

GEOLOGY LABORATORY:

MINERAL PROPERTIES

Objectives

- Learn to examine minerals and to do tests for common properties
- Learn to identify common rock-forming and ore minerals on the basis of common physical properties

Introduction

As this class deals with earth materials and processes, it is important that we gain knowledge of the materials that make up the Earth's crust. The rocks that make up the Earth and the minerals that compose them have significant effects on our lives.

The minerals that we will study here represent the most common rock-forming minerals plus the most important economic minerals. These are of interest to us because a good understanding of the physical and chemical oceanographic processes we will be learning about in this class requires a good understanding of the solid materials that are at the core of these processes.

To understand the relationship between minerals and rocks, imagine a Snickers candy bar. It is made up of several different materials: chocolate, nuts, caramel, and nougat (whatever the heck that is). A rock is, like that candy bar, an aggregate of distinctive components; the components are, like minerals, homogeneous substances with properties that distinguish them from each other.

Minerals differ from each other in chemical composition and architecture, and these factors produce distinctive physical properties that enable minerals to be identified. The most useful physical properties for identifying minerals are examined here. Next week we will use these properties to identify minerals.

What Is A Mineral?

A mineral satisfies all four of the following criteria:

- It is a **naturally occurring** substance;
- It is an **inorganic** substance;
- It has an **orderly internal structure**, and;
- It has a **fixed, (or uniformly variable) chemical composition**.

That they are naturally occurring and inorganic separates minerals from most manufactured substances as well as materials formed only in biological processes. Their internal structure and chemical composition gives minerals characteristic physical and chemical properties that provide clues to the identity of the minerals.

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 the shells of clams or snails). A few naturally occurring substances called **mineraloids** have characteristic chemical compositions but are amorphous. Opal is an example.

The precise chemical composition and internal atomic structure that defines each mineral also directly determines 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, tenacity, taste, odor, feel, and presence of striations-are helpful in identifying certain minerals.

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? Generally the first thing you notice when identifying an unknown sample is the mineral's luster. Important examples of mineral luster are shown in **Figure 1** below.

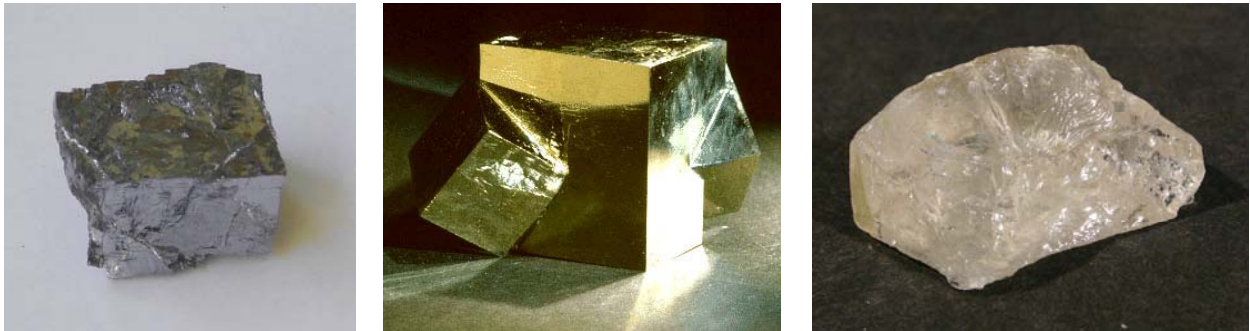
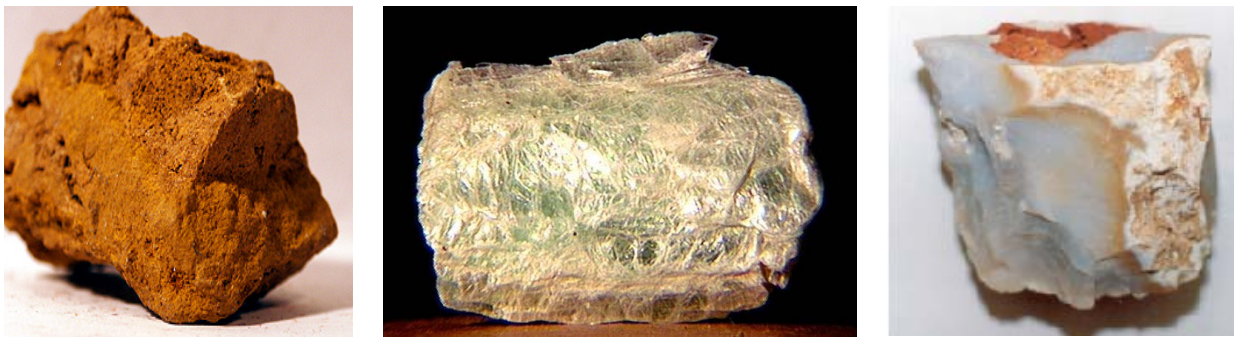


Figure 1: Examples of mineral luster, clockwise from top left: Metallic (galena); Metallic (pyrite); Vitreous (quartz); Waxy (chalcedony); Pearly (talc); and Earthy (goethite).



Minerals with a ***metallic luster*** look like a metal, such as steel or copper. They are both shiny and opaque, even when looking at a thin edge. Many metallic minerals become dull or earthy when they are exposed to the elements 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 an **earthy luster** look like earth, or dirt. Like metallic minerals these are completely opaque, but dull. Again, think of rust on iron or tarnish that forms on precious metals.

Vitreous luster is like that of glass, shiny and translucent to transparent. Remember that glass can be almost any color, including black, so don't be fooled by the color. Also, a dark piece of glass may appear to be opaque if it is thick enough. If you hold a thin edge up to the light you should be able to see light bleeding through.

Minerals with a **waxy luster** look like paraffin, typically translucent but dull. While minerals with **pearly luster** have an appearance similar to a pearl or the inside of an abalone shell – translucent and shiny but with a bit of light refraction, producing a rainbow effect on the surface (similar to an oil slick).

Color

Color is one of the most obvious properties of a mineral but it is often of limited diagnostic value, especially in minerals that are not opaque. While many metallic and earthy minerals have distinctive colors, translucent or transparent minerals can vary widely in color. Quartz, for example, can vary from colorless to white to yellow to gray to pink to purple to black (**Figure 2**). On the other hand the colors of some minerals, such as biotite (black) and olivine (olive green) can be distinctive. *Never use color as a final diagnostic property -- check other properties before making an identification.*

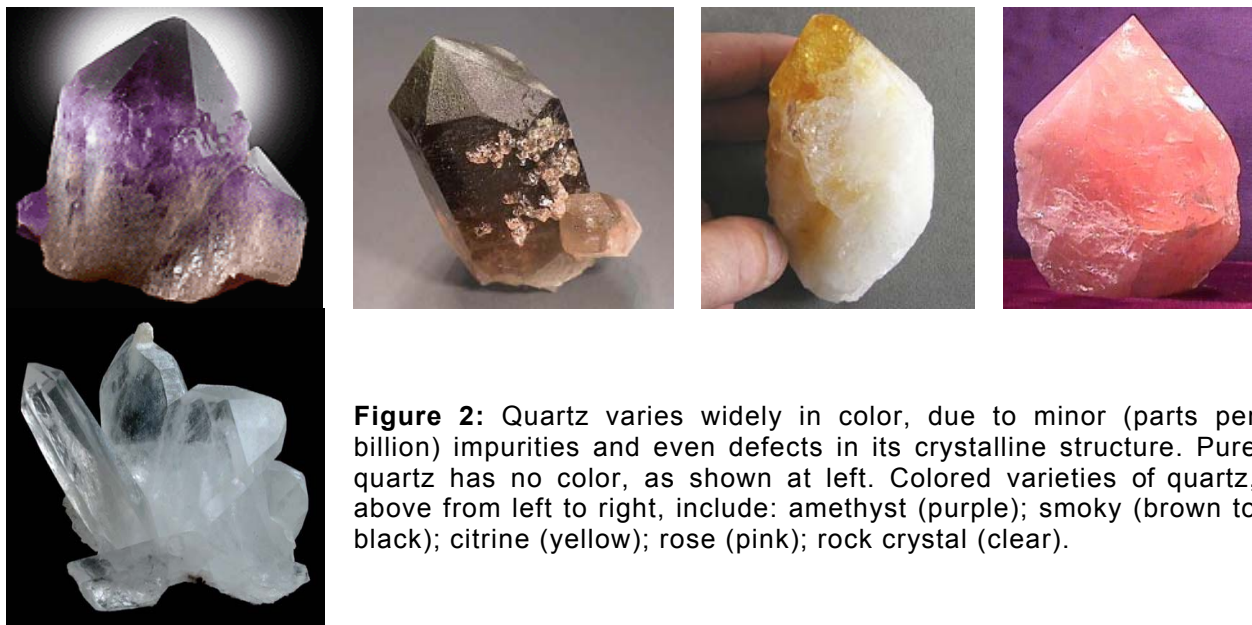


Figure 2: Quartz varies widely in color, due to minor (parts per billion) impurities and even defects in its crystalline structure. Pure quartz has no color, as shown at left. Colored varieties of quartz, above from left to right, include: amethyst (purple); smoky (brown to black); citrine (yellow); rose (pink); rock crystal (clear).

Streak

Streak refers to the color of the mineral in its powdered form, which may or may not be the same color as the mineral. Streak is helpful for identifying minerals with metallic or earthy luster, because (with a few exceptions) minerals with nonmetallic luster generally have a colorless or white streak that is not diagnostic. Streak is obtained by scratching the mineral on an unpolished piece of white porcelain called a streak plate (**Figure 3**).

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.



Figure 3: The streak of this dark gray mineral (hematite), obtained by rubbing it on the white streak plate is reddish brown.

Hardness

Hardness is the resistance of a mineral to scratching or abrasion by other materials. Hardness is determined by scratching the surface of the sample with another mineral or material of known hardness. The standard hardness scale, called **Mohs Hardness Scale (Table 1)**, consists of ten minerals ranked in ascending order of hardness with diamond, the hardest known substance, assigned the number 10. The hardness kits we use in class contain only minerals 2-7, as these are the most useful for testing most of the minerals we will encounter in this class. Since most of us don't wander the outdoors with a pocketful of standard minerals table one also lists the relative hardness of other common items.

Table 1: Relative hardness
Mohs Scale of Hardness

- 1. Talc
- 2. Gypsum
- 3. Calcite
- 4. Fluorite
- 5. Apatite
- 6. Feldspar
- 7. Quartz
- 8. Topaz
- 9. Corundum
- 10. Diamond

Common objects (hardness)

- Fingernail* (2.5)
- Copper penny* (3-3.5)
- Glass* (5.5)
- Steel nail or knife blade* (6-6.5)

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 (**Figure 4**). 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. 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.



Figure 4: Testing mineral hardness. The harder mineral (quartz) scratches the softer one (calcite).

A piece of glass is provided in the hardness kits as a standard for determining hardness. There are several reasons for this:

- it is easy to see a scratch on glass;
- the hardness of glass (5 to 5½) is midway on the Mohs scale; and
- glass is inexpensive and easily replaced.

The hardness of a mineral when compared to glass is one of the principal bases in identifying a mineral. Put the piece of glass on a stable, flat surface such as a tabletop. Drag a corner or edge of the mineral across the surface of the glass and check to see if the glass was scratched. **DO NOT HOLD THE GLASS IN YOUR HAND WHEN DOING THIS TEST, AND DO NOT ATTEMPT TO SCRATCH THE MINERAL WITH THE GLASS PLATE.**

The Mohs scale was developed by Friedrich Mohs in 1822 as a diagnostic tool. One measure of absolute hardness is an indentation test in which a diamond-tipped tool is impressed into a sample with a fixed amount of pressure and the depth of the resulting groove is measured. **Figure 5** shows a graph comparing this numerical hardness (called the Knoop hardness) to Mohs hardness.

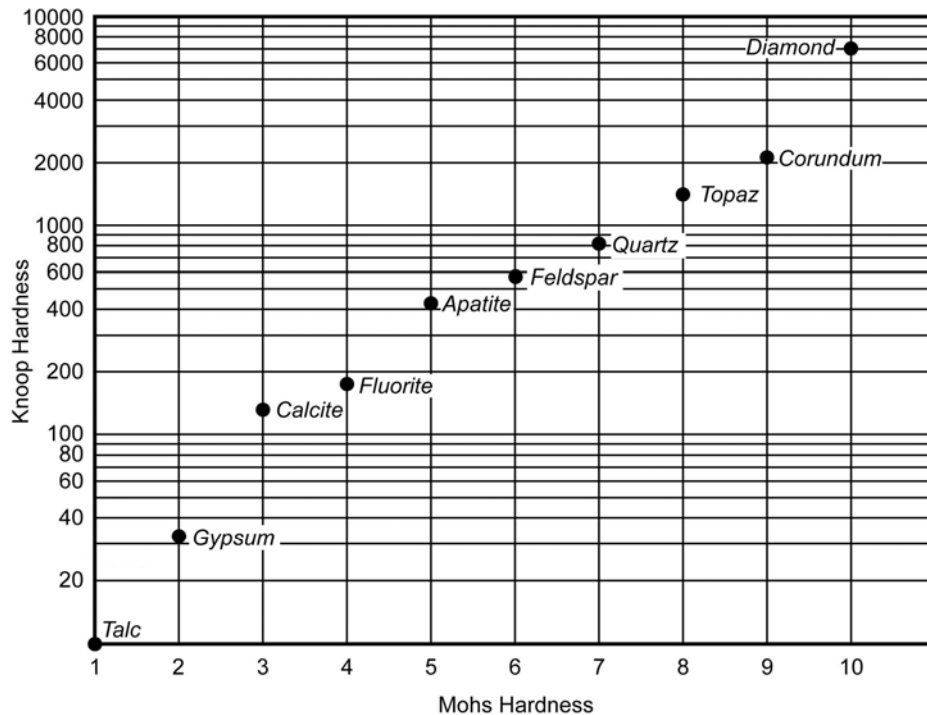


Figure 5: Comparison between Mohs scale hardness and Knoop hardness. Note that the Knoop hardness is shown with a logarithmic scale.

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. 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.

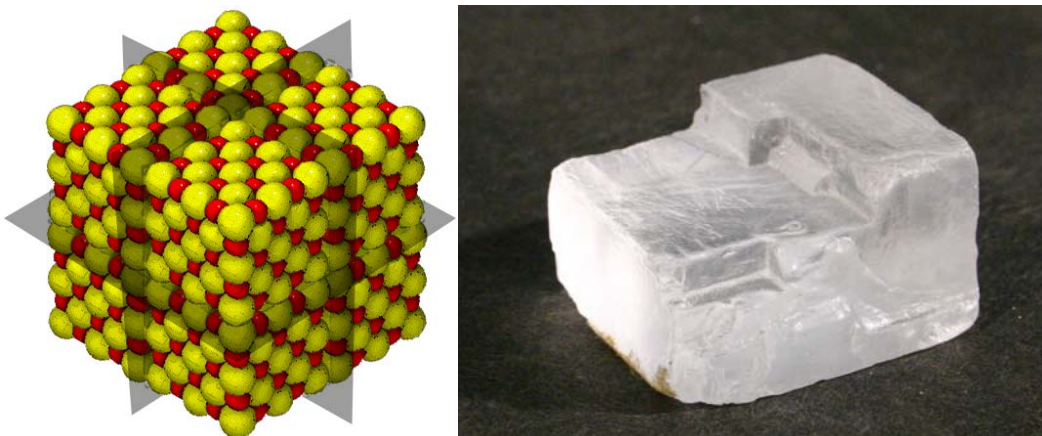


Figure 6: The illustration shows that atoms of sodium (red) and chlorine (yellow) in the mineral halite are parallel to three planes that intersect at 90°. Halite breaks, or cleaves, most easily between the three planes of atoms, so it has three directions of cleavage that intersect at 90°. The photograph illustrates the three directions of cleavage in halite.

The mineral halite (NaCl, or sodium chloride) illustrates how atomic arrangement determines the way a mineral breaks. **Figure 6** shows the arrangement of sodium and chlorine atoms in halite. 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 defines 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 (**Figure 7**) or, more commonly, they may be offset from each other by small amounts, as illustrated in Figure 1.8. Even though they are offset, they work as tiny mirrors that create the single flash seen in Figure 1.9. Figures 1.10 and 1.11A also show offset cleavage surfaces. 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. All cleavages illustrated here are perfect or good.

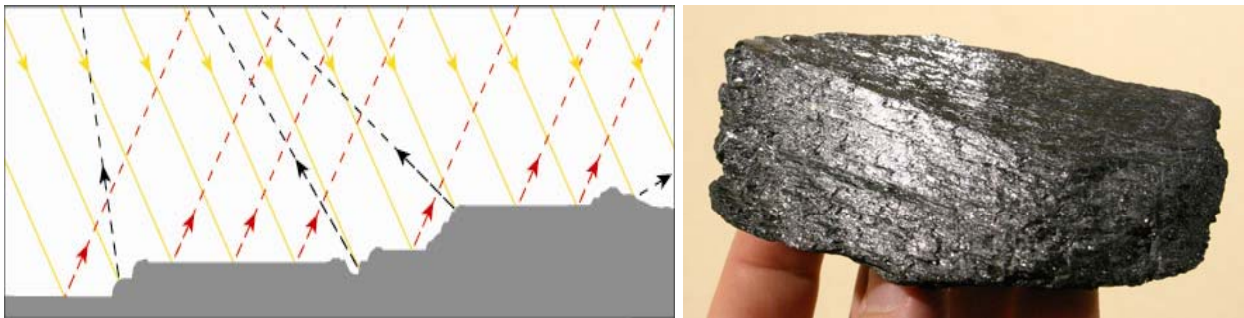


Figure 7: When incoming light rays (yellow lines) strike parallel cleavage surfaces, the rays are all reflected in the same direction (red lines), even though the surfaces are at different elevations. When viewed from that direction, the mineral shines. Rays striking irregular fracture surfaces reflect in many different directions (black lines), causing fracture surfaces to appear duller. The parallel cleavage planes in hornblende shine because the light is reflected in the same direction.

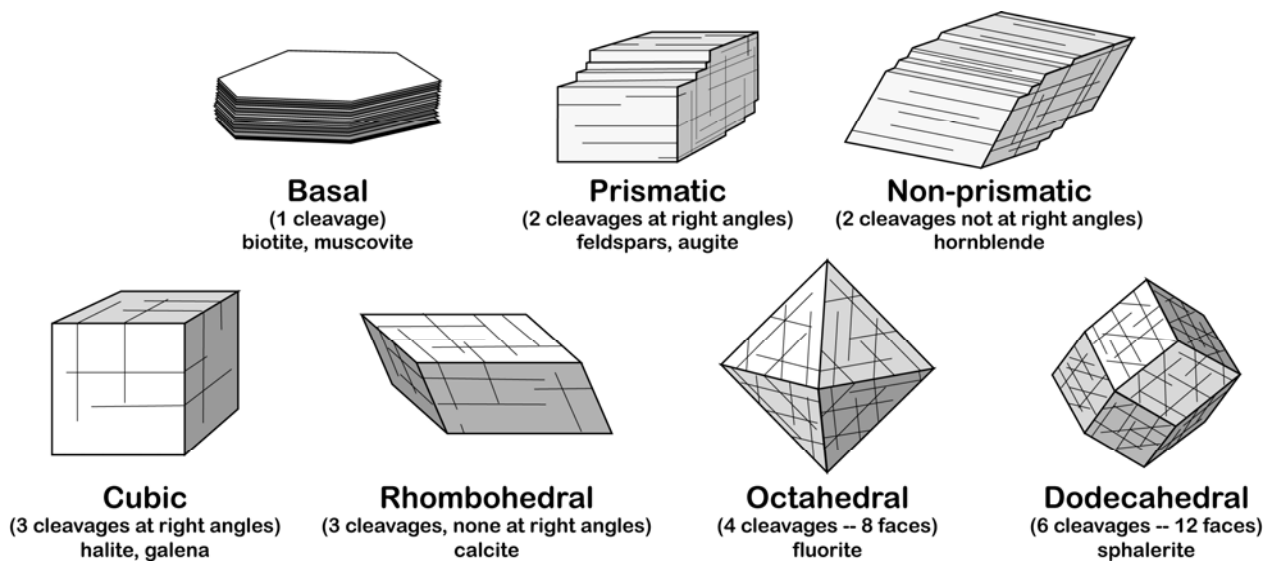


Figure 8: Types of cleavage common in minerals with examples of minerals.

Minerals have characteristic numbers of cleavages (**Figure 8**). This number is determined by counting the number of cleavage surfaces that are not parallel to each other. For example, the mineral in **Figure 9** has two planes of cleavage, one that is visible and one lying on the table. However, each of these cleavage surfaces is parallel to the other, so this mineral is said to have only one cleavage direction. Minerals with one cleavage are often said to have a **basal cleavage**.



Figure 9: The mineral biotite has basal cleavage, meaning it has one perfect cleavage. The cleavage plane is apparent in the flat, reflective surface on top of this sample. The flat surface on the bottom, in contact with the table top, is parallel to the top and therefore represents the same plane of cleavage.

Two cleavage directions are present when planes of breakage occur along two non-parallel planes (**Figures 8, 10**). These two planes can be perpendicular (at 90°) to one another, in which case the mineral is said to have **prismatic cleavage**. In some minerals the two planes of cleavage may not be perpendicular – this is known as **non-prismatic cleavage**. When there are two cleavages, you should note the angle between them. Most commonly, cleavage angles are close to 60°, 90°, or 120°.



Figure 10: Two directions of cleavage: A. Cleavages in potassium feldspar intersect at 90° ; B. Prismatic cleavages in hornblende intersect at 56° and 124° .

Some minerals have three planes of cleavage: If the three cleavages intersect at 90° the mineral is said to have **cubic cleavage** (**Figures 8, 11A**): If none of the cleavage planes intersect at right angles the shape is a squashed cube known as a **rhombohedron** (called **rhombohedral cleavage** -- **Figures 8, 11B**). A third variant occurs when a mineral has two cleavage planes that are perpendicular, and a third that is not perpendicular to the other two (**Figure 11C**).

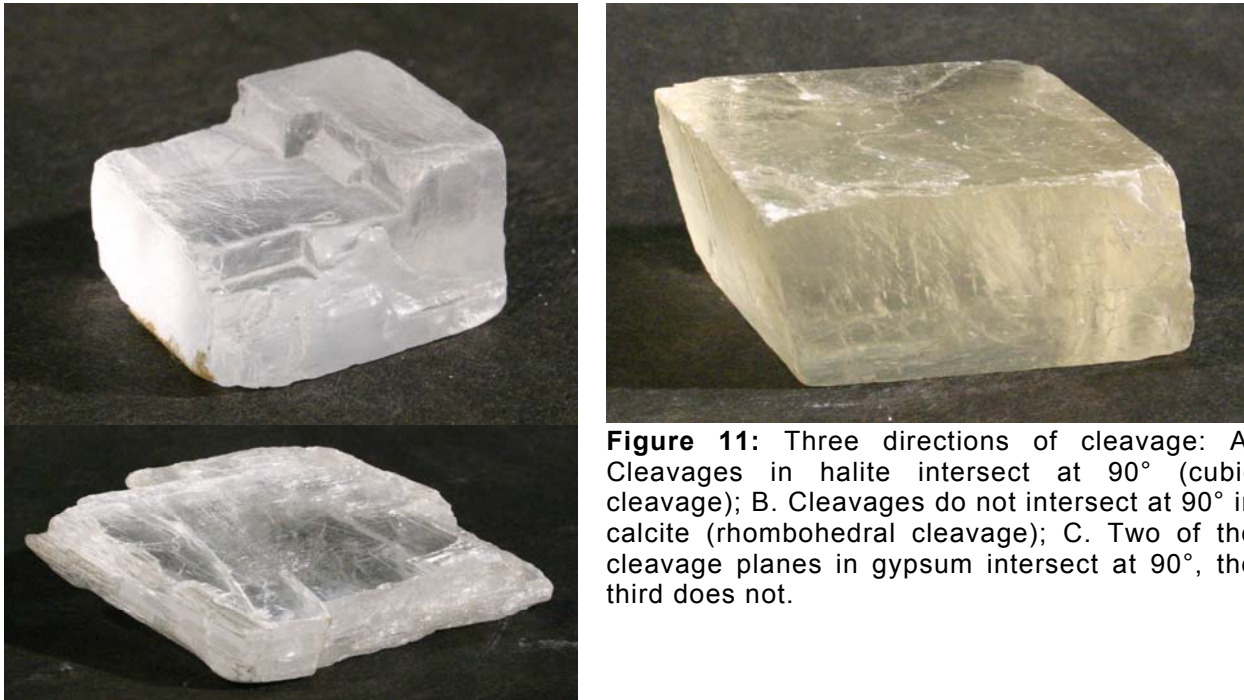


Figure 11: Three directions of cleavage: A. Cleavages in halite intersect at 90° (cubic cleavage); B. Cleavages do not intersect at 90° in calcite (rhombohedral cleavage); C. Two of the cleavage planes in gypsum intersect at 90° , the third does not.

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 (**Figure 12**). 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 (**Figure 13**).



Figure 12: Fluorite (left) has four perfect cleavages; this octahedron is made up of eight equilateral triangular faces. The mineral sphaerulite has six directions of cleavage (dodecahedral cleavage).

When counting cleavage directions it is essential that you count surfaces on just one mineral crystal. The photographs shown here used single large, broken crystals to illustrate cleavage. 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 cleavage surfaces from more than one crystal, a wrong number is likely.



Figure 13: Conchoidal fracture in quartz (left) and Chalcedony (right). This type of fracture once made flint (black chalcedony) and obsidian (volcanic glass, which also displays conchoidal fracture) valuable for making sharp stone tools.

Finally, **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 **conchoidal fractures (Figure 13)**. Though other kinds of fracture exist in nature, such as fibrous, splintery, or irregular, conchoidal fracture is the only type we will concern ourselves with here.

In the field you will often have to break samples into pieces to observe cleavages and fractures on fresh surfaces. While it is instructional (*and fun!*) 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 (**Figure 14**). The arrangement of atoms within a mineral determines the external shape of its crystals. Some crystals have smooth, planar faces and regular, geometric shapes; these are what most people think of as crystals. These crystals occur only rarely in nature however, because in order to develop those beautifully-shaped faces the mineral must have unlimited space in which to grow.



Figure 14: A visitor stands among a cluster of giant prismatic gypsum crystals discovered in a section of the Naica lead-zinc mine in Chihuahua, Mexico. Some of the individual crystals here are up to 10 meters in length.

When a mineral begins to solidify, either due to the cooling of molten material or due to precipitation from a solution, microscopic crystals always form and grow. These tiny crystals will continue to grow until they run out of space. At this point their external shape will simply reflect the shape of the void which they grew. If the growing crystal runs out of material before it runs out of space, you will be left with a nicely shaped crystal within an otherwise empty void such as a geode

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 (**Figure 15**). Pyrite occurs as **cubes** or **pyritohedrons** (forms with twelve pentagonal faces)

(**Figure 16**). Garnets occur as **dodecahedrons**, 12-sided forms that have a roughly round shape (**Figure 17**).



Figure 15: Crystal of quartz. Sides form a hexagonal prism that is capped with pyramid-like faces. Note the fine grooves on some crystal faces.

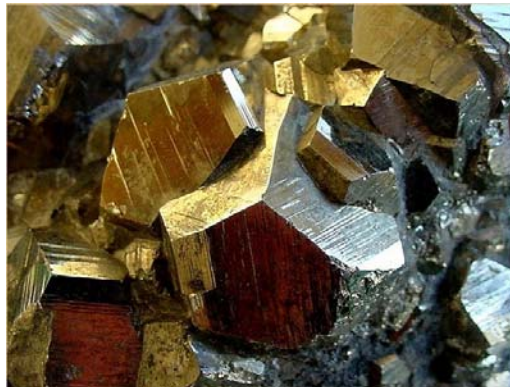


Figure 16: Crystals of pyrite in the form of a cube (left) and pyritohedrons (right). Note the fine grooves on the faces of these crystals.



Figure 17: Garnets usually form dodecahedral (12-sided) crystals with rhombic faces. Note that the color of garnet may vary widely, from the reddish-brown **pyrope**s in the image on the left to the white-green **grossular garnets** on the right.

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 (**Figures 15, 16**) 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.

Additional 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 [HCl] is used.) When a drop of dilute hydrochloric acid is placed on calcite, it readily bubbles or effervesces, releasing carbon dioxide (**Figure 18**). BE CAREFUL when using the acid -- dilute acid can burn your skin (especially if you have a cut) or stain or put a hole in your clothing. Only a small drop of acid is needed to see whether or not the mineral bubbles. When you finish making the test, wipe the acid off the mineral immediately. Should you get acid on yourself, wash it off right away; if you get it on your clothing, rinse it out immediately.



Figure 18: Calcite reacting to a drop of acid.

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 always strongly magnetic.

Striations

Plagioclase feldspar can be positively identified and distinguished from potassium feldspar by the presence of *very thin, parallel grooves* called **striations** (**Figure 19**). 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 (**Figure 19**). However, these have variable widths, are not strictly parallel, and are not grooves, so they are easily distinguished from striations.



Figure 19: The thin veinlets seen in some potassium feldspars (left) should not be confused with striations in plagioclase (right). Striations are visible on the upper surface of this sample of plagioclase.

Specific Gravity

The specific gravity of a mineral is the weight of that mineral divided by the weight of an equal volume of water. The specific gravity of water equals 1.0, by definition. Most *silicate*, or 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 two different minerals, the one with the higher specific gravity will feel the heaviest; it has a greater heft. For most minerals, specific gravity is not a particularly noteworthy feature, but for some, high specific gravity is distinctive (examples are barite and galena).

Taste, Odor, Feel

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

Procedures for identifying minerals:

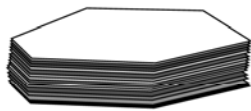
1. **Separate metallic/earthy minerals from nonmetallic minerals. If you're not sure about the luster of the mineral, then it is probably nonmetallic.**
 - a. **EARTHY AND METALLIC** minerals are totally opaque. If you hold the sample up to the light and can see any light bleeding through, especially along a thin edge or corner, the mineral is non-metallic.
 - **METALLIC MINERALS** are those with a metallic appearance in their untarnished state (shiny but completely opaque surface, i.e., silver, copper, iron); they may appear to be earthy if they are tarnished (i.e., rust). If any part of the mineral appears to be metallic, then the mineral is metallic.
 - **EARTHY MINERALS** have a luster like dirt. Though colors can vary widely, they are opaque and have a dull luster.
 - b. **NON-METALLIC MINERALS** may be **vitreous** (glassy), **waxy** (translucent but dull), or **pearly** (like mother-of-pearl). For identification purposes we will divide these into light-colored and dark-colored minerals.

2. **For the metallic or earthy minerals (Table 1):**
 - a. **COLOR:** Describe the mineral's dominant color.
 - b. **STREAK:** Determine the color of the mineral's streak.
 - c. **OTHER:** Determine other properties such as (*not necessarily in this order*):
 1. *the mineral's **HARDNESS?***
 - It is important to note that some minerals (such as chalcopyrite and malachite) often have inclusions that will give an anomalous hardness, so look at the mineral carefully before you test the hardness.
 2. *the presence or absence of **CLEAVAGES**;*
 3. *the presence or absence of **MAGNETISM**;*
 4. ***SPECIFIC GRAVITY** (does the sample feel particularly heavy for its size?).*
 - d. Use the metallic minerals table to determine the probable name of the mineral.

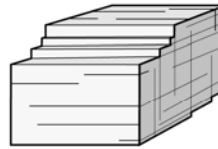
3. **For the non-metallic minerals (Table 2 or Table 3):**
 - a. **HARDNESS:** Determine relative to the glass plate ($H = 5.5$) and to your fingernail ($H = 2.5$), you may want to refine the hardness number using a copper penny ($H = 3.5$) or the hardness minerals in your kit.
 - It is important to note that some minerals (such as chalcopyrite and malachite) often have inclusions that will give an anomalous hardness, so inspect the mineral carefully before you test the hardness.
 - b. **CLEAVAGE:** Determine the mineral's cleavage:
 1. *If cleavage is present, how many planes are there? Do the faces appear to be at right angles to one another?*
 2. *If there is no cleavage apparent, do broken surfaces appear to be random, fibrous (splintery fracture), or smooth and curved (like broken glass: conchoidal fracture)?*

- c. *OTHER*: Determine the mineral's other properties such as:
1. **TASTE** (*halite has distinctive salty taste*);
 2. **LUSTER** in non-metallic minerals can be described as glassy, waxy, earthy, pearly, opalline, etc... ;
 3. **ACID TEST** (*calcite and other carbonate minerals will effervesce; other minerals will not*);
 4. **CRYSTAL FORM** (*quartz may be pyramid-capped hexagonal prisms; pyrite and fluorite sometimes display cubic crystals; garnets often are 12-sided crystals with rhombic faces*);
 5. **COLOR** is generally not important but sometimes useful, especially in dark-colored minerals; for minerals that are not metallic or earthy, we have separated them into dark-colored non-metallic minerals and light-colored non-metallic minerals
 6. **SURFACE MARKINGS** such as striations in pyrite and plagioclase (*appear like "record grooves" etched into cleavage face*) and exsolution lamellae in orthoclase (*like opaque, discontinuous wavy lines*)
- d. Use the tables for light-colored or dark-colored nonmetallic minerals to determine the probable name of the mineral.

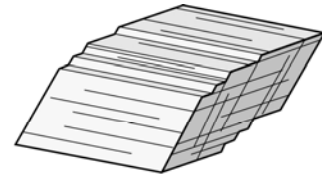
Mineral Cleavage



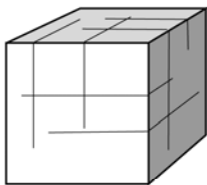
Basal
(1 cleavage)
biotite, muscovite



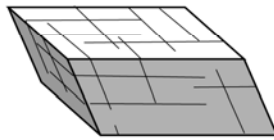
Prismatic
(2 cleavages at right angles)
feldspars, augite



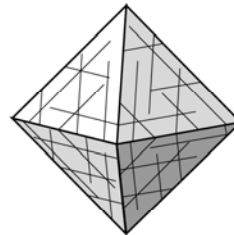
Non-prismatic
(2 cleavages not at right angles)
hornblende



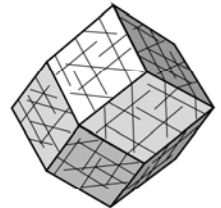
Cubic
(3 cleavages at right angles)
halite, galena



Rhombohedral
(3 cleavages, none at right angles)
calcite



Octahedral
(4 cleavages -- 8 faces)
fluorite



Dodecahedral
(6 cleavages -- 12 faces)
sphalerite

TABLE 1: METALLIC OR EARTHY MINERALS

What is the mineral's color?	What is the mineral's streak?	Compare the mineral's physical properties to other characteristic properties below.	Find mineral name(s) and check the mineral database for additional properties.
Black (yellow to gold at edges)	No streak -or- light brown/green streak	Excellent basal cleavage; may barely scratch with fingernail; H = 2.5	Biotite mica [K(Mg,Fe) ₃ AlSi ₃ O ₁₀ (OH) ₂]
Black to dark green	No streak -or- barely discernable green/gray streak	<i>Non-prismatic</i> cleavage (2 @ 56° and 124°); often black and shiny; H = 5.5-6	Hornblende (Amphibole) [Ca ₂ (Fe,Mg) ₄ (Al,Fe)]Si ₇ AlO ₂₂ (OH) ₂]
Dark green to black		<i>Prismatic</i> cleavage (2 @ nearly right angles: 87° & 93°); Dull to shiny; H = 5.5-6	Augite (Pyroxene) [(Ca,Na)(Mg,Fe,Al)(Si,Al) ₂ O ₆]
Dark brown (yellow to gold at edges)	White to pale yellow	May smell of sulfur, especially when powdered on streak plate; 6 cleavages (<i>dodecahedral</i>)	Sphalerite [ZnS]
Black to dark red to red/brown	No streak	Distinctive 12-sided crystals; Red to deep red-brown to black; Hardness = 7-7.5	Garnet [A ₃ B ₂ (SiO ₄) ₃] A= Ca, Mg, Fe; B= Fe, Al, Mn
Dark gray (metallic to earthy)	Dark gray to black	Greasy feel; Hardness ≤ 2, writes on paper	Graphite [C]
Dark gray to black	Dark gray to black	Magnetic; Tarnishes yellow-orange; High specific gravity	Magnetite [Fe₃O₄]
Silver (glittery)	Red to dark red-brown	May be specular (glittery); Tarnishes red; Sometimes magnetic	Hematite [Fe₂O₃]
Gray			
Brick red (earthy)			
Silver	Dark gray to black	High specific gravity; Cubic cleavage good to excellent	Galena [PbS]
Brassy yellow or gold	Dark gray to black	H = 6 (will scratch glass); consistent color; Often displays small cubic crystals	Pyrite [FeS₂]
Brassy yellow or gold to copper	Dark gray to black	H = 4 (will not scratch glass); Tarnishes dark brown to orange to purple to blue	Chalcopyrite [CuFeS₂]
Yellow to Yellow-brown (earthy)	Yellow to brown	Chalky; Contains hard, round inclusions (<i>piezoliths</i>)	Bauxite [Al(OH) ₃ – AlO(OH)]
Yellow to Yellow-brown (earthy)	Yellow/brown (similar to color)	Chalky; Tarnishes yellow; Amorphous	Goethite / Limonite [FeO(OH)]
Dark Brown (metallic to earthy)	Dark Brown (similar to color)	Color dark brown to black; May have pitted texture (rusted iron)	
Green	Green	Opaque green in laminated crusts or massive; Pale green streak; May effervesce in dilute HCl	Malachite [Cu₂CO₃(OH)₂]
Yellow	Yellow	Yellow crystals or earthy masses; "Rotten egg" odor; H = 1.5-2.5	Sulfur [S]
White to gold to light brown	No streak	Excellent basal cleavage; barely scratches with fingernail; H = 2-2.5	Muscovite mica [KAl ₂ (AlSi ₃ O ₁₀)(OH) ₂]

TABLE 2A: LIGHT-COLORED NONMETALLIC MINERALS: HARD			
What is the mineral's hardness?	What is the mineral's cleavage?	Compare the mineral's physical properties to other characteristic properties below.	Find mineral name(s) and check the mineral database for additional properties.
HARD (H > 5.5) scratches glass Not scratched by nail or knife blade	Cleavage excellent or good	<i>Prismatic</i> cleavage (2 at right angles); "record groove" striations; White to gray (most common) or pink; H = 6	Plagioclase feldspar [NaAlSi₃O₈ - CaAl₂Si₂O₈]
		<i>Prismatic</i> cleavage (2 at right angles); Wavy discontinuous lines; Pink or white (most common), gray, green; H = 6	Orthoclase feldspar <i>(potassium feldspar or K-feldspar)</i> [KAlSi₃O₈]
	No cleavage, but crystal faces may be mistaken for cleavages; may display conchoidal fracture	Vitreous luster; Distinctive 12-sided crystals; Red to green to creamy white; H = 7-7.5	Garnet [A₃B₂(SiO₄)₃] <i>A= Ca, Mg, Fe; B= Fe, Al, Mn</i>
		Vitreous luster; Massive or hexagonal crystals; Transparent or translucent; H = 7	Quartz [SiO₂] <i>milky (white), citrine (yellow), rose (pink), etc...</i>
	No cleavage; may display conchoidal fracture	Waxy to opaline luster; Translucent or opaque; Massive or laminated; Colorless, white, gray, or pastel colors; H = 7	Chalcedony [SiO₂] <i>(cryptocrystalline quartz; usually sedimentary or hydrothermal)</i>
		Pale olive green to yellow; Often appears as masses of sand-sized crystals; H = 7	Olivine [(Fe,Mg)₂SiO₄]

TABLE 2B: LIGHT-COLORED NONMETALLIC MINERALS: <i>MED.-SOFT</i>				
<p>MEDIUM (H ≤5.5)</p> <p>Does not scratch glass</p> <p>Scratched by nail or knife blade</p>	<p>Cleavage excellent or good</p>	<p>4 cleavages</p>	<p>Excellent <i>octahedral</i> cleavage; Colorless, purple, blue, green, or yellow; H = 4</p>	<p>Fluorite [CaF₂]</p>
		<p>3 cleavages not at right angles</p>	<p>Excellent <i>rhombohedral</i> cleavage; Effervesces in dilute HCl; Colorless, white, yellow, pink or other colors; H = 3</p>	<p>Calcite [CaCO₃]</p>
		<p>3 cleavages at right angles</p>	<p>Excellent <i>cubic</i> cleavage; Salty taste; Colorless, white, or other colors; H = 2.5</p>	<p>Halite [NaCl]</p>
		<p>3 cleavages at right angles</p>	<p>Excellent <i>cubic</i> cleavage; Colorless, white, red, or other colors; Bitter taste; H = 2.5</p>	<p>Sylvite [KCl] (not in kit)</p>
	<p>No cleavage</p>	<p>Yellow crystals or earthy masses; "Rotten egg" odor; H = 1.5-2.5</p>		<p>Sulfur [S]</p>
		<p>Opaque green in laminated crusts or massive; Pale green streak; May effervesce in dilute HCl</p>		<p>Malachite [Cu₂CO₃(OH)₂]</p>
		<p>Deep blue; Crusts, small crystals, or massive; Light blue streak</p>		<p>Azurite [Cu₃(CO₃)₂(OH)₂] (not in kit)</p>
<p>SOFT (H ≤2.5) Scratched by fingernail</p>	<p>Cleavage excellent or good</p>	<p>1 cleavage</p>	<p>Excellent <i>basal</i> cleavage; Pearly luster; White, yellow, light brown, H = 2-2.5</p>	<p>Muscovite mica [KAl₂(AlSi₃O₁₀)(OH)₂]</p>
		<p>1 good, 2 poor cleavages</p>	<p>Easily scratched with fingernail; Massive or tabular crystals, or fibrous; Colorless to white; H = 2</p>	<p>Gypsum [CaSO₄ * 2H₂O]</p>
	<p>No cleavage</p>		<p>Slippery, soapy feel; pearly to greasy luster; Opaque white, gray, green; H = 1 (<i>harder if impure</i>)</p>	

TABLE 3A: DARK-COLORED NONMETALLIC MINERALS: HARD			
What is the mineral's hardness?	What is the mineral's cleavage?	Compare the mineral's physical properties to other characteristic properties below.	Find mineral name(s) and check the mineral database for additional properties.
HARD (H > 5.5) scratches glass Not scratched by nail or knife blade	Cleavage excellent or good	<i>Prismatic:</i> 2 cleavages @ right angles; "record groove" striations; Dark gray to blue gray; H = 6	Plagioclase feldspar [NaAlSi₃O₈ - CaAl₂Si₂O₈]
		<i>Non-prismatic:</i> 2 cleavages @ ~56 and 124 ; Black; H = 5.5-6	Hornblende (<i>Amphibole</i>) [Ca₂(Fe,Mg)₄(Al,Fe)Si₇AlO₂₂(OH)₂]
		<i>Prismatic:</i> 2 cleavages @ nearly right angles (87 ; Dark green to black; H = 5.5-6	Augite (<i>Pyroxene</i>) [(Ca,Na)(Mg,Fe,Al)(Si,Al)₂O₆]
	No cleavage, but crystal faces may be mistaken for cleavages; may display conchoidal fracture	Distinctive 12-sided crystals; vitreous luster; Red to deep red-brown to black; H = 7-7.5	Garnet [A₃B₂(SiO₄)₃] <i>A = Ca, Mg, Fe; B = Fe, Al, Mn</i>
		Vitreous luster; Massive or hexagonal crystals; Transparent or translucent; H = 7	Quartz [SiO₂] <i>Smoky (brown-black), Amethyst (purple)</i>
	No cleavage; May display conchoidal fracture	Waxy to opalline luster; Translucent or opaque; Massive or laminated; Various colors; H = 7	Chalcedony [SiO₂] <i>(cryptocrystalline quartz)</i> <i>Flint (black), Jasper (red-brown), Petrified wood (varies)</i>
		Pale olive green; Often appears as masses of sand-sized crystals; Transparent to translucent; H = 7	Olivine [(Fe,Mg)₂SiO₄]
		Opaque earthy brick red	Hematite [Fe₂O₃]

TABLE 3B: DARK-COLORED NONMETALLIC MINERALS: MED-SOFT				
<p>Medium (H ≤5.5)</p> <p>Does not scratch glass</p> <p>Scratched by nail or knife blade</p>	<p>Cleavage excellent or good</p>	<p>6 cleavages</p>	<p>Color brown to yellow-brown; Yellow to white streak, powder smells sulfurous; <i>dodecahedral</i> cleavage</p>	<p>Sphalerite [ZnS]</p>
		<p>4 cleavages</p>	<p>Excellent <i>octahedral</i> cleavage; cubic crystals; Colorless, purple, blue, green, or yellow; H = 4</p>	<p>Fluorite [CaF₂]</p>
	<p>Cleavage poor or absent</p>		<p>Color yellow-brown to brown; Chalky; Yellow streak; Amorphous</p>	<p>Goethite / Limonite [FeO(OH)]</p>
			<p>Color dark brown to black; Brown streak; May have pitted texture (looks like rusted iron)</p>	<p>Malachite [Cu₂CO₃(OH)₂]</p>
			<p>Opaque green in laminated crusts or massive; Pale green streak; <i>May effervesce in dilute HCl</i></p>	
			<p>Deep blue; Crusts, small crystals, or massive; Light blue streak</p>	<p>Azurite [Cu₃(CO₃)₂(OH)₂] <i>(not in kit)</i></p>
<p>SOFT (H ≤2.5)</p> <p>Scratched by fingernail</p>	<p>Cleavage excellent or good</p>	<p>1 cleavage</p>	<p>Black; H = 2.5</p>	<p>Biotite mica [K(Mg,Fe)₃AlSi₃O₁₀(OH)₂]</p>
			<p>Pearly luster; Light to dark brown; H = 2-2.5</p>	<p>Muscovite mica [KAl₂(AlSi₃O₁₀)(OH)₂]</p>
			<p>Slippery, soapy feel; pearly to greasy luster; Opaque white, gray, green; H = 1</p>	<p>Talc [Mg₃Si₄O₁₀(OH)₂]</p>