GY 111 Lab Lecture Note Series
Lab 1: Introduction to Mineral Identification

Lecture Goals:
A) Definitions
B) How to identify minerals
C) Physical Properties

Reference: Haywick (2001). GY 111; Earth Materials Lab Manual; Chapter 1.

A) Definitions

This will be a long lecture. It's purpose is to introduce the basic tests and mineral properties that you will have to understand in order to identify minerals and later, rocks. Next week you will be able to "play" with the specimens. For today, just sit back and enjoy the ride.

You need to know two definitions at this time:

Mineral: a naturally occurring, inorganic, solid substance with a well-defined crystal structure and a unique chemical composition

Rock: a naturally occurring substance containing 2 or more minerals.

In this class, you will eventually learn how to identify both rocks and minerals. We usually start off with minerals because they have more ordered properties (i.e., they are easier to identify using a flow-chart methodology).

B) How to identify minerals

The first thing you have to do is distinguish between a rock and a mineral. If the substance looks relatively pure (e.g., it contains a single material or looks homogeneous), it may be a mineral. If it looks like an agglomerate of stuff (multi-coloured or different types of reflectance), it is likely a rock. **Beware!** Some minerals display multiple colors or are slightly stained by weathering rinds. Do not get confused by color masking.

So what are some examples of minerals? The most common around here is **quartz** (image to right from www.csm.jmu.edu). This substance is solid, naturally occurring, inorganic, has a unique chemical composition (SiO_2) and has a well defined crystal structure (hexagonal shaped crystal **-bi-pyramidal**). Here are some other substances worth discussing.

Fluorite (CaF_2)
Gold (Au)
Gypsum ($CaSO_4.2H_2O$)
Shells ($CaCO_3$)
Chert (SiO_2)
Opal ($SiO_2.H_2O$)
High School Ring Ruby (Al_2O_3)

The first 4 are all minerals. The last 3 are not. Many rubys are today synthetic, so they do not meet the naturally occurring requirements. Chert and opal are naturally occurring, but they do not have a crystalline structure. They are like glass and as such, do not meet the definition of a mineral. We refer to these substances as **mineraloids**. Other mineraloids include limonite (FeOOH) and bauxite (Al_2O_3).

Were you surprised by shells being classified as minerals? Although organically produced, the carbonate minerals that form shells followed inorganic pathways. Some people (e.g., your humble instructor) like to refer to these substances as **biogenic minerals**. The most important ones are aragonite and calcite (both $CaCO_3$) and silica.

Identification of minerals is relatively easy. All that you have to do is recognize the properties that characterize them. You distinguish people based upon their appearance, and minerals are identified in the same way. With people, you use height, hair color, weight, sex, age etc. to distinguish your friends. With minerals, its color, luster, specific gravity, cleavage, crystal habit etc. Incidentally, some of these properties are more readily recognized and remembered than the properties you use to identify people (e.g., how old is your father?).

Now for the scary stuff. At last count, there were over 4000 separate minerals. Luckily, there are really only 30 or 40 that are important **rock-formers** and of these, only 20 or 25 are really common. So you really do not have to learn too many. Expect 40-45 minerals in your sample tray.

Now for the demonstration:

Property 1: Colour (sulfur, malachite, fluorite, quartz varieties)

Mineral 1: **sulfur** (S): Sulfur is easy to remember because of its **color**. Color is an important property, but it is not always reliable. For sulfur, it is a **diagnostic property.** The color in sulfur is caused by the atomic structure and its chemical composition. It is always the same. When colour is a diagnostic property, it is said to be **idiochromic**

Mineral 2: **quartz** (SiO_2), **fluorite** (CaF_2). Quartz comes in many different shades. Each of the different colours of quartz is given a specific sub-name (**variety**). They include rose, citrine, smoky, milky, amethyst, crystal. Despite the color variation, all of the varieties are the same mineral. The different colours are induced by minute quantities of foreign substances like dust, water or trace elements. Even radiation causes color changes. For quartz and a large number of other minerals (including calcite and fluorite; image to right from www.icminerals.com), color is **non-diagnostic** and the color is said to be **allochromic.**

Minerals are largely separated on the basis of overall colour (i.e., dark vs. light), but sometime they "fool" you (e.g., dark quartz, light quartz). A better property to describe mineral color is **streak.**

Property 2: Streak (quartz, sphalerite, hematite, pyroxene)

Streak is the colour of a mineral when powdered. Most light-coloured minerals produce a white or colourless streak. Some however give diagnostic streaks:

Sphalerite (ZnS): pale yellow
Hematite (Fe_3O_4): red-brown

Try to streak all mineral specimens, but be careful to choose clean surfaces. Contamination can miscolor your streak.

Property 3: Specific Gravity (quartz, galena, celestite)

The apparent mass (or weight) of a specimen is also a useful property in the identification of minerals. The only problem is that weight is determined by both the **density** of a mineral and the size of the specimen (don't believe what you hear - *size does matter*). Minerals that are more dense will weigh more than minerals of similar size that are less dense. Density is largely controlled by the mass of the elements that comprise the mineral. Quartz is composed of one part Si to 2 parts oxygen (both are relatively light elements according to the periodic table). In contrast, galena which is composed of 1 part lead to 1 part sulfur is a heavy mineral (locate the position of lead on the periodic table of the elements).

Density is expressed in units of g/cm^3 as it is a ratio of mineral's weight to its volume (this is how you get around the different sizes of specimens - a small sample of galena has a different weight that a large specimen of galena, but their densities are identical). Geologists actually don't normally use mineral density (I think it is because we don't like dealing with units). Instead, geologists use **specific gravity**. This property is officially defined as: *the ratio of a mineral's density to the density of water* (since the density of water is 1.0 g/cm^3, all this really does is to dump the units). So where were we? Minerals containing heavy elements/ions will usually be more dense and will therefore have higher specific gravities than minerals composed of less dense elements/atoms. Here are some examples:

Quartz: 2.65
Galena (PbS): 7.5
Silver (Ag) 10.0
Gold (Au) 19.3 (see image to right from www.csm.jmu.edu)

You are not really expected to remember the specific gravities of the minerals, but you should recognize which minerals are "heavy" and which minerals are "light".

Property 4: Hardness (talc, gypsum, graphite, quartz, corundum, diamond)

Some minerals are hard, some minerals are soft and this is useful as a means of identification. Mineral **hardness** was first qualitatively employed by an Austrian-German mineralogist named Frederick Mohs. He grabbed a handful of relatively common minerals and arranged them in order of increasing hardness:

Hardness	Mineral	Economic uses
1 (softest)	Talc	Baby powder
2	Gypsum	drywall, Plaster of Paris
3	Calcite	cement
4	Fluorite	Toothpaste, steel manufacturing
5	Apatite	Fluoroapatite = teeth
6	Orthoclase	Not much; it looks pretty though
7	Quartz	Glass, computer chips
8	Topaz	gemstone
9	Corundum	gemstone, abrasives
10 (hardest)	Diamond	gemstone, abrasives

Note: the hardness scale is not absolute (refer to your lab manual for a good diagram illustrating this). Be careful where you scratch! Contamination may mislead you. Also note that streak plates have a hardness of 5.5 to 6 (may cause problems with streaking).

You are not expected to carry a bunch of minerals around in your pocket to test mineral hardness. Instead, you can substitute other more common items:

fingernail: H = 2.5
penny: H = 3.5
Glass: H = 5.5 to 6
Swiss Army knife: H = 6

Property 5: Luster (pyrite, muscovite, hematite, quartz, satin spar, bauxite, sphalerite)

The way a mineral reflects light is called its **luster.** It is a very subjective property because it is described according to intensity and quality and nobody agrees about these. In general, there are 2 major types of luster: 1) **metallic** and 2) **non-metallic**. Some people also recognize a intermediary luster (**sub-metallic**) for those minerals that display lusters midway between metallic and non-metallic.

Minerals that display metallic lusters reflect light like metals. They include g**alena, specular hematite, chalcopyrite, pyrite** and real metallic minerals like **copper, gold** and **silver**)

Submetallic minerals are more rare and the only ones that you have to worry about are muscovite and chlorite.

The non-metallic minerals are the most abundant minerals. There are so many that it is necessary to use several luster subdivisions:

Luster		Description	Mineral examples
Metallic		reflects light in the same way as a metal	pyrite, galena
Sub-metallic		reflects light somewhat like a metal	muscovite, chlorite
Non-metallic	Vitreous	reflects light similar to a glass window pane (most common type of luster)	quartz, fluorite, beryl (image to right from www.icminerals.com)
	Adamantine	reflects light similar to a diamond (very intense)	diamond, sulfur (rare)
	Resinous	a luster having the appearance of resin or crystallized tree sap	sphalerite
	Waxy	a surface which look like it has been coated in wax or sugar glazing	chert, milky calcite
	Pearly	exhibits mother-of-pearl quality in how it reflects light	gypsum
	Greasy	has an oily quality in the way it reflects light	talc
	Silky	reflects light in much the same way as silk fiber	gypsum (v. satin spar)
	Earthy-Dull	relatively non-reflective; looks like earth or chalk	kaolinite

Property 6: Other optical properties (calcite, opal, labradorite, quartz, biotite, galena)

Diaphaneity: how light is transmitted through a mineral (color is not a factor)

1) transparent minerals - pass light and images through them (e.g., crystal quartz)
2) translucent minerals - transmit light but not images (e.g., milky quartz, fluorite)
3) opaque minerals - do not transmit any light at all (e.g., hornblende, galena, graphite)

note: color occasionally masks transparency (demonstrate biotite)

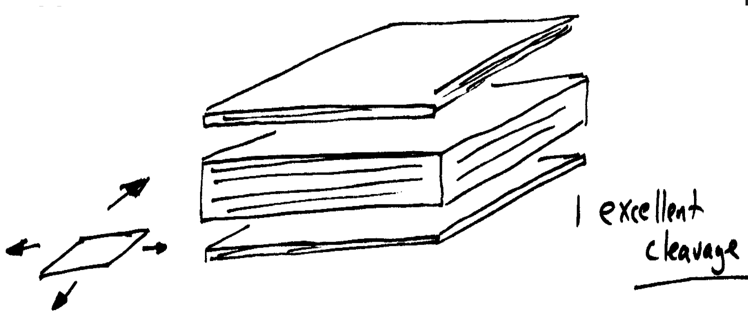
Internal reflection: light just penetrates the surface skin of a mineral before being reflected back toward the observer. Some minerals refract the light first giving rise to a spectrum of color. The 2 most common minerals displaying this property are opal (**opalescence:** red-green-yellow-blue) and labradorite (Ca-plagioclase; **labradorescence**: blue-green-yellow). This property is a diagnostic property of the Ca-Plagioclase specimens that you will see.

Double refraction: Optical calcite (Icelandic Spar) displays this property. You see 2 images instead of one when you look through it.

Fiber optics: The mineral ulexite displays this property. Ulexite is often called TV rock for obvious reasons. You won't see this in your mineral kit.

Property 7: Fracture and Cleavage (calcite, quartz, biotite, hornblende, pyroxene, galena)

When a mineral breaks, it will do so in one of 2 ways. It will either be random (**fracture**), or it will be along specific planes of weakness that are dictated by the atomic structure and packing of atoms. This is called **cleavage.** Consider the mineral **biotite.** It can be peeled into very thin (paper-thick) layers because it has 1 plane of cleavage:



Halite and galena can be broken up into cubes because they have 3 planes of cleavage that are arranged at 90 degree angles to one another:

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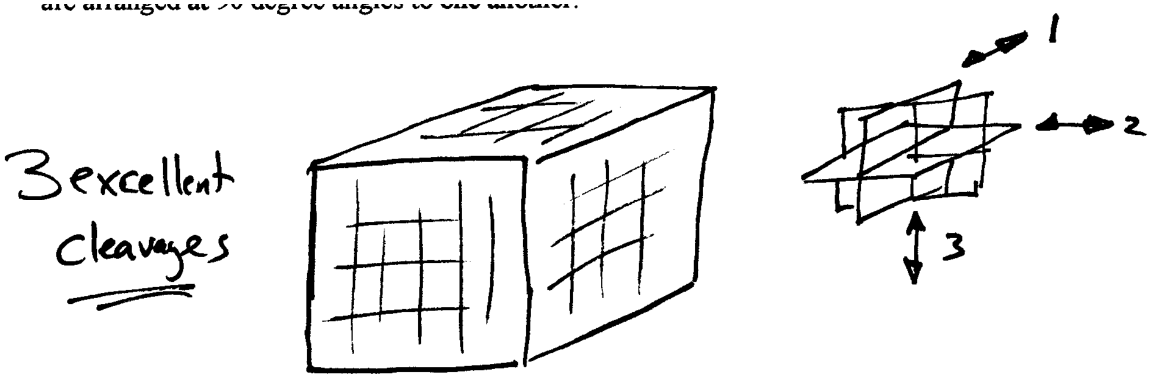


Biotite and halite and galena all have perfect cleavages, but not all cleavage planes are created equal. The mineral **orthoclase** ($KAlSi_3O_8$) has 2 planes of cleavage more or less at 90 degrees to one another, but neither is considered excellent (they are *good*). Orthoclase usually displays vestiges of cleavage, but you don't necessarily see square crystals all of the time. The same is true of gypsum (see image on lower right of last page from www.csm.jmu.edu).

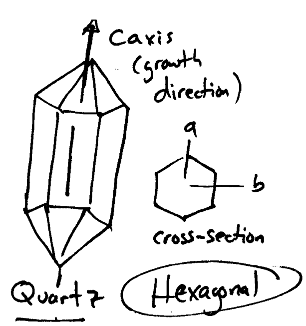
The two most problematic minerals that you will encounter in GY 111 are **pyroxene** and **amphibole**. These are not really distinct minerals; they are groups (by this we mean that there are many different pyroxene minerals that differ in chemical composition and many amphiboles that differ in composition, but they are otherwise the same mineral in terms of crystallinity and structure). The amphibole and pyroxene that you will see in this class look very similar in terms of colour, specific gravity, luster, hardness and streak. The only real difference is their cleavage. Both have 2 good cleavages, but they are arranged at 90-degrees in pyroxene and at 56-124 degrees in amphibole.

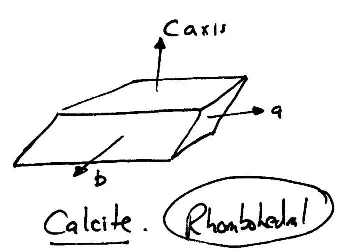
-minerals like quartz do not have cleavage because their bonds are equally strong in all directions. Their surfaces are not flat (like cleavage planes are). Instead they are jagged or irregular. Some of the broken patterns have a spiral or circular plucking appearance which is called **conchoidal fracture**. This is typically exhibited by window glass and glass-like mineraloids (e.g., chert).

Property 8: Crystal Habit (calcite, quartz, garnet, galena)

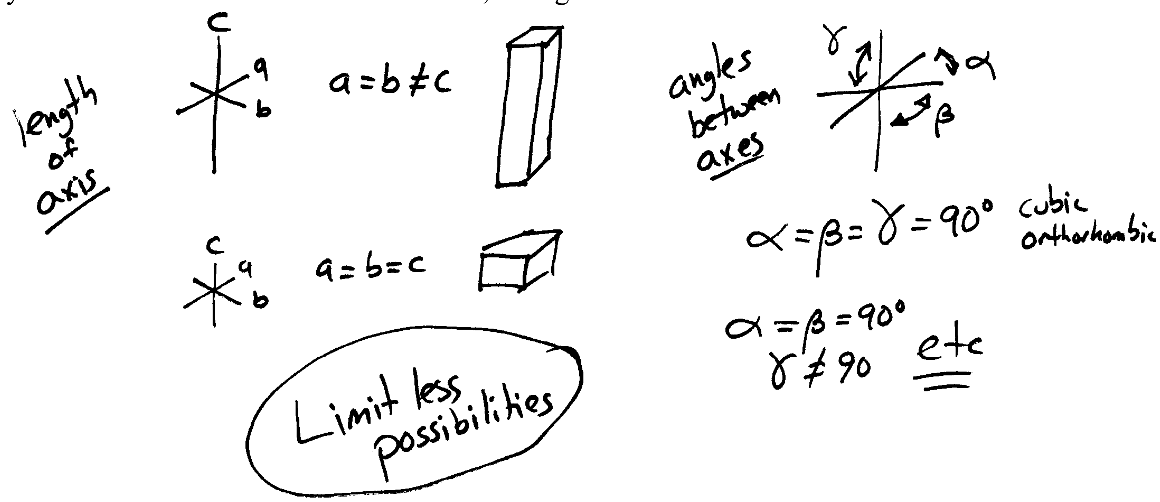
The way a crystal grows is called its **habit**. Minerals like quartz, calcite and garnet can form wonderfully-shaped crystals during growth **provided that they grow unencumbered**. This means that they don't "bump" into other crystals along the way.

The crystal habit is controlled by the way a minerals atomic or ionic structure is built up. For quartz, the habit is **bi-pyramidal** (hexagonal with 2 pyramids stuck on either end. Galena and halite are cubic; calcite rhombohedral and garnet dodecahedral.





It is the length of the growth axis (and their angles between one another) that controls the overall habit and **crystallography** of a mineral. Geology majors will get their fill of this in GY 341, but for those of you that are interested in how it all work, here goes:



Beware crystal aggregates! These are clumps of crystals that may mask the overall habit of a crystal. Examples of minerals that aggregate are asbestos, satin spar gypsum and goethite (metallic limonite)

Property 9: Other properties (calcite, magnetite, halite, talc)

Taste: Halite can be easily identified as ordinary table salt by its taste. Sylvite (KCl) is another mineral that also tastes salty, but it has a bitter aftertaste.

Reaction with Hydrochloric acid (HCl): Some minerals like calcite and to a lesser degree dolomite (when powdered) react with hydrochloric acid. When HCl is added to calcite it effervesces as bubbles of CO_2 gas are driven off into the atmosphere.

$$CaCO_3 + H_2O + 2HCl = Ca^{2+} + 2Cl^- + 2H_2O + CO_2$$

Feel: Minerals that are softer than your skin (Hardness = 1) rub off on your skin and consequently feel greasy or soapy. This is a useful property for identifying the minerals talc and graphite.

Pliability: The mineral kaolinite ($Al_2Si_2O_5(OH)_4$) readily absorbs water. When wet, it can be molded, a useful property since this is one of the clay minerals used by potters to make pottery and sculptures.

Smell: Some minerals have a distinctive smell such as the earthy odor of kaolinite and the rotten egg (sulfurous) smell of powdered sphalerite.

Magnetism: a few minerals (especially magnetite) have natural magnetic properties and form natural lodestones. A diagnostic test for magnetite is whether a magnet will be attracted to it.

Important terms/concepts from today's lecture

(Google any terms that you are not familiar with)

There are so many terms to be familiar with in this part of the lab that I refuse to list them all!