Lab 3: Minerals

Introduction

Minerals

Minerals are the basic building blocks that make up the solid Earth. Therefore, any study of the solid Earth must begin with an understanding of minerals.

A mineral, by definition, is a (1) naturally occurring, (2) solid, (3) usually inorganic, element or compound, with a (4) definite crystalline structure and (5) chemical composition which varies only within specific limits. Common examples are quartz, diamond, garnet, talc, and halite (salt).

(1) Although compounds produced in a laboratory can have many of the characteristics of a mineral, they are not naturally occurring and therefore are not minerals.

(2) Minerals are solids, therefore liquids and gases are not considered minerals.

(3) Nearly all minerals are inorganic, that is, not produced by living organisms.

(4) Minerals have a distinct crystalline structure. Each mineral has an orderly, predictable arrangement of atoms. For example, the minerals graphite and diamond are both made of carbon but what makes them unique is a significant difference in the way the atoms are arranged (Figure 1-1). (A mineraloid differs from a mineral in that it lacks crystalline structure (i.e., is amorphous). For example, opal is a mineraloid; it has the same composition as quartz but lacks the crystal structure.)

(5) Minerals have a definite chemical composition that can be expressed as a specific chemical formula. Quartz, for instance, is composed of silicon and oxygen and has the formula SiO_2. Some minerals have more complex compositions. Garnet's formula, for instance, is $A_3B_2(SiO_4)_3$, where A and B represent a variety of elements such as Ca, Mg, Fe, and Mn. Although the exact composition of garnet can vary, the ratio between A and B is constant — 3 atoms of A for every 2 atoms of B.

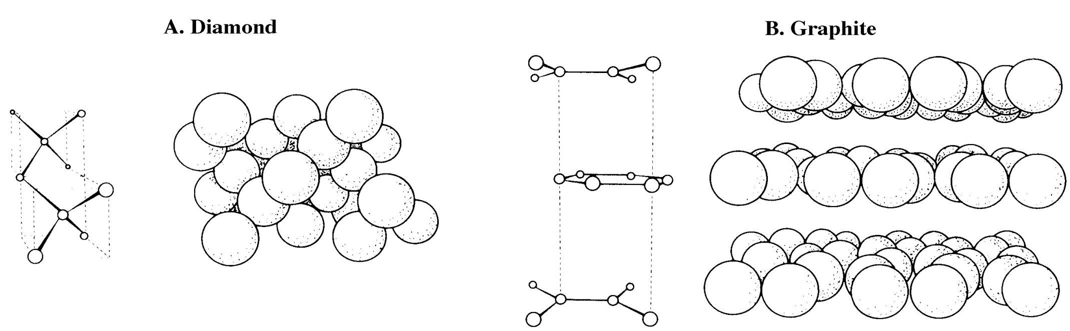


Figure 3-1. The atomic structure of (a) diamond and (b) graphite. Diagrammatic inserts show bonding relationships of carbon atoms. In diamond, each carbon atom is strongly bonded to four adjacent carbon atoms. In graphite, each carbon atom is strongly bonded to only three neighboring atoms. Strongly

bonded atoms in graphite occur in sheets, which are only loosely attached to one another.

The unique composition and structure of minerals give them each a unique set of physical properties. Minerals are classified based on these physical properties.

During today's lab you will become familiar with the important physical properties of minerals and learn how to identify the common rock-forming minerals. Your ability to determine the physical properties of minerals by observation and testing is more important than merely being able to recognize and name minerals. You will be given the opportunity to identify many of these minerals in the future, when we examine rocks.

A rock is any natural aggregate of minerals, mineraloids, glass, and/or organic particles. For example, granite is a rock composed of several different minerals, rock salt is a rock composed of a single mineral (halite), rock opal is a rock composed of the mineraloid opal, obsidian is a rock composed of volcanic glass, and coal is a rock composed of organic particles. Mineral identification is an important component of geology because the mineral composition of a given rock can tell us a lot about how and where the rock formed.

Classification Systems

Classification schemes can be subdivided into two principal types, descriptive and interpretive. Descriptive schemes are based on observable physical properties, while interpretive schemes imply a knowledge of how those properties were acquired. We classify minerals based on their physical properties. These properties reflect the chemical elements and crystalline structure of the mineral. Therefore, mineral classification is basically descriptive. We also classify rocks based on their physical properties; however, with rocks, their name also implies something about how and where they formed. Therefore, rock classification is both interpretive and descriptive. To say a rock contains certain minerals is descriptive; to say that it must be igneous is interpretive. Ideally, a good description will lead to an unambiguous interpretation, but distinction between these two steps should be kept in mind.

A. Physical Properties of Minerals

Because a mineral's physical properties are based on its specific chemical composition and crystalline structure, these properties are unique to each mineral and can be used for identification. The following is a discussion of common properties used for mineral identification.

Your group has been given a tray of numbered mineral specimens. Each mineral has been assigned a specimen number for this lab. The lab questions will be based on this tray of mineral specimens.

Luster

Luster refers to the appearance of a mineral when it reflects light. A mineral with high luster is very shiny. Luster is either metallic (looks like a metal) or nonmetallic. Non-metallic lusters are further subdivided; a partial list is shown below.

Non-metallic lusters include:

- vitreous – glassy (common), such as quartz, olivine, plagioclase, etc.
- pearly – has the sheen of a pearl or the inside of a shell, such as talc
- resinous – appearance of resin or tree sap, such as sphalerite
- silky – fibrous appearance, such as asbestos
- dull – has an earthy appearance, such as clay

1. Determine the luster of the 14 mineral specimens in your tray. (First, determine whether it is metallic or nonmetallic. If nonmetallic, use one of the lusters listed above.) Write the appropriate luster in the column labeled "luster" on the mineral ID chart (page 10).

Color and Streak

Although color is diagnostic for some minerals, most minerals occur in many hues *and generally cannot be distinguished by color alone*. Quartz, for example, can be transparent, white (milky quartz), red (rose quartz), black (smoky quartz), or purple (amethyst). Therefore, color should only be used in conjunction with other physical properties, as an aid in identification.

The color of the powdered mineral, the streak, is usually much less variable than the color seen in hand specimens. The streak can be obtained by rubbing the mineral on an unglazed porcelain plate. The powdered mineral produced can then be observed against a white background. Streak color is particularly useful in distinguishing metallic minerals that look very similar in hand sample, such as hematite, an iron oxide (rust) and an important iron-ore mineral, and galena, an ore mineral of lead. *Nonmetallic minerals generally have a colorless or white streak.*

2a. Determine color of the streak of the *metallic minerals*. Write the appropriate streak in the column labeled "streak" on the mineral ID chart (for nonmetallic minerals, write NA for “not applicable”).

2b. List the mineral color of your mineral samples under "other properties".

Hardness

Hardness is defined as a mineral's ability to resist scratching or abrasion. For example, diamond is the hardest natural substance known and will scratch all other minerals. A mineral can be scratched by all minerals harder than itself and will scratch all minerals softer than itself. Each mineral has a characteristic hardness that reflects its crystal structure and interatomic bond strength. Samples are tested for hardness against a set of index minerals that are scaled from 1 (softest) to 10 (hardest), called Mohs Hardness Scale (Figure 3-2). Mineral hardness is determined by comparing the relative hardness of an unknown specimen with an index mineral or other material with known hardness. Glass is often used because: (1) it is easy to see a scratch on glass, and (2) the hardness of glass is midway on the Mohs Scale and therefore is one of the principal bases in mineral identification.

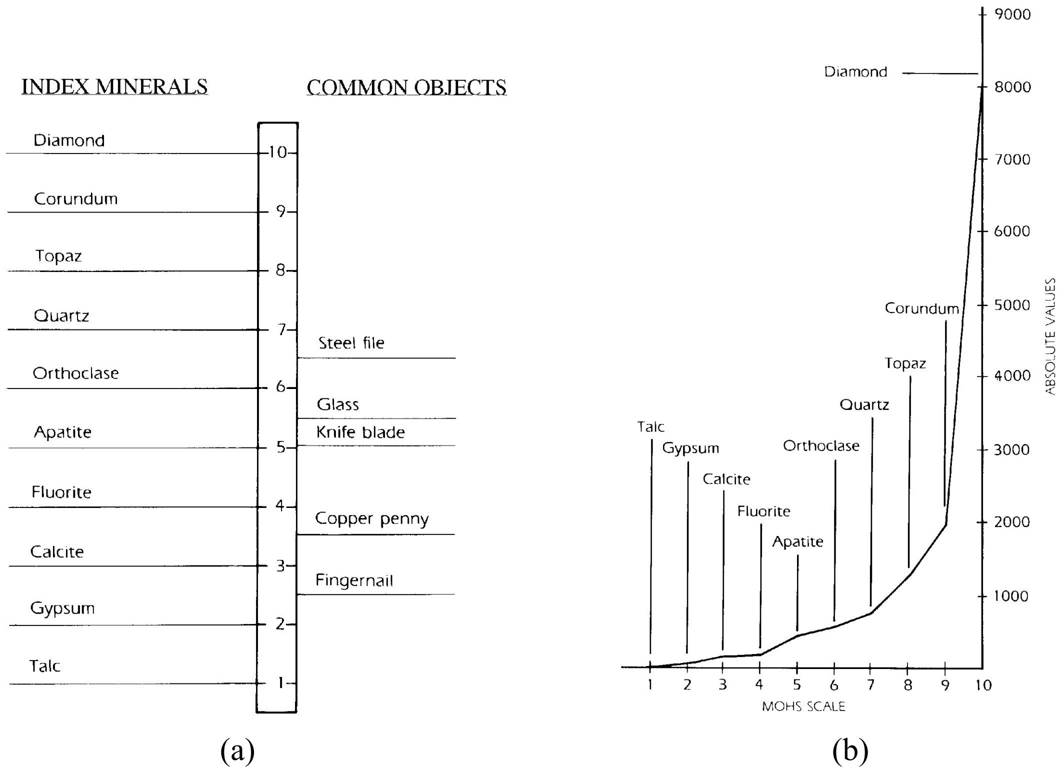


Figure 3-2. Mohs Hardness Scale, showing (a) index minerals and the hardness of common objects, and (b) the relationship between the relative and absolute hardness of minerals. Note the change of absolute hardness between the index minerals changes from talc to diamond.

3. **The hardness of a mineral is often one of its most diagnostic properties. Determine whether your 14 mineral samples are harder than, softer than, or similar to the hardness of glass. (Minerals that are similar to the hardness of glass will sometimes scratch glass.) Write "harder", "softer", or "similar" in the column labeled "hardness" on the mineral ID chart.**

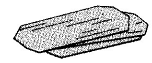
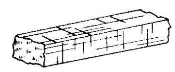
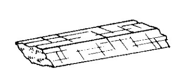
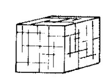
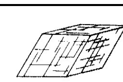
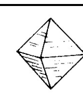
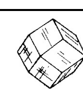
4. **Use your hardness test kit to bracket the hardness of the following minerals on the Mohs Hardness Scale.**

Specimen #	Hardness
1	
6	
7	

Cleavage, Fracture, and Crystal Form

Cleavage is the ability of a mineral to split, or cleave, along closely spaced parallel planes. The planes along which a mineral cleaves (when hit with a hammer, for example) are the planes along which the bonds between atoms in the mineral are the weakest. Imagine a mineral as a brick wall: the atoms are the bricks and the bonds are the mortar between them. Now say that the mortar between one layer of bricks and the next layer above it is particularly weak — not mixed properly. If a big hammer hits this brick wall "mineral", the "mineral" will split, or cleave, along the plane of weak mortar. A wall with uniformly strong mortar, however, would simply fracture irregularly. The same principle applies to real minerals.

Minerals that break easily and cleanly along one or more planes are said to have good cleavage. If the break is less clean the cleavage is referred to as poor. The number of cleavage planes and the angles between cleavage planes are commonly used to distinguish minerals. The table below includes examples of cleavage in common minerals.

# of Cleavage Planes	Angle Between Planes	Shape	Sketch	Number of Flat Surfaces
0 No cleavage, only fracture	NA	Irregular masses		0
1	NA	Flat sheets		2
2	90°	Elongate form with rectangle cross-section		4
2	not at 90°	Elongate form with parallelogram crosssection		4
3	90°	Cube		6
3	not at 90°	Rhombohedron (Smeared out cube)		6
4	not at 90°	Octahedron **(no examples in lab)**		8
6	not at 90°	Dodecahedron **(no examples in lab)**		12

Mica minerals have only one cleavage plane, producing a series of sheets. Halite has cleavage in 3 directions, with all planes at right angles (90°). *Note that even though a cube has six sides, opposite sides are parallel to each other and therefore represent the same cleavage plane.*

Cleavage planes are flat and reflect light (Figure 3-3). Slowly turn a mineral under light and watch for these reflections. Hold transparent samples up to a light and look for cleavage planes running through the interior, too. Also note that some minerals have corners or "steps" cut into their edges, indicating at least two different planes of cleavage.

Minerals that don't readily split along planes break, or fracture, along uneven surfaces. Many glassy minerals fracture smoothly along shell-like curved surfaces, sometimes forming sharp edges (like broken glass). This particular type of breakage is called **conchoidal fracture**.

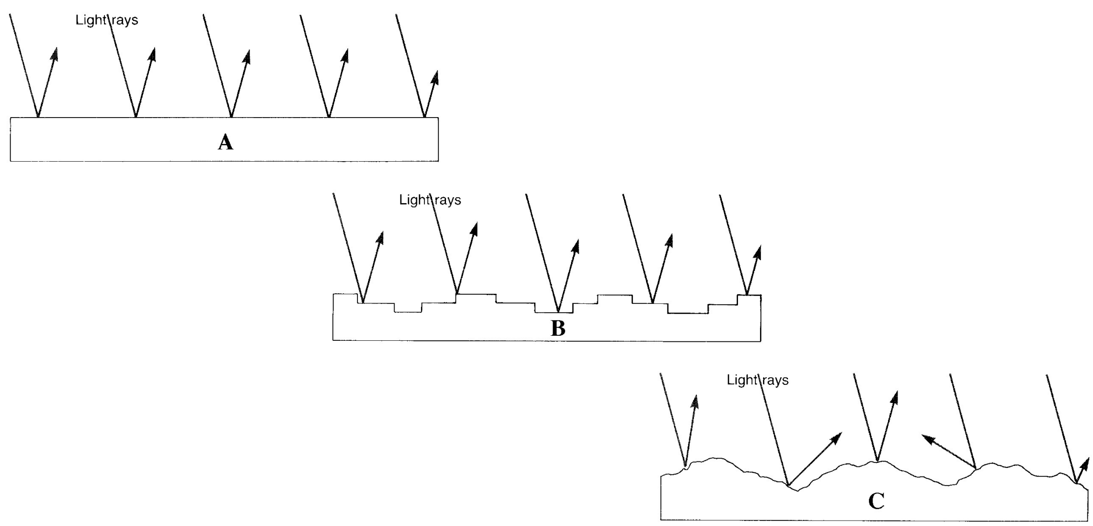


Figure 3-3. Examples of how a mineral surface reflects light for minerals with (A) good cleavage, (B) poor cleavage, and (C) fracture.

If a mineral forms in an environment where its growth is unimpeded, it may develop smooth faces that outline a geometric shape, or crystal form. The specific form of a crystal is determined by its internal atomic arrangement. It is the same for a particular mineral species, regardless of crystal size.

Some minerals commonly occur as well-developed crystals, and their crystal forms are diagnostic. A detailed nomenclature has evolved to describe crystal forms. For example, quartz commonly occurs as hexagonal (six-sided) prisms with pyramid-like faces at the top; pyrite occurs as cubes; calcite occurs as rhombohedrons (six-sided forms that look like cubes squashed by pushing down on one of the corners); or more complex, 12-faced forms called dodecahedrons.

Cleavage surfaces may be confused with natural crystal faces; in fact cleavage planes are sometimes parallel to 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. (Plagioclase is an exception — it has striations on its cleavage planes.) (3) Finally, unless crystal faces happen to coincide with cleavage planes (e.g., calcite and halite), the mineral will not break parallel to them.

5. Determine whether the flat faces you see on the following minerals are crystal growth faces or are due to cleavage.

Specimen #	Cleavage/Crystal Face
8	
9	

6. How many cleavage planes are there in the following minerals? If there is more than one cleavage direction, what is the angle between cleavage planes ("NA", "90°", or "Not at 90°")?

Specimen #	# Planes	Angle Between Cleavage Planes
10		
11		
12		
13		

7. Determine whether your 14 mineral specimens have cleavage or fracture. (Remember, not all flat surfaces are cleavage planes; some are crystal faces. Use the characteristics described above to distinguish between the two types of flat surfaces.) If the mineral exhibits only fracture, write "fracture" in the column labeled "cleavage/fracture" on the mineral ID chart. If the mineral exhibits cleavage, write the number of cleavage planes (1, 2, or 3) and angle between planes ("NA", "90°", or "Not at 90°") on the mineral ID chart. If the mineral exhibits crystal faces you should make a note of this in the "Other Diagnostic Properties" column of the chart.

Specific Gravity

Specific gravity is a measure of relative weight. It is determined by comparing the weight of a material to the weight of an equal volume of water. A mineral with a specific gravity of 3.0 would be three times heavier than an equal volume of water. Specific gravity is not expressed in units of any kind (it is a ratio).

$$\text{Specific Gravity} = \frac{\text{weight of mineral}}{\text{weight of equal volume of water}}$$

Your T.A. has class specimens of samples 5 and 14 which have been cut to have the same volume. **Hold each sample in your left and right hands and compare their relative weights.**

8. In the table below record which specimen has the higher versus lower specific gravity based on their respective weights per same volume.

Specimen #	Specific Gravity
5	
14	

Other Properties

Magnetism - Some minerals, such as magnetite, are attracted to magnets.
Taste - Some minerals have a characteristic taste. For example, halite tastes like salt.
Acid reaction - Some minerals that contain carbonate (CO3) will react with diluted hydrochloric acid (HCl), forming carbon dioxide (CO2) gas bubbles. Calcite (CaCO3) will react with HCl.
Feel - Some minerals, such as talc, feel soapy or greasy.
Presence of striations - Some minerals, such as pyrite, have closely spaced fine grooves located on their crystal faces.

8. Examine specimens 1, 2, and 7. Determine which specimen has the following physical characteristics.

Characteristic	Specimen #
Magnetic	
Reacts with acid	
Feels greasy	

B. Identifying the Common Rock-Forming Minerals

Although over 2,000 different minerals species have been identified, only 20 to 30 are abundant constituents of rocks. Of these 20 to 30 minerals, those found in Table 3.1 can be used to identify most rocks. The mineralogic composition of a rock depends upon the conditions under which that rock formed. Igneous rocks tend to have minerals that form at high temperatures; sedimentary rocks contain minerals that are stable at the surface of the

Earth; and metamorphic rocks consist of minerals that form under a range of conditions of temperature and pressure below the Earth's surface. Below is a list of the common rockforming minerals found in each of the major rock types.

Common Igneous RockForming Minerals	**Common Sedimentary Rock-Forming Minerals**	**Common Metamorphic Rock-Forming Minerals**
Quartz	Quartz	Quartz
Orthoclase	Clay Minerals	Biotite
Plagioclase	Iron Oxides (rust)	Muscovite
Biotite	Orthoclase	Amphibole
Muscovite	Biotite	Garnet
Amphibole	Muscovite	Talc
Pyroxene	Calcite	Chlorite
Olivine	Dolomite	Staurolite
	Halite	Kyanite
	Gypsum	Orthoclase
		Plagioclase

Table 3.1: The Common Rock-Forming Minerals. These are the most common minerals found with each type of rock. Notice that some minerals are common a number of kinds of rocks, specifically quartz.

To identify a mineral, you must first list as many of the properties you can determine. Next, use mineral identification tables and flow charts to identify the minerals. Use the following procedure for each mineral:

(Step 1) Determine whether the mineral has a metallic (go to step 2) or nonmetallic (go to step 3) luster. If you are uncertain about a mineral's luster, then it is probably nonmetallic.

(Step 2) If the mineral is metallic, determine the mineral's characteristics in the following order and use Table A-1 (Appendix A) to identify the mineral:

i. streak color
ii. hardness
iii. other properties as needed

(Step 3) If the mineral is nonmetallic, determine whether it is light-colored (go to step 4) or dark-colored (go to step 5).

(Step 4) If the mineral is nonmetallic and light-colored, determine the mineral's characteristics in the following order and use Table A-2 (Appendix A) to identify the mineral:

i. hardness relative to glass
ii. number of cleavage planes and angles between cleavage planes
iii. other properties as needed

(Step 5) If the mineral is nonmetallic and dark-colored, determine the mineral's characteristics in the following order and use Table A-3 (Appendix A) to identify the mineral:

i. hardness relative to glass
ii. number of cleavage planes and angles between cleavage planes
iii. other properties as needed

10. Use the characteristics you have determined in Part A, other diagnostic properties, and the mineral identification charts (Tables A-1, A-2, and A-3 (Appendix A)), to identify the minerals in your tray, then fill in their names in the mineral ID chart provided.

Remember, you should use all the characteristics of a mineral, not just one, to identify it. **----**

------ MINERAL ID CHART ----------

Specimen Number	Luster	Streak (metallic minerals)	Hardness (relative to glass)	*Cleavage vs Fracture	Color & other Diagnostic Properties	Mineral Name
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						

*If the mineral has cleavage planes describe the number of planes and whether they are at right angles or not right angles.

Appendix A-1
Metallic Mineral Identification Chart

Luster	Streak	Hardness	Cleavage	Color	Specific Gravity	Other Properties	Name
Metallic	Dark Gray to Black	6.0-6.5	No	brass yellow	5.0	cubic crystals (with striations) common	**PYRITE**
Metallic	Dark Gray to Black	6.0	No	dark gray to black	5.2	strongly magnetic	**MAGNETITE**
Metallic	Dark Gray to Black	3.5-4.0	No	golden yellow	4.2	may tarnish to bronze or purple; massive	**CHALCOPYRITE**
Metallic	Dark Gray to Black	2.5	Yes	silvery gray	7.5	perfect cubic cleavage (3 planes at 90°)	**GALENA**
Metallic	Dark Gray to Black	1.0	Yes-d	gray to black	2.5	marks paper and fingers; greasy feel	**GRAPHITE**
Metallic	Red to Red-Brown	5.0-6.5	No	silver to gray to red	5.0	may be tiny glittering flakes	**HEMATITE**
Metallic	Yellow-Brown	3.5-4.0	Yes-d	yellow-brown to dark brown	4.0	submetallic to resinous luster; 6 cleavage planes	**SPHALERITE**
Metallic	Copper	2.5-3.0	No	copper to dark brown	8.9	malleable	**NATIVE COPPER**

Note: Yes-d means cleavage is present but may be difficult to see

Appendix A-2. Light Colored Non-metallic Mineral Identification Chart

Luster & Color	Relative Hardness	Hardness	Cleavage	Color	Specific Gravity	Other Properties	Name
Non-Metallic Light Colored	Harder than Glass	7.0	Yes-d	pistachio green	3.3-3.6	surface coatings, or massive	**EPIDOTE**
		7.0	No	variable	2.7	vitreous luster; conchoidal fracture; massive but also occurs as 6-sided crystals	**QUARTZ**
	Similar to Glass	6.0	Yes	pinkish-orange (variable)	2.5	vitreous luster; banding; 2 cleavages at 90°	**ORTHOCLASE** (Potassium Feldspar)
		6.0	Yes	white to gray	2.6-2.8	vitreous luster; 2 cleavages at 90°; striations common on cleavage faces	**PLAGIOCLASE** (Na & Ca Feldspar)
		5.0-7.0	Yes-d	bluish-gray	3.5	vitreous luster; blade shaped crystals	**KYANITE**
	Softer than Glass	4.0	Yes	clear, purple, yellow (variable)	3.2	vitreous luster; 4 perfect cleavages forming octahedrons	**FLUORITE**
		3.0	Yes	white to clear (variable)	2.7	reacts with HCl; rhombic cleavage; 3 perfect cleavages not at 90°	**CALCITE**
		2.5	Yes	clear to milky white	2.2	3 perfect cleavages at 90° (cubes); salty taste	**HALITE**
		2.0-2.5	Yes-d	white to tan	2.6	dull luster, powdery; earthy odor; white streak	**KAOLINITE**
		2.0-2.5	Yes	clear to light yellow	2.5-3.0	vitreous luster; perfect cleavage in 1 dir.;forms flexible, transparent, thin sheets	**MUSCOVITE**
		2.0	Yes	clear, white, yellow (variable)	2.3	vitreous to pearly luster; brittle flakes; perfect cleavage in 1 direction	**GYPSUM**
		1.5-2.5	No	yellow	2.0	yellow streak; distinctive sulfurous odor	**SULFUR**
		1.0	Yes-d	apple green to silvery white	2.7	pearly luster; greasy feel	**TALC**

Note: Yes-d means cleavage is present but may be difficult to see.

Appendix A-3. Dark Colored Non-metallic Mineral Identification Chart

Luster & Color	Relative Hardness	Hardness	Cleavage	Color	Specific Gravity	Other Properties	Name
Non-Metallic Dark Colored	Harder than Glass	9.0	No	brown (variable)	4.0	six-sided prismatic crystals	**CORUNDUM**
		7.0	Yes-d	brown	3.8	vitreous to dull luster; prismatic to cross-shaped crystals	**STAUROLITE**
		7.0	No	red or brown	3.5-4.3	twelve-sided crystals common; vitreous luster	**GARNET**
		7.0	No	variable	2.7	vitreous luster; conchoidal fracture; massive but also occurs as 6-sided crystals	**QUARTZ**
		6.5-7.0	No	olive green	3.3-4.4	vitreous luster; granular	**OLIVINE**
	Similar to Glass	6.0	Yes	gray to white	2.6-2.8	vitreous luster; 2 cleavages at 90°; striations common on cleavage faces	**PLAGIOCLASE**
		5.0-6.0	Yes-d	dark green to black	3.3	vitreous to dull luster; 2 poor cleavages at 90°	**PYROXENE**
		5.0-6.0	Yes	dark green to black	3.3	vitreous luster; splintery appearance; 2 perfect cleavages at 120° and 60°	**AMPHIBOLE**
		5.0-6.0	No	reddish-brown to black	5.0	red-brown streak; dull luster; massive	**HEMATITE**
		5.0	Yes-d	green, brown, blue, black	3.2	vitreous luster; six-sided crystals common	**APATITE**
	Softer than Glass	3.5-4.0	Yes-d	grass green	4.0	occurs as surface coatings, masses, or tiny crystals; green streak	**MALACHITE**
		2.5-3.0	Yes	brown to black	2.8-3.0	vitreous luster; perfect cleavage in 1 direction; forms flexible thin sheets	**BIOTITE**
		2.0-2.5	Yes-d	dark or light green	2.6-2.9	flexible crystal flakes; crystal aggregates common	**CHLORITE**

Note: Yes-d means cleavage is present but may be difficult to see.