore, you must look at a recently broken part of the mineral. Minerals with nonmetallic luster can be any color. At first, you may have difficulty determining whether some black minerals have metallic or nonmetallic luster. However, thin pieces or edges of minerals with nonmetallic luster generally are translucent or transparent to light, and even thick pieces give you the sense that the reflected light has entered the mineral a bit before being reflected back. There are several types of nonmetallic lusters. Vitreous luster is like that of glass. Remember that glass can be almost any color, including black, so don't be fooled by the color. A dull luster has an earthy appearance caused by weak or diffuse reflection of light. Other nonmetallic lusters include: pearly luster, like a pearl or the inside of a fresh clam shell ,greasy luster, as though covered by a coat of oil; waxy luster, like paraffin and resinous luster, like resin or tree sap.

**Hardness**

Hardness is the resistance of a smooth surface to abrasion or scratching. A harder mineral scratches a softer mineral, but a softer one does not scratch a harder one. To determine the hardness of a mineral, something with a known hardness is used to scratch, or be scratched by, the unknown. The minerals in the Mohs Hardness Scale are used as standards for comparison. The Mohs harnesses are also given for some common items, which you can use to determine the hardness of an unknown mineral if you don't happen to have a pocketful of Mohs minerals. To determine hardness, run a sharp edge or a point of a mineral with known hardness across a smooth face of the mineral to be tested. Do not scratch back and forth like an eraser, but press hard and slowly scratch a line, like you are trying to etch a groove in glass. Make sure that the contact points of both minerals are the minerals you intend to test, and not impurities. Also, make sure that the mineral has actually been scratched. Sometimes powder of the softer mineral is left on the harder mineral and gives the appearance of a scratch on the harder one. Brush the tested surface with your finger to see if a groove or scratch remains. You may need to use a hand lens or magnifying glass to see whether a scratch was made. To double check your results, try scratching the substance of known hardness with the mineral of unknown hardness. If two minerals have the same hardness, they may be able to scratch each other. A piece of window glass is commonly used in geology labs as a standard for determining hardness. There are several reasons for this: (1) it's easy to see a scratch on glass; (2) the hardness of glass (5 to 5/4) is midway on the Mohs scale; and (3) glass is inexpensive and easily replaced.

Put the piece of glass on a stable, flat surface such as a tabletop. Then rub the mineral on the glass, and check to see if the glass was scratched. DO NOT TRY TO SCRATCH THE MINERAL WITH THE GLASS, because glass chips easily. More sophisticated methods than the scratch test have been developed to determine hardness.

**Streak**

Streak is the color of the mineral where finely powdered; it may or may not be the same color as the mineral. Streak is more helpful for identifying minerals with metallic lusters, because those with nonmetallic lusters generally have a colorless or light colored streak that is not very diagnostic. Streak is obtained by scratching the mineral on an unpolished piece of white porcelain called a streak plate. Because the streak plate is harder than most minerals, rubbing the mineral across the plate produces a powder of that mineral. When the excess powder is blown away, what remains is the color of the streak. Because the streak of a mineral is usually the same, no matter what the color of the mineral, streak is commonly more reliable than color for identification.

**Cleavage and Fracture**

The way in which a mineral breaks is determined by the arrangement of its atoms and the strength of the chemical bonds holding them together. Breakage occurs where chemical bonds are relatively weak and where there are no atoms. Because these properties are unique to the mineral, careful observation of broken surfaces may aid in mineral identification. A mineral that exhibits cleavage consistently breaks, or cleaves, along parallel, flat surfaces called cleavage planes. A mineral fractures if it breaks along random, irregular surfaces. Some minerals break only by fracturing, while others both cleave and fracture. The mineral halite (sodium chloride [NaCl] or salt illustrates how atomic arrangement determines the way a mineral breaks. Notice that there are planes with atoms and planes without atoms. When halite breaks, it breaks parallel to the planes with atoms but along the planes without atoms. Because there are three directions in which atom density is equal, halite has three directions of cleavage, each at 90° to each other. The number of cleavage directions and the angles between them are important in mineral identification because they reflect the underlying atomic architecture that helps define each mineral. Cleavage planes, as flat surfaces, are easily spotted by turning a sample in your hand until you see a single flash of reflected light from across the mineral surface. Individual cleavage surfaces may extend across the whole mineral specimen or, more commonly, they may be offset from each other by small amounts. Cleavage quality is described as perfect, good, and poor. Minerals with a perfect or excellent cleavage break easily along flat surfaces and are easy to spot. Minerals with good cleavages do not have such well-defined cleavage planes and reflect less light. Poor cleavages are the toughest to recognize, but can be spotted by small flashes of light in certain positions. Minerals have characteristic numbers of cleavages. This number is determined by counting the number of cleavage surfaces that are not parallel to each other. Minerals with one cleavage are often said to have a basal cleavage. Intersecting cleavages may define an elongate geometric object called a prism; such minerals are said to have a prismatic cleavage. When there are two cleavages, you should note the angle between them. Most commonly, cleavage angles are at or close to 90 or 60° and 120°. With three cleavage directions, a mineral can be broken in the shape of a cube if the three cleavages intersect at 90° (called a cubic cleavage) or a rhombohedron if the angles are not 90° (called a rhombohedral cleavage). Minerals with four or six cleavage directions are not common. Four cleavage planes can intersect to form an eight-sided figure known as an octahedron. Fluorite is the most common mineral with an octahedral cleavage. Six cleavage directions intersect to form a dodecahedron, a twelve-sided form with diamond-shaped faces. A common mineral with dodecahedral cleavage is sphalerite. When counting cleavage directions it is essential that you count surfaces on just one mineral crystal. In nature you often find that a single hand-sized sample contains a large number of crystals grown together (see following discussion under "Crystal Form"). If you count up cleavage surfaces from more than one crystal, a wrong number is likely.

**Fracture**

fracture surfaces can cut a mineral grain in any direction. Fractures are generally rough or irregular, rather than flat, and thus appear duller than cleavage surfaces. Some minerals fracture in a way that helps to identify them. For example, quartz has no cleavage but, like glass, it breaks along numerous small, smooth, curved surfaces called conchoids fi-actures. Other kinds of fracture have descriptive names such as fibrous, splintery, or irregular. In the field you will often have to break samples into pieces to observe cleavages and fractures on fresh surfaces. While it is instructional to hammer some mineral samples yourself, do not break the lab samples without your instructor's approval! Samples cost money and in most cases have already been broken to show characteristic features.

**Crystal Form**

A crystal is a solid, homogeneous, orderly array of atoms and may be nearly any size. Some crystals have smooth, plane faces and regular, geometric shapes. These are what most people think of as crystals. However, a small piece broken from one of these nicely shaped crystals is also a crystal, because the atoms within that small fragment have the same orderly arrangement throughout. When examining minerals, and especially when determining cleavage, you must determine whether you are looking at a single crystal with well-developed crystal faces, a fragment of such a crystal, or a group of small, irregularly shaped intergrown crystals. Cleavage surfaces may be confused with natural crystal faces; in fact, cleavage planes are parallel to possible (but not always developed) crystal faces. They can be distinguished as follows: (1) Crystal faces are normally smooth, whereas cleavage planes though also smooth, commonly are broken in a step-like fashion. (2) Some crystal faces have fine grooves or ridges on their surfaces whereas cleavage planes do not. Similar-looking, very thin, parallel grooves, or striations, are seen on plagioclase cleavage surfaces, but these features persist throughout the mineral and are not surficial, as described below. (3) Finally, unless crystal faces happen to coincide with cleavage planes, the mineral will not break parallel to them. The arrangement of atoms in a mineral determines the shape of its crystals. Some minerals commonly occur as well developed crystals, and their crystal forms are diagnostic. A detailed nomenclature has evolved to describe crystal forms, and some of the common names may be familiar. For example, quartz commonly occurs as hexagonal (six-sided) prisms with pyramid-like shapes at the top, pyrite occurs as cubes or pyritohedrons (forms with twelve pentagonal faces; calcite occurs as rhombohedrons (six-sided forms that look like cubes squashed by pushing down on one of the corners) or more complex, twelve-faced forms called scalenohedrons .

**Other Properties**

Special properties help identify some minerals. These properties may not be distinctive enough in most minerals to help with their identification, or they may be present only in certain minerals.

**Reaction with Acid**

Some minerals, especially carbonate minerals, react visibly with acid. (Usually, a dilute hydrochloric acid [HC1] is used.) The acid test is especially useful for distinguishing the two carbonate minerals calcite and dolomite. When a drop of dilute hydrochloric acid is placed on calcite, it readily bubbles or effervesces, releasing carbon dioxide. When a drop of acid is put on dolomite, the reaction is much slower unless the dolomite is powdered first; you may even have to look with a hand lens to see the bubbles, or, if the acid is weak, there may not be any. BE CAREFUL when using the acid—even dilute acid can burn your skin or put a hole in your clothing. You need only a small drop of acid to see whether or not the mineral bubbles. When you finish making the test, wash the acid off the mineral immediately. Should you get acid on yourself, wash it off right away, or if you get it on your clothing, rinse it out immediately.

**Magnetism**

Some minerals are attracted to a hand magnet. To test a mineral for magnetism, just put the magnet and mineral together and see if they are attracted. Magnetite is the only common mineral that is strongly magnetic.

**Striations**

Plagioclase feldspar can be positively identified and distinguished from potassium feldspar by the presence of veij thin, parallel grooves called striations. The grooves are present on only one of the two sets of cleavages and are best seen with a hand lens. They may not be visible on all parts of a cleavage surface. Before you decide there are no striations, look at all parts of all visible cleavage surfaces, moving the sample around as you look so that light is reflected from these surfaces at different angles. Until you have seen striations for the first time, you may confuse them with the small, somewhat irregular, differently colored intergrowths or veinlets seen on cleavage faces of some specimens of potassium feldspar. However, these have variable widths, are not strictly parallel, and are not grooves, so they are easily distinguished from striations.

**Specific Gravity and Density**

The specific gravity of a mineral equals its weight divided by the weight of an equal volume of water. The specific gravity of water (at 4°C) equals 1.0, by definition. Density is the mass of an object divided by its volume. Specific gravity and density give essentially identical numerical values even though specific gravity, being a ratio of weights, is a unitless number, whereas density is commonly given in units of grams per cubic centimeter. Most of the rock-forming minerals have specific gravities of 2.6 to 3.4; the ore minerals are usually heavier, with specific gravities of 5 to 8. If you compare similar-sized samples of different minerals with sufficiently different specific gravities, the one with the higher specific gravity will feel heavier. For example, the mineral barite has an unusually high specific gravity (S.G. = 4.5) for a mineral with a nonmetallic luster. When compared with a similar-sized piece of, say, calcite (S.G. = 2.7), the barite will feel much heavier. For most minerals specific gravity is not a particularly noteworthy feature, but for some, such as barite or galena, high specific gravity is distinctive.

**Taste, Odor, Feel**

Some minerals have a distinctive taste (halite is salt, and tastes like it), some a distinctive odor (the powder of some sulfide minerals, such as sphalerite, a zinc sulfide, smells like rotten eggs), and some a distinctive feel (talc feels slippery).

**Tenacity**

The tenacity, or toughness, of a mineral describes its resistance to being broken. Brittle minerals, such as quartz, shatter when broken; flexible minerals, like chlorite, can be bent without breaking, but will not resume their original shape when the pressure is released; elastic minerals, such as the micas, can be bent without breaking and will spring back to their original position when the pressure is released; malleable minerals can be hammered into thin sheets (examples are gold and copper); sectile minerals can be cut with a knife (for example, gypsum).