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**REDSTONE EXPLORATION SERVICES: 'FILE NOTE SERIES'**  
**Note 03.**

## **ROCK-FORMING MINERALS IN THE FIELD - A BASIC INTRODUCTION**



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Compiled by Dr. Mike Mlynarczyk

So... It's your first day ever in the field on your own... Just you and the rugged landscape you love. You've got a heck of a job to do: field mapping. Unless you are a seasoned geologist, this ain't easy. And there's no one around to ask for advice or an opinion. Well..., then you gotta be tough and do it alone. Beginnings are always hard, but the more rocks you will see, the easier this will get. I strongly suggest, if you have a chance, to get an experienced geologist to mentor you and share his knowledge. But if there is no-one around, I hope the very basic notes below will give you somewhat of an edge. Don't worry – the rocks won't get upset at you if you call them the wrong names. Your senior geologist or project supervisor could, though.

Hence, give your best shot, pull out your hammer and your hand lens, get down to the rocks and dirty (just beware of snakes and scorpions), and be very consistent in the observations you put down in your field notebook. If you do, it will be easy to correct potential mistakes, and I am sure that in the end you will produce a good piece of work and deserve the cold beer waiting for you back in the camp. Good luck!

## **SOME BASIC TESTS HELPING IDENTIFY ROCK & ORE-FORMING MINERALS:**

### **• HARDNESS**

Mineral hardness is quite a tricky feature to determine, because of its dependence on potential weathering, the fine- versus coarse-grained character of the mineral, and because of the complexity of the test itself (i.e., "crushing versus scratching"). Still, it is a very useful test. **You should always test a fresh surface and remember that a definite scratch must be produced in the tested mineral** (blow air, rub the place, and observe the scratch with a hand lens, to check if it is not just a dust trail!).

Now, let's do a quick & practical review of the Mohs hardness scale:

- Minerals having a hardness about 1 are kind of "soapy" / "greasy" in feeling;
- **A fingernail** has a hardness of 2.5 (i.e., can scratch a mineral up to hardness 2);
- **Copper wire / penny** has a hardness of 3-3.5 (scratches a mineral up to hardness 3);
- **A big sewing needle** has a hardness of 5-5.5 (scratches a mineral up to hardness 5);
- **Glass** occurs in many varieties, but its hardness is generally about 5.5 (up to 6.5), so a mineral with hardness 6 *should* scratch it, and one with hardness 7 surely will;
- **A swiss-army knife** has a hardness of 5.5-6 (scratches a mineral up to hardness 5);
- **A steel file** has a hardness of 6.5 (can scratch a mineral up to hardness 6);
- **A quartz crystal or a shard of flint** has a hardness of 7.
- Your **tungsten carbide scriber**, with a hardness about 9, is three times harder than quartz, and therefore can scratch quartz and silicified rocks.

### • CHEMICAL TESTS

A useful solution to have with you in the field is **dilute hydrochloric acid (1M or 5%)**. A drop of cold acid will instantly cause calcite / aragonite (and therefore, limestone) to fizz, whereas dolomite (and dolostone) will not be affected, unless you heat the acid up or powder beforehand a small area of dolomite with your pen scratcher.

**A solution of alizarin red**, though less commonly used, can also be handy – it readily stains calcite (and limestone) in bright red color, whereas dolomite remains unstained. Finally, for the identification of some ore minerals, two useful solutions to have with you in the field are:

- the **zinc zap** [a commercially available solution of 3% potassium ferricyanide ( $K_3Fe(CN)_6$ ) and 0.5% diethylaniline dissolved in 3% oxalic acid], which causes a bright red coloration on the rocks when zinc is present, and
- a concentrated solution of **sulphuric acid** (e.g., car battery acid) **plus some clean iron nails** (Fe). In this simple field test, you put a few drops of this strong acid on what you suspect to be dark, oxidized copper sulfides in your rock, and once it reacts you dip in an iron nail. If these are indeed copper sulfides (and not Mn oxides, for example), the surface of the iron nail will soon get a thin but very conspicuous coating of copper.

### • OTHER MINERAL FEATURES TO LOOK FOR:

- **MAGNETISM** – use a pencil swing magnet, else a strong shower curtain magnet or a compass needle, and if the mineral is magnetic it likely is either magnetite or pyrrhotite (though pyrrhotite is sometimes inconsistent). Also, siderite and chromite can be weakly magnetic, especially when heated.

- **MINERAL COLOR** – this is an important property which, however, should not be relied upon in the case of translucent/transparent minerals, as many display a large range of colors. The observation should be done in good light (ideally daylight) and on a fresh surface, i.e., neither tarnished nor weathered. In some cases weathering can be of additional help, e.g., dolomite typically weathers brown.

- **MINERAL STREAK** – i.e., the color of finely pulverized/crushed mineral, is sometimes very characteristic, e.g., red for hematite, black for pyrite, and yellow for native gold. You will either need a streak plate or a broken/unglazed ceramic tile to do the test, which only works for minerals with a hardness inferior to about 6.5.

- **CRYSTAL HABIT AND TWINNING** (for example: acicular, prismatic, platy, tabular, bladed, lamellar, blocky, stubby, equant, fibrous, radiating, botryoidal, dendritic, nodular, oolitic, etc.)

- **CLEAVAGE** versus **FRACTURE**. These are determined by breaking the mineral with a rock hammer and, if needed, using a hand lens. **Cleavage** is a smooth break along a plane of weakness in the mineral, which produces a clean flat surface, parallel to a possible crystal face, and it is definitely reproducible. It can be classified as perfect, imperfect, good, distinct, indistinct, fair, and poor (quasi-synonymous with 'parting'), and its direction is very characteristic. Some minerals virtually lack cleavage (e.g., quartz), others cleave in only one direction (e.g., micas), some in two directions (e.g., feldspar), and some in three or more directions (e.g., calcite, fluorite). Thus, a mineral that breaks into sheets has one dominant cleavage, one which breaks into splinters or prisms has two cleavage directions, whereas one that breaks into cubes or rhombs has three cleavages or more. Cleavage is said to be 'basal' when it occurs perpendicular to the c axis of the mineral and 'prismatic' when it occurs parallel to it. Note that good cleavage can be obtained even when the mineral has a subhedral / anhedral development, as this is an inherent property of the mineral's crystal structure. Last of all, not only the direction of cleavage is important, but also the angle between cleavage directions. For example, pyroxenes and amphiboles are distinguished primarily by cleavage angle, with the pyroxenes having a more acute angle (see below). The cleavage angle can also help identify the type of cleavage. Three identical directions of cleavage in one mineral can only be either cubic, rhombic or prismatic cleavage (the latter forming six-sided prisms) - if the angle between the cleavage directions is  $90^\circ$ , then the cleavage is cubic, if it is  $60^\circ$  - the cleavage is prismatic, else it is rhombic.

On the other hand, **fracture** is the tendency of a mineral to break along irregular, uneven, non-reproducible surfaces, and does even occur in minerals which possess cleavage. It can be classified as: conchoidal (curvy, shell-shaped, like in broken glass – e.g., quartz), uneven (e.g., anhydrite), jagged (with sharp points or edges protruding on the surface – e.g., native metals/alloys), splintery (in fibrous or finely acicular minerals – e.g., chrysotile or kyanite), and earthy (producing a texture of broken clay – e.g., limonite).

- **LUSTER** should be examined on a fresh mineral surface. It can be metallic, adamantine, glassy (vitreous), silky, greasy, resinous/waxy or dull/earthy.

- **TRANSPARENCY / TRANSLUCENCY** – note that a transparent mineral can be so strongly colored that it may appear opaque, therefore you need to view it against bright light and inspect near-surface internal fractures, as well as crystal edges.

- **DENSITY** (or specific gravity, i.e., density compared to that of water) - gauge it by simply taking the mineral in your hand and paying attention if it is unusually heavy (e.g., galena, barite, native gold) or unusually light (e.g., halite, native sulfur, amber).

Alternatively, you could take in your other hand a known mineral with an average density ( $\sim 2.75 \text{ g/cm}^3$ ) and compare the unknown mineral to your 'standard'.

- **UV LUMINESCENCE** - have a small UV lamp handy. Scheelite, fluorite, calcite, gypsum, sodalite, scapolite, franklinite, willemite, chalcedony, hemimorphite, aragonite, are only a few from among the many fluorescent minerals.

- **MINERAL ASSOCIATION** - the other associated minerals can often give a clue to the mineral's identity. For example, note that of the mafic minerals – olivine, orthopyroxene, and clinopyroxene are anhydrous minerals, and therefore tend to occur in mafic rocks. Conversely, amphiboles and micas are hydrous minerals and are most commonly found in felsic rocks.

- Some other, less useful features include: **CRYSTAL SYMMETRY** (if euhedral), **STRIATION ON CRYSTAL FACES** (e.g., in quartz, tourmaline, feldspars, pyrite, sphalerite, garnet), **RADIOACTIVITY** (U/Th minerals, though these elements can also substitute for REEs in rare earth oxides and occur in 'trash can minerals'), **TASTE** (halite – salty, Mg salts – bitter), **SCENT** (e.g., native sulfur, some sulfides, arsenic minerals, clay minerals), **SOLUBILITY IN WATER** (e.g., nitrates, borates, and some phosphates/sulfates/carbonates), etc.

## **BRIEF PRACTICAL REVIEW OF SOME COMMON ROCK-FORMING MINERALS:**

### **• QUARTZ versus NEPHELINE**

Whereas plagioclase and K-feldspar are commonly 'white', quartz and nepheline generally look 'greyish'. The mineral association is helpful here, as nepheline only occurs in silica-undersaturated rocks (i.e., no quartz present). Both quartz and nepheline are translucent and do not have a noticeable cleavage. Quartz typically looks like a piece of glass, whereas nepheline appears a little more "greasy" than quartz, and can display alteration to sodalite ('blue seam'). Also, nepheline (hardness 5.5-6) weathers more easily than feldspar, which in turn weathers more easily than quartz (hardness 7). Therefore, on a weathered rock surface, if the 'grey mineral' sticks out above feldspar (i.e., is more resistant to weathering than feldspar), it is quartz; conversely, if it produces a 'cavity' in between the feldspars, it is nepheline. Quartz in rocks, especially when it is white, could also be confused with feldspars – the latter, however, possess excellent cleavage, have a lower hardness (6), and generally a tabular habit. High-T quartz has an isometric habit, and euhedral low-T quartz forms prisms with a characteristic transversal striation on the prism's sides. Note that quartz and olivine cannot coexist in equilibrium in the same rock!

### • **FELDSPARS**

You can be almost sure that in every rock you pick up, there will be some kind of feldspar present, as this is the most ubiquitous group of minerals. If there is only some 20% of a "white mineral" in a rock, it is plagioclase, as the rock is too mafic for it to be K-feldspar or quartz. In terms of color, feldspars are generally light-colored, however, plagioclase in mafic rocks can be quite dark (dark grey with a greenish tinge due to epidote inclusions). Conversely, if the feldspar has 'warm' colors, e.g., pink/reddish/creamy/brownish, it is usually K-feldspar (the red color is due to hematite inclusions). Now, both plagioclase and K-feldspar have two cleavages, parallel to (100) and (010), which intersect at  $\sim 90^\circ$  and produce shiny cleavage surfaces (only when they are fresh). K-feldspar may show simple twins, whereas plagioclase shows multiple, parallel twins: the lamellar twinning on (010) "flashes" and can only be seen on one of the two cleavages. Here, don't confuse albite twinning with perthitic exsolution - albite twinning looks like a very fine ruling (it is absolutely straight) and does not show any color difference across boundaries, whereas perthites display a difference in color or turbidity between the lamellae and their host. Iridescence can occur almost only in plagioclases, and is particularly conspicuous in the labradorite member of the series (a characteristic component of anorthosite rocks). Feldspars have a hardness of 6 and a tabular habit, with K-feldspars forming somewhat 'thicker' crystals. They can grow into large phenocrysts (>10 cm long), which commonly exhibit marked color and compositional zoning, especially visible in the plagioclase series. Of the K-feldspars - orthoclase and microcline are the most common, whereas sanidine occurs only in volcanic rocks, and adularia in low-temperature veins of felsic plutonic rocks and in cavities in crystalline schists.

### • **MICAS**

Typical examples of micas include: muscovite, biotite, phlogopite, lepidolite, glauconite, etc. Characteristic features include: a pseudo-hexagonal habit (thin tabular crystals); excellent basal cleavage parallel to (001) – they easily split into numerous 'springy' flakes; shiny/metallic luster (responsible for its typical glittering in granites, gneisses, and slates); and a very low hardness (2-3). The color of micas varies from colorless/silvery to dark green/brown/almost black, in the thicker crystals. Weathered biotite can take on a characteristic golden/brassy color (here note that gold flakes can be bent, whereas mica flakes cannot – they will simply break apart). Micas are hydrous minerals and cannot crystallize from lavas. They are found in plutonic, metamorphic, hydrothermally altered, and sedimentary rocks.

## • **OLIVINE**

Olivines have a hardness of 6.5-7, an 'olive green' color - in relatively fresh rocks, but commonly display a black or red color in the more altered, for example serpentinized rocks. This is because the alteration/weathering processes expel the iron into finely disseminated magnetite, which upon rusting turns red, and therefore in the altered rocks olivine commonly will be red on the outside, and black inside. In contrast, clinopyroxene, which is less prone to alteration will more commonly look green. When fresh, olivine has a glassy appearance, but becomes vitreous when altered. It does not have cleavage, but instead a conchoidal fracture, and the presence of fractures is common in olivine crystals. It can have two different habits: either rounded (spheroidal) – in cumulates, or as euhedral/subhedral phenocrysts – in lavas. The latter phenocrysts typically have 'pointy' terminations, which pyroxenes do not have (pyroxene phenocrysts have blunt ends and cleavage).

## • **PYROXENES (ORTHOPYROXENE versus CLINOPYROXENE)**

Most common examples of orthopyroxene ['opx'] include: enstatite, bronzite, and hyperstene, and most common examples of clinopyroxene ['cpx'] include: diopside-hedenbergite, augite-ferroaugite, pigeonite, aegirine-aegirine augite, jadeite, and spodumene. Now, how do we go about differentiating orthopyroxenes from clinopyroxenes, from amphiboles? All three groups of minerals have cleavage, are relatively dark, and are more resistant to alteration than olivine. You should note that pyroxenes and amphiboles are the harder to differentiate the darker (i.e., Fe-rich) they are. In terms of color, opx are generally brownish, cpx – greener and darker than the opx, and amphiboles are typically darker than cpx. In more detail: pure diopside is white, but with increasing Fe content it becomes green, then black (and when its composition is closer to augite, it is also black). Hedenbergite is black, enstatite – light brown to greenish brown, hyperstene black, and aegirine dark green to black. When cpx and opx coexist, the cpx is usually darker than the opx (e.g., black versus green). Pyroxenes have a hardness of 5.5-6.5, and a vitreous luster when fresh, but dull when altered. They form 4- or 8-sided short-prismatic crystals, except aegirine which has an acicular habit. Cleavage is by far the strongest in the amphiboles, then decreases from opx to cpx. In fact, cleavage is usually not very good in the pyroxenes, and the "shiny" surfaces are more commonly parting. So, if the dark, 'mafic mineral' has a splendid cleavage, it is likely to be an amphibole.

In both pyroxene and amphibole crystals the cleavage is parallel to (110), [or (210) for opx], and occurs in two directions (see figure below). In the pyroxenes these cleavage planes crosscut at  $\sim 90^\circ$ , whereas in the amphiboles at  $\sim 120^\circ$  (or  $60^\circ$ ). The

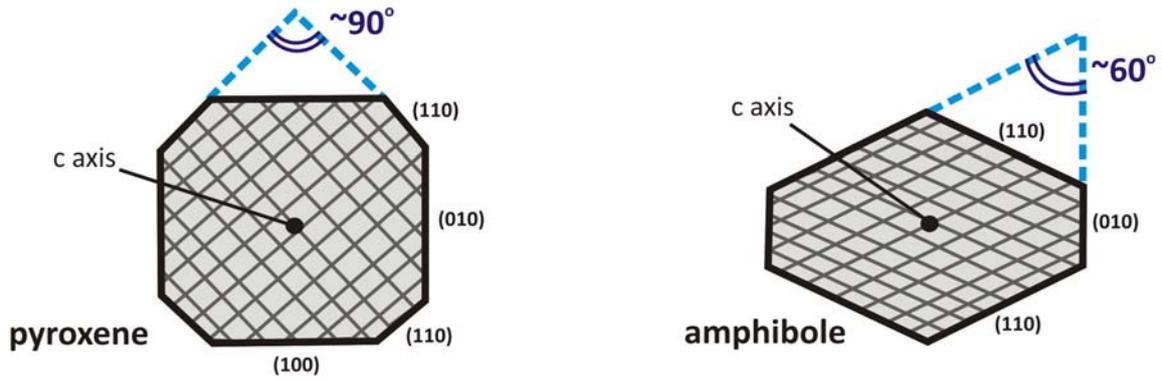
easiest way to observe this is by "extending" alternate crystal faces (110) and by looking at the angle they form, i.e., in pyroxenes the angle formed by the 'extended' crystal faces will be  $\sim 90^\circ$ , whereas in the amphiboles it will be  $\neq 90^\circ$ .

In clinopyroxenes, much better developed than cleavage is parting, parallel to (001), which can lead to confusion of a cpx with an amphibole. However, on the faces where it occurs, it is present together with the cleavage parallel to (110), which is more weakly developed. Also, whereas the parting on cpx has a pearly luster, the cleavage has a glassy luster. Therefore, we can be sure that we observe the two cleavages on the face of a pyroxene crystal if both are equally developed. If there is one direction that is better developed than the other, we are looking at parting and (weak) cleavage - see figure below. Also in opx, the parting (commonly related to twins) is better developed than cleavage, but whereas in cpx parting is parallel to (001), in opx parting is parallel to (010), which gives the opx a "woody character" (a kind of crenulation, fine striation). Therefore, on a (100) face of an opx crystal we observe the two directions of cleavage to be parallel, but on a (001) face they cross at  $\sim 90^\circ$  and occur with parting (see figure below).

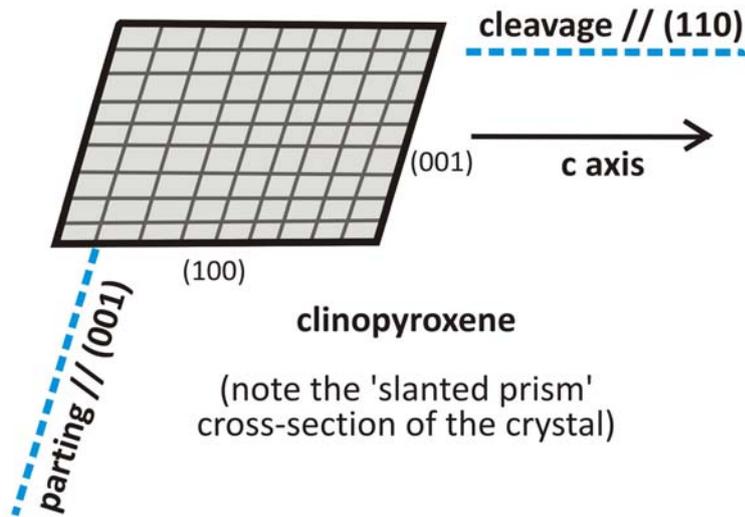
Augite, a common clinopyroxene differs from the amphibole hornblende by its short, stubby crystal habit and a different cleavage (see above); from tourmaline – by its short, stubby crystal habit, lower hardness, and the mere presence of cleavage; and from dark micas – by its much higher hardness and a quite different crystal habit.

- **AMPHIBOLES** (*See also earlier comments, about comparing opx vs. cpx vs. amph.*)  
Typical examples of amphiboles include: hornblende, tremolite-actinolite, cummingtonite, antophyllite, glaucophane, riebeckite, arfvedsonite, etc. Amphiboles are generally much more elongated than pyroxenes (the rare exception being the acicular pyroxene aegirine), and they form prismatic or lozenge-shaped, 6-sided crystals. Note also the two directions of well developed cleavage, which unlike in pyroxenes is parallel to the crystal elongation. Common amphiboles, such as hornblende, have a hardness of 5-6 and a vitreous luster when fresh, but dull when altered. With increasing Fe content, the color of amphiboles becomes darker: tremolite is white, actinolite – green, hornblende – greenish to black. Antophyllite may look similar to the pyroxene enstatite, but unlike the latter it displays a very good cleavage. Riebeckite commonly has an acicular habit. Short-prismatic hornblende crystals could be confused with augite, which exhibits a different cleavage (see above). Else, typical hornblende differs from pyroxenes by its elongated crystal habit, from tourmaline – by its lower hardness and the presence of cleavage, and from dark micas – by its much higher hardness, and again an elongated crystal habit.

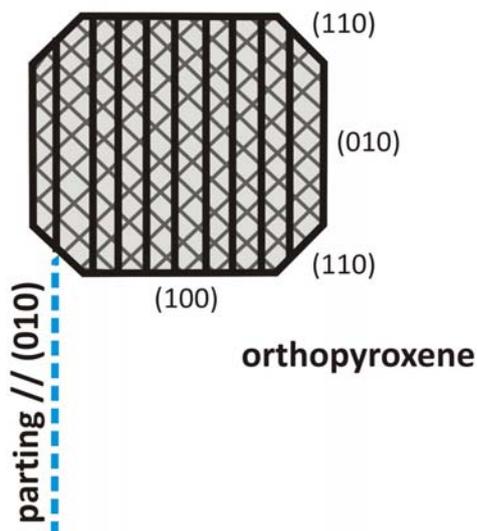
Looking at pyroxene and amphibole crystals down the C axis, i.e., at the (001) crystal face:



Looking at a clinopyroxene crystal down the B axis, i.e., at the (010) crystal face:



Looking at an orthopyroxene crystal down the C axis, i.e., at the (001) crystal face:



### • **TOURMALINE**

Tourmaline is most commonly black, has a vitreous shiny luster and hardly any cleavage. It forms long, thin prismatic crystals, often in clusters, with occasional longitudinal striation (in contrast to the transversal striation of smoky quartz crystals). Lastly, it has an elevated hardness of 7 in the Mohs scale.

### • **GARNET**

Minerals from the garnet group are typically brown, red or yellow, with resinous, dull, and in the case of crystals - glassy lustre. Their hardness is about 7, and they do not show cleavage. Garnets typically form isometric-shaped crystals, commonly showing crystal faces typical of the cubic system. They are common in metamorphic rocks, such as gneisses, schists, granulites, etc. Weathered garnets occasionally get a rusty coating of limonite.

### • **EPIDOTE**

Epidote-group minerals range in color from pale yellow to green, and in some cases can even be brown or red. They have a hardness of 6-6.5, a vitreous lustre and display one good cleavage direction. They occur in various habits, such as groups of elongated / radiating crystals, but coarse, stubby varieties are also known.

### • **CHLORITE**

Chlorites exhibit a range of green colors (usually dark green), and owing to one good cleavage direction easily produce thin 'sheets'. They are quite soft (hardness of 2-3) and possess a dull/pearly/micaceous luster. They typically occur as aggregates of fine crystals or thin tabular flakes, which are the alteration product of mafic minerals in igneous rocks. Unlike dark mica flakes, chlorite flakes can be bent, which helps to differentiate the two mineral groups. Also, the color of finely ground chlorite is green, whereas that of dark mica is colorless (streak test). Finally, chlorites shouldn't be confused with glauconite (also green), which typically occurs in marine siliciclastic rocks, such as sandstone, but does not form euhedral crystals - instead small, rounded grains <2mm in size.

### ***Postscriptum***

*I would like to finish this note with a brief anecdote from my Ph.D. time at McGill University. One day, when I was hanging out by the admin office, a man in his 50s came in, together with his small daughter. He was a prospector and had travelled*

*from far away to inquire whether the mineral sample he had was gold. I had a close look at the sample and with regret had to inform him it wasn't... It was just weathered dark mica, which had taken on its characteristic golden/brassy color. When I recall this moment, I feel for him. It really pays to be able to tell your gold from your 'fool's gold' and your 'cat gold'...*

*MM*