ESA21
Environmental Science Activities for the 21st Century

Earth Resources: Mineral Identification

Introduction

Animal, Vegetable, or Mineral?

If you are like most Americans, at some time, you have played the guessing game "Animal, Vegetable, or Mineral?" The premise behind the game is that one individual receives a certain number of questions in which to guess what material object another person has chosen. Of course, the first question is the aforementioned one, as every object that we can think of is supposed to fall within one of these three broad classification schemes. Alas, this is not really true. One problem is that some objects fall into 2 or more of these categories (some viruses have a crystalline stage, some animals undergo photosynthesis, etc.). However, the idea behind the game is that everything made of matter will fall into a classification of either living or non-living, with minerals being the catch all for non-living.

The other problem with the game is that a mineral is much more than just a non-living object. What it is exactly, though, will raise a debate amongst geologist. A check of different textbooks will find many different definitions for mineral. For the purposes of this activity, we are going to define a mineral as a **substance that is naturally occurring, inorganic, crystalline in nature, and has a definite chemical make-up**. The first of these criteria means that anything man-made is not considered a mineral. This is somewhat problematic, as mankind has developed ways of creating certain gemstones in the lab that are almost indistinguishable from their natural counterparts. For instance, industrially created diamonds are used for many different tools, such as diamond-tipped saw blades. The second criterion is not without its problems, too. Certain minerals such as graphite, diamonds, and calcium carbonate can and do have biological origins. Graphite and diamonds can come from plant matter. Calcium carbonate is the chemical that makes up seashells. By convention, they are usually included amongst minerals.

The third and fourth criteria are less problematic. The fact that a mineral must have a crystalline structure eliminates all liquids. It also eliminates all glasses, as these are amorphous solids with no definite atomic arrangement. The chemical make-up does come with one caveat: some minerals are allowed to have substitutions of certain chemicals in their molecular structure. As an example, hornblende is a complex mixture of hydrous ferromagnesium silicate that can various proportions of calcium, aluminum, and sodium within it. These substitutions usually just change the color of the mineral and do not radically alter the other properties of the mineral.

Fig. 1: Calcite crystal (*USGS*)

Identification

To accurately identify a mineral and be 100% certain, an individual would have to run a number of laboratory tests on a sample. They would have to run an X-ray diffraction analysis of the material to find out what its true crystalline shape is. A ground-up and prepared sample would have to be put through a chemical analyzer to determine its chemical formula. Both of these procedures would take a lot of time and money, and some of the sample would be destroyed in order to perform the analysis. For these reasons, we rarely run such test unless there is a great need to know the answer for sure.

Instead, most minerals are identified by their physical properties. Since minerals have a definite chemical make-up and crystalline shape, one can usually identify them things like their hardness, color, or crystalline shape. Some of the more common properties used to identify them are listed below.

1. Hardness – One of the most common properties upon which to base identification, this is a measure of the scratchability of a mineral. It is evaluated on the basis of the Mohs' hardness scale, which identifies the hardness of certain keystone minerals on a 1-10 scale. The scale is 1 for talc, 2 for gypsum, 3 for calcite, 4 for fluorite, 5 for apatite, 6 for orthoclase, 7 for quartz, 8 for topaz, 9 for corundum, and 10 for diamond, the hardest substance known to humans. The principle behind the scale is that any substance that is higher in number is able to scratch a substance of a lower number. topaz will scratch quartz, fluorite will scratch gypsum, and diamond will scratch them all. For further reference, it should be noted that the average human fingernail is about a 2 ¼, a copper coin is a 3 ½, a steel nail is about a 5 – 5 ½, and glass is about a 5 ½ – 6.
   To do the hardness test, you will sometimes need to use considerable force. You should try to minimize the scratching of the mineral by limiting the size of the mark. Further, you should wipe the mineral after the scratch test to make sure that it did indeed scratch, and that you are not just seeing powdered residue on the surface left behind by the device with which you performed the test.
2. Luster – This is the appearance of the mineral surface in reflected light. This test can be very hard to perform, as dirt on the surface or an uneven surface will skew results. The test is best carried out when you are looking at a large crystal face. The different categories are metallic (reflect a considerable amount of light and look like a metal surface), adamantine (brilliant, like a polished jewel), vitreous (glassy), resinous, pearly, silky, and earthy (dull, very little reflection).
3. Color – While this seems to be a very simple property, it is far from easy to use this property. Impurities can greatly change the color of a mineral. Dirt or other substances on the surface can also give a false reading. Color is also very subjective. What one person would call green, another might call grayish. This property is most reliable for metallic minerals, and fails a lot for transparent minerals. As an example, gold and iron pyrite often look very similar in color (see Fig. 2). This is one reason why iron pyrite is often called "fool's gold".

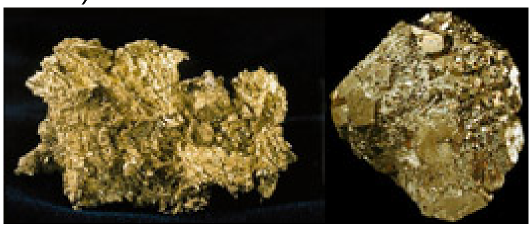

Fig. 2: Gold (left) and iron pyrite *(USGS)*

4. Streak – This property is the color of the mineral residue when it is powdered. Amazingly, this property is usually much more reliable than color. To create a streak, one would usually use a mortar and pestle to crush a small sample. However, the most used tool for measuring this is to use a piece of white, unglazed pottery. Since pottery has a hardness of about 6, this tool is unusable for minerals that have hardnesses of 6 and greater.
5. Cleavage – This is the tendency of a mineral to split along certain planes. A great example of a mineral that has excellent cleavage would be mica, which cleaves along flat planes to give very thin sheets. Other minerals such as halite will have several different faces upon which they will cleave, while some other minerals such as quartz have no cleavage (and yes, geologist are know to make bad, sexist jokes during the discussion of this property).
6. Crystalline shape – This is the geometric pattern that a lone crystal of the mineral will have. To see this pattern, though, the crystal needs to be reasonably large and not convoluted by many crystals growing over one another. Oftentimes, all that one sees is just a face or two of the crystal. This might be enough if the shape of the crystal is simple.
7. Fracture – This is the shape of a mineral when it is broken. This occurs for minerals like quartz that do not have cleavage. The different types of fractures are conchoidal (concave breakage reminiscent of glass), splintery, or uneven.
8. Specific gravity – This is the density of the mineral compared to water (1 gm/cm^3). Most minerals will have a specific gravity in the 2.5-3.5 range. Some, such as the natural metal ores and few other minerals rich in metals, will have specific gravities much higher than this. Others, such as halite and gypsum, will be much less than this. To determine this property, one needs a graduated cylinder with water in it and a mass scale. Putting the mineral in the graduated cylinder will tell one the volume of the mineral by the amount of water it displaces. Putting the mineral on the scale will give its mass, which when divided by its volume in cubic centimeters, gives its specific gravity.

There are other specialized properties that exist that will identify one or two minerals. Magnetism is a property that quickly identifies magnetite or loadstone. Taste can be very useful in identifying halite, although one can get very sick of licking every transparent mineral in their collection hoping to find it. Calcite has the unusual property of birefringence, which means that unpolarized light travelling through it will be bent at two different angles. In other words, light passing through clear calcite will produce two different images.

Additional Reading

The following link goes to a USGS website that discusses many of the common minerals that we encounter in our everyday lives. Links to information are provided that give detailed descriptions of the minerals, as well as listing the more common uses for them and the locations of mines within the U.S.

USGS	**Topic**: Minerals and Materials **Summary**: Contains information about different minerals, their uses, and their origins **Link**: http://resourcescommittee.house.gov/subcommittees/emr/usgsweb/

Activity

For this activity, we are going to try to identify ten different minerals from their properties. There is an attached listing of the major properties of the most commonly found minerals. Use it and any other resources you might have to identify the ten minerals, and list your findings on the sheet below. In order to help you by giving you a little practice with mineral identification, we suggest the following virtual identifier:

http://facweb.bhc.edu/academics/science/harwoodr/Geol101/Labs/Minerals/

Your instructor will provide you with up to 10 different mineral samples for identification. To test for hardness, you will also be provided with a copper plate or penny, a steel nail, and a glass plate (you can provide your own fingernail). You will also be given a piece of unglazed porcelain tile to use as a streak plate and a magnet to test for magnetism. You might also be provided with a weak hydrochloric acid solution, depending upon the discretion of the instructor. Using these simple tools and your powers of observation, you should be able to identify the minerals.

References

General Geology of the Western United States – A Laboratory Manual by Bassett and O-Dunn, pp. 2-18, Peek Publications, Palo Alto, CA, 1980.

ESA21: Environmental Science Activities

Activity Sheet
Mineral Identification

Name:

#	**Mineral**	**Identifying Characteristics**
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

DESCRIPTIVE MINERAL TABLE

Minerals with Metallic Luster

Name and Composition	Hardness	Color	Streak	Features
Graphite C	1	Silver gray	Black	Marks paper like a pencil, greasy feel, light in weight. One perfect cleavage.
Molybdenite MoS_2	1-1 ½	Blueish-gray	Greenish-gray	Soft, flexible, shiny plates (one perfect cleavage), often with hexagonal outline. Marks paper.
Galena PbS	2 ½	Silver-gray	Black	Cube or octahedron crystals, cubic cleavage, bright metallic luster, heavy.
Native Copper Cu	2 ½ - 3	Copper-rose	Copper-rose	Copper-rose color on fresh surfaces; greenish-gray surface film where altered. Heavy and malleable. Rare crystals; usually in compact masses. Often has a pale green surface coating of malachite.
Native Gold Au	2 ½ - 3	Gold, white-gold, rose	Same as color	Color varies with impurities. Extremely heavy. May be gouged or sliced with a knife. Dissolves in aqua regia. Rare small crystals, and dendrites; nuggets in sedimentary deposits
Native Silver Ag	2 ½ - 3	Silver-white	Silver-white	Tarnishes dark gray. Irregular fracture. Very heavy. Sectile. May occur as dendrites (see Gold) and wires in calcite and other minerals. Usually tarnished blackish-gray.
Bornite Cu_5FeS_4	3	Rose to brown	Gray-black	Irridescent alteration coating common; brittle conchoidal fracture. “Peacock ore.”
Chalcopyrite $CuFeS_2$	3 ½	Brass-yellow	Greenish-black	Often tarnished irridescent or chalky greenish-blue. Brittle, fairly soft, usually massive. Conchoidal fracture.
Pyrite FeS_2	6	Light brass-yellow	Black	Occurs in cubes with grooved faces, and pyritohedrons with 5-sided faces. Called “fool’s gold,” much lighter than true gold. Poor cleavage; fragile.
Magnetite Fe_30_4	6	Black	Black	Magnetic, granular or octahedral crystals common. No cleavage.
Specular Hematite Fe_20_3	6	Shiny steel-gray	Dark red	Glittering flakes or wavy sheets. Streak is distinctive. Tendency to flake obscures true hardness.

Minerals with Non-Metallic Luster

Name and Composition	Hardness	Color	Streak	Features
Talc $Mg_3Si_40_{10}(0H)_2$	1	White, pale green	Pearly	Extremely soft; soapy feel. Impurities may increase apparent hardness. One perfect cleavage; often in scaly masses.
Kaolinite $Al_2Si_2O_5(OH)_4$	1 – 2 ½	White, cream	Earthy, dull	Soft, powdery texture. Smells earthy when damp. Usually in clay-like masses with dull appearance.
Native Sulfur S	1 ½ - 2 ½	Yellow	Resinous, greasy	Color, low hardness, light in weight. Detectable sulfur odor. Often in well-developed blocky crystals, or as a fine coating on volcanic rock.

Gypsum $CaSO_4 \sim 2H_2O$	2	Coloroless, white; sometimes pale orange	Vitreous, pearly	Soft, one perfect cleavage. Selenite is clear, satin spar is fibrous, alabaster is massive. Selenite may occur in large (to 1 m.) sword-like crystals; or in bladed groups incorporating sand and known as "desert roses."
Borax $Na_2B_4O_7$ $\bullet 1OH_2O$	2	White	Vitreous	Short, stubby crystals. Conchoidal fracture. Brittle, soft. Also in earthy, massive form.
Chlorite	2	Light to dark green	Vitreous to earthy	Green color and micaceous habit (one good cleavage). Flakes are not elastic like mica.
Carnotite $K_2(U0_2)_2(VO_4)$ $3H_2O^2$	2	Canary yellow	Dull, earthy	Usually a coating or powder in sandstone or other rock; imparts a strong yellow color. Very radioactive. Hardness indeterminate.
Cinnabar HgS	2 – 2 ½	Cinnamon red	Adamantine to dull	Color diagnostic. May appear almost metallic or in earthy, pinkish-red masses. Scarlet streak. Toxic.
Biotlte Mica $K(Mg, Fe)_3$ $AISi_3O_{10}$ $(OH)_2$	2 ½	Dark brown, black	Vitreous	Occurs in six-sided mica "books" and as scattered flakes. Peels into thin flexible greenish-brown sheets along one perfect cleavage. Black mica.
Muscovite Mica $KAI_2(AISi_3\ O_{10})$ $(OH)_2$	2 ½	Colorless, pale green	Vitreous to Pearly	Occurs in mica "books" and as scattered flakes. Peels into thin flexible transparent sheets along one perfect cleavage. White mica.
Lepidolite Mica $KLi_2(AISi_4O_{10})$ $(OH)_2$	2 ½ - 4	Colorless, lilac, yellow	Vitreous to pearly	Lilac color is diagnostic. Often in granular masses of small mica "books." Lavender mica.
Halite NaCl	2 ½	Colorless, salmon, pastels	Vitreous to greasy	Easily dissolves in water. Often has stepped-down "hopper" faces. Cubic cleavage. Crystal masses or coating on other material.
Asbestos $Mg_6Si_4O_{10}(OH)_8$	2 ½ - 3	Light green, light brown	Silky	Long, threat-like fibers with silky sheen. The commercial variety is fibrous serpentine.
Calcite $CaCO_3$	3	Colorless, white; rarely pastel	Vitreous	Effervesces freely in cold dilute hydrochloric acid. Perfect rhombohedral cleavage. Doubly refracting. Frequently in rhombohedral crystals; hundreds of other forms known. May be fluorescent.
Barite $BaSO_4$	3	Colorless, white, blue	Vitreous	Heavy for a non-metal. Often occurs as tabular crystals; such crystals in circular arrangement form "barite roses." Perfect cleavage.
Bauxite	3 – 3 ½	White; usually stained with goethite	Earthy	Pea-sized round concretionary grains show color banding in cream, yellow, and brown. Actually a rock made up of various hydrous aluminum oxides.
Sphalerite ZnS	3 ½	Usually yellow-brown; also black, green, red	Adamantine to metallic	Light yellow streak in most color varieties. Heavy. Perfect dodecahedral cleavage; cleavage chunks often triangular in shape. Occurs as crystals, compact masses, and coatings.

Azurite $Cu_3 (C0_3)_2 (OH)_2$ Malachite Cu_2 C03(OH)2	3 ½ - 4	Azure blue and bright green, respectively	Dull or velvety	Colors and association distinctive; both effervesce in hydrochloric acid. Azurite often in radiating masses. Malachite frequently in curved masses exhibiting color banding in shades of green.
Dolomite $CaMg (CO_3)_2$	3 ½ - 4	White, yellow, pink	Vitreous to pearly	Slowly effercesces in cold dilute acid when powdered. Pale pink color is indicative. Often associated with calcite. Usually in rhombohedral crystals; perfect rhombohedral cleavage.
Fluorite CaF_2	4	Colorless, all pastels, deep purple	Vitreous	Crystals often cubic or octahedral. Color banding common. Octahedral cleavage. Usually fluorescent in ultraviolet light.
Colemanite $Ca_2 B_6O_{11}$~ $5H_2O$	4 ½	Colorless, white	Vitreous	May be in stubby, glassy crystals, or in compact granular masses. Perfect cleavage.
Apatite $Ca_5(P0_4)3F$	5	White, blue, brown	Vitreous	Will not scratch glass. Commonly in 6-sided prisms. Green, Blue, Yellow. One poor cleavage.
Scheelite $CaWO_4$	5	White, yellow, brown	Vitreous	Will not scratch glass. Heavy. Flu-oresces. Good cleavage, crystal faces may be grooved.
Goethite $HFeO_2$	5-5½	Dark rusty brown, ochre yellow	Dull, earthy	Streak distinctive yellow-brown. Often spongy, porous or earthy; also bladed, fibrous. Also called limonite. Often occurs in cubes and pyritohedrons as an alteration of pyrite.
Hematite (earthy) Fe_20_3	5	Dull brownish red to bright red	Sub-metallic to earthy	Characteristic red-brown streak. Often earthy and too powdery for accurate hardness test. May be granular or oolitic. Crystals rare; no cleavage.
Rhodonite $MnSiO_3$	6	Pink to deep rose	Vitreous	Massive, dense or granular aggregates often have black veins. Color and hardness diagnostic. Blocky crystals, nearly 90° cleavage.
Hornblende	5½-6	Greenish-black	Vitreous	Barely scratches glass. Shiny on cleavage faces; opaque; often splintery at edges. Usually massive; occasionally in chunky crystals. Two directions of cleavage at 124° and 56°.
Auglte	6	Dark green	Vitreous to dull	Stubby prismatic crystals. Usually duller and greener than closely related horn blende. Two cleavages at 87° and 93°, and uneven fracture.
Orthoclase Feldspar $KAISi_3O_8$	6	WhIte, pink	Vitreous	Two good cleavages. Will scratch glass. Wavy internal pattern and pink color distinguish it from plagioclase when present. May be massive, or in large, well-developed coffin-shaped crystals.
Plagloclase Feldspar $NaAISi_3O_8$ $CaAl_2Si_2O_8$	6	WhIte, gray	Vitreous	Two good cleavages. Will scratch glass. “Record grooves.” Rectangular cleavage faces often seen In igneous rocks.

Spodumene $LiAlSi_2O_6$	6½	Colorless, white, lavender	Vitreous	Elongated prismatic crystals. Associated with lepidolite, tourmaline, beryl. Deep grooves often parallel long crystal faces. Perfect prismatic cleavage.
Olivine $(Mg, Fe)_2SiO_4$	6 ½ - 7	Olive green	Vitreous	Crystals often appear as glassy green beads, isolated or in masses. Color distinctive. Conchoidal fracture.
Epidote $Ca_2(Al, Fe)_3$ Si_30_{12} (OH)	6 ½ - 7	Light to dark green	Vitreous	Usually a dull avocado massive; crystals are dark green, with striations and well developed cleavage.
Quartz Family SiO_2	7	Colorless White Gray, brown Pink Purple Yellow	Vitreous to greasy	Crystals are 6-sided prisms, often with terminations and steps perpendicular to crystal length. Conchoidal fracture; no cleavage. Crystals may be in clusters, or line cavities in rock; some weigh several hundred pounds.
Chalcedony (Quartz) (petrified wood, flint, chert, agate, jasper)	7	Variable	Waxy	Massive, dense, often bumpy masses; waxy surface. Color banded or mottled appearance common. Not wholly crystalline. May line rock cavities to form geodes, or replace organic material to "petrify" wood, shell or bone.
Staurolite $FeAl_4Si_20_{10}$ $(OH)_2$	7-7½	Brown	Vitreous	Usually found as prismatic crystals; often twinned to form crosses. Crystal faces are pitted and rough. Cruciform twinning is diagnostic when present.
Tourmaline	7-7½	Black, brown, green, pink, blue yellow	Vitreous to dull	Typically in elongated crystals with grooved faces and rounded triangular cross section. Common variety shiny black. Crystals often occur in parallel or radiating groups. No cleavage.
Garnet Fe_3Al_2 $(Si0_4)_3$	7-7½	Brown, red; also purple, green, yellow, black, pink	Vitreous to resinous	Commonly in shades of red. Dodecahedral crystals have diamond-shaped faces. Color and hardness aid identification. No cleavage. Transparent to opaque.
Beryl $Be_3Al_3Si_6$ 0_{18}	7½ - 8	Colorless, white, pink, blue, light green, emerald green	Vitreous	Commonly pale green, and in 6-sided prisms with flat terminations. Harder than quartz. Poor cleavage.
Topaz $Al_2SiO_4(OH,F)_2$	8	Colorless, white, golden yellow, light blue	Vitreous	Distinct glassy prismatic crystals with perfect basal cleavage exhibit ing diamond-shaped cross section. Internal rainbows. Striations on crystal faces.
Corundum Al_20_3	9	Gray, all pastels, red, dark blue, brown	Vitreous to greasy	Commonly in barrel-shaped 6-sided crystals, tapered or with flat ends. Extremely hard. No cleavage.
Diamond C	10	Colorless, pastels, blue, yellow, gray, black	Adamantine to greasy	Octahedral crystals with greasy luster. Hardest known substance. Two directions of cleavage.

From General Geology of the Western United States – A Laboratory Manual by Bassett and O-Dunn, pp. 6-18, Peek Publications, Palo Alto, CA, 1980.