L1 - Minerals: definition & occurrences

Monday, July 20, 2020 7:20

Time on task: about 2 hours (Material posted on August 17th, Office hours: Wednesday Aug. 26th and Monday Aug. 31st)

Goals:

Upon completion of this lecture, you should be able to:

1. Give the complete definition of a mineral
2. List the diagnostic properties to identify minerals in hand samples
3. Know the mineral classification

This lecture is complemented with your Lab #1 (due on Friday Sept 4th)

1. Definition.

A mineral is an element or a chemical compound that is normally crystalline and has been formed as the result of geological processes (synthetic or human-fabricated materials are not minerals).

The definition of a mineral is changing. Until recently, a mineral was always considered as inorganic. We also keep discovering minerals. We now discovered about 5700 minerals on Earth. Dr Nash, emeritus professor in our department, is involved in the characterization of 77 new minerals and has a mineral that is named after her: Nashite

I encourage you to look at the presentation Dr Nash gave for the Open House last year.

A crystal is a homogeneous chemical compound with a regular and periodic arrangement of atoms. These arrangements present symmetries. A crystal is not always a mineral (e.g., a synthetic crystal; a protein).

Mineral Mountain, Utah - Credits: Pete Lippert

1.1. Occurrences and environment.

Depending on the type of rocks and environment, minerals associations will vary. In this class, you will learn how to identify individual minerals. However, in practice, we often use some context to help us identify a mineral assemblage . On Earth, we have three rock categories: Igneous, sedimentary and metamorphic. Some minerals (or mineral association) are more commonly found in one category.

Igneous	**Sedimentary**	**Metamorphic**
Olivine + pyroxenes	Carbonates (calcite, dolomite,…)	Omphacite, jadeite (pyroxenes)
Plagioclase + pyroxenes	Salts (halite)	Epidote, chlorite
	Gypsum	

In Utah, we have fabulous examples of all three!!

1.2. Most common mineral in rocks

A rock is identified base on its mineral assemblage.

- **In igneous Rocks**

	Acid (SiO_2 > 63 wt.%)	**Intermediate (52<SiO_2 <63 wt.%**	**Basic (45<SiO_2 <52 wt.%**	**Ultrabasic (SiO_2 <45 wt%)**
Rock name (intrusive, extrusive)	Rhyolite, Granite	Andesite, dacite, diorite, tonalite	Basalt, gabbros pyroxenites	Kimberlite, Peridotite
Common minerals	Quartz, alkali feldspar (Plagioclase, hornblende, micas)	Sodic plagioclase (=albite-rich) (hornblende, biotite, quartz, pyroxene	Pyroxene, plagioclase (olivine, Fe- & Ti-oxide, quartz, amphibole, micas)	Olivine, pyroxene (Plagioclase, garnet, amphibole, spinel, micas)

Arches, Utah - Credits: Christophe Brosson

Alta stock, Utah- Credits: TravelingGeologist

- **In sedimentary rocks**

Clastic sedimentary rocks
Conglomerates and breccias (>2mm)
Sandstones (0.06-2mm)
Mudrocks (<0.06mm)

Quartz, apatite, calcite, clays, gold, diamond

Chemical sedimentary rocks
Siliceous rocks (silex)
Evaporite
Limestone, dolostone

Calcite, gypsum, anhydrite, halite, sylvite, borate minerals

Organic sedimentary rocks
Carbonate rocks (guano, coal)

Calcite, Phosphates, graphite

- **In metamorphic rocks**

Protolith:	**Basic rock** (basalt, gabbro)	**Clay-rich sedimentary rock** (shale, mudstone)	**Limestone**
Rock name	**Metabasite**	**Metapelite**	**Marble**
Common minerals	**Amphiboles** + epidotes for LMG +plagioclase for HMG	**Muscovite + quartz** +chlorite, biotite, garnet for LMG + sillimanite, opx, cordierite for HMG	**Calcite or dolomite** +micas, quartz, clay, pyrite

L1 - Minerals properties (part 2)

Monday, July 20, 2020 19:40

2. Diagnostic macroscopic properties

Before reading this section, look at your mineral kit and try, by yourself, to list all the mineral properties you would use to distinguish between these minerals. This will be the subject of your first lab.

2.1. Habit

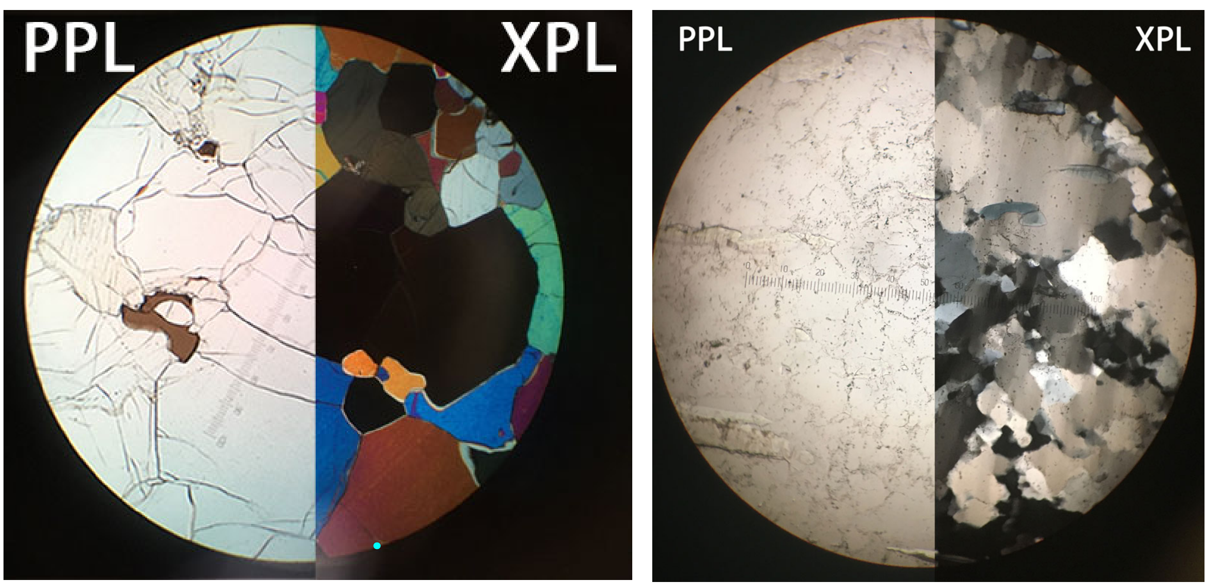
Habit is the general appearance a mineral tends to have – whether it is found as blocky crystals, long slender ones, or aggregates of some type, etc.

For a full list of mineral habits, I invite you to look at this link: http://www.webmineral.com/help/Habits.shtml

In this lecture, we will separate the habit in three main groups: **equant, tabular and prismatic.**

a) Equant: grains do not show any preferential elongations. We also call these grains "blocky" or "granular" e.g., Quartz, olivine

Granular dunite (rock mostly composed of olivine) in contact with basalt



Plane (PPL) and crossed (XPL) polarized images *of a thin section of a peridotite (left - olivine are colorless in PPL, show vivid interference colors in XPL, moderate relief and no cleavage) and a quartzite (right- quartz are colorless in PPL, has low inference color, low relief and no cleavage) from the G&G petrology collection. Note that the grains vary in size but are all equant. Field of view (FOV): 4mm*

*The colors in XPL are called **interference colors** and are due to the fact that light in minerals do not necessarily travel at the same speed depending on the orientation of the crystals. We will see more about this later, but I want you to familiarize with what you can expect to see with a petrographic microscope.*

b) Tabular: one direction is shorter than the two others.
Also named "platy"
Micas show an "extreme" tabular habit sometime called "flaky" or simply "micaceous"

Barite crystal (Credits: MSA)

Bladed crystals are intermediate between tabular and prismatic habits as they are usually long crystals, but with a flatten side like the blade of a knife
e.g., actinolite

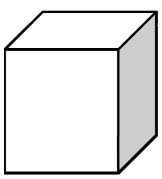
Which mineral in your kit has a bladed habit?

c) **Prismatic:** one direction longer than the two others
e.g., quartz (yes, the same mineral can show different habits), tourmaline

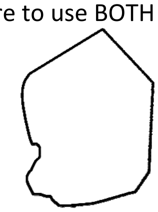
Subcategory of the prismatic habit: acidular (= needle-like) and fibrous (e.g., sillimanite often has a fibrous habit. It is then referred as fibrolite; minerals in the asbestos category are also fibrous)

Planed polarized image of a thin section of a sillimanite-Garnet biotite schist (R142 - G&G petrology collection). The fibrolite can be seen in the red circle. FOV: 4mm

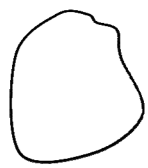
Finally, we also describe the minerals by their **morphology**, that is, by how well the faces of the crystal are developed. In labs and exercise, make sure to use BOTH terminology: habit (i.e. h=shape) and morphology.



Euhedral



Subhedral



Anhedral

2.2. Transparency

The ability of a mineral (in hand sample) to transmit light. We distinguish between:

Transparent (can see through it)
e.g., quartz

Translucent (light goes through but we can't see through it)
e.g., garnet

Opaque (light is not transmitted)
e.g., lapis-lazuli

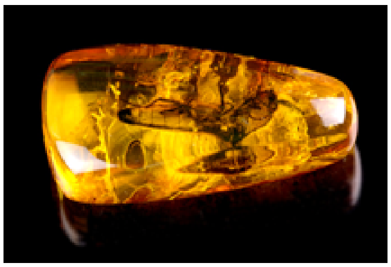
2.3. Luster

The ability of a mineral to reflect the light:

Metallic
e.g., pyrite

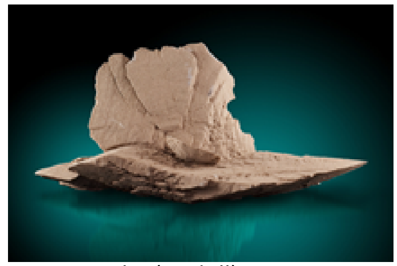
Submetallic
e.g., rutile

Adamantine
e.g., diamond



Resinous
e.g., amber

Vitreous
e.g., amethyst, quartz



Earthy (or dull)
e.g. desert flower

A transparent mineral with a high index of reflection with show an adamantine luster, while a transparent mineral with a low index of reflection will appear glassy, i.e., vitreous.

Other luster examples:

Metallic	Submetallic	Adamantine	Resinous	Vitreous	Earthy
Silver, Mercury, bismuth, galena Molybdenite, Graphite, copper, Marcasite, gold	Hematite, ilmenite, Manganite, magnetite	Zircon, Cassiterite, wulfenite	Apatite, Nepheline, halite Gypsum, Serpentine, Talc, sulfur	Opal, amphibole, Pyroxene, olivine, Felspar, anhydrite, Garnet, beryl, Fluorite, calcite	Graphite, hematite, clay minerals, chlorite

2.4. Color

Color is not often a good diagnostic property as many minerals display a large range of colors. Colors of the minerals is one of the diagnostic property that is mostlty controlled by the chemical composition and the presence of certain elements, even in trace amounts (i.e., <0.1%) sometime control the color of the mineral.

For instance, beryl exist in a large variety of colors and the presence of certain ions make of beryl some of the most famous gem crystals:

- Green beryl is known as Emerald. The green color is due to trace amount of Cr^{3+} in the crystal structure.
- Aquamarine is a cyan variety of beryl and the color is attributed to ions Fe^{2+}.
- Red beryl is the rarest and the dark red color is attributed to Mn3+ ions. Red beryl is found in Utah! (e.g., Thomas Range and the Wah Wah Mountains)

Credits: Arkenstone

Some minerals (e.g., Kyanite) however are easily identified thanks to the uniqueness of their color.

2.5. Streak

Credits: Mark Steinmetz

Streak is usually considered as the true color of a mineral. In fact, the luster sometime hides the color of a mineral. The best way to determine the true color of a mineral is to scratch it against a porcelain plate. The mark produced by the scratch is called the streak.

e.g., hematite often displays a submetallic luster that hides the true color of the mineral. The mineral appear gray while the luster is brown.

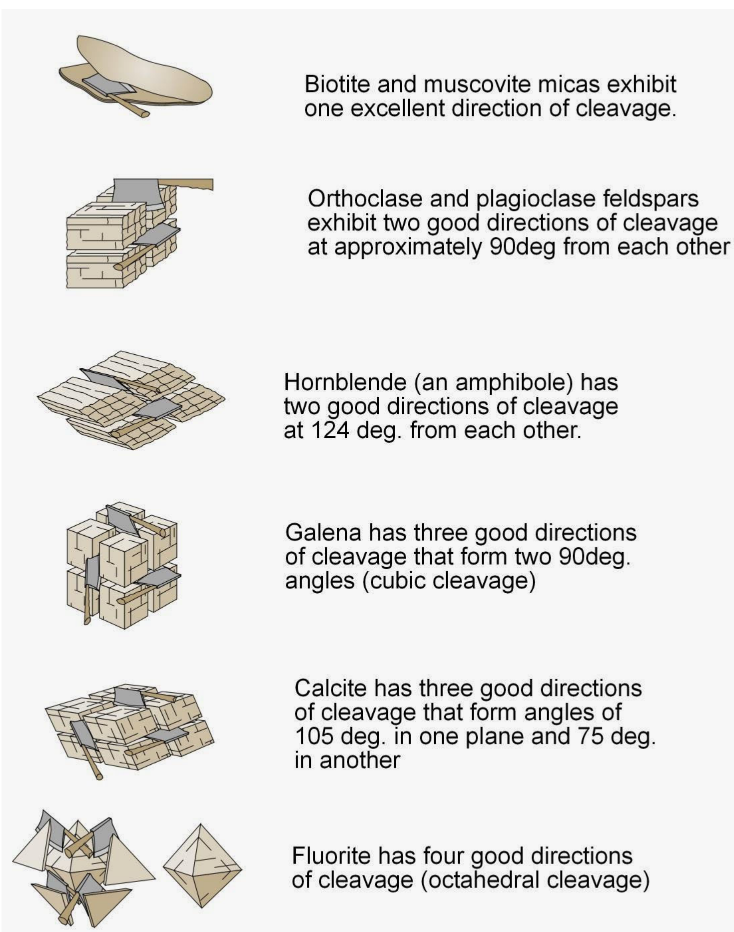
2.6 Cleavages

Cleavages are plans of weakness in the minerals. They can be consider as perfect, good, or poor. With a perfect cleavage, a mineral will break very easily along this plans (e.g., muscovite).
A mineral can have up to six cleavages plans (e.g., sphalerite), of various quality.

- a mineral has **one cleavage direction**, it is often called: **Basal** cleavage
- minerals with **two cleavages** are said to have **prismatic** cleavages. The angle between the cleavage plans can also be used to identify a mineral (e.g., pyroxenes ~90° vs. amphibole ~120°)
- mineral with **three cleavages** are said to have **cubic** (when plans intersect at 90 °) or **rhombohedral** (≠90°) cleavages
- Minerals with 4 and 6 cleavages: octahedral and dodecahedral cleavages, respectively (uncommon)

Conchoidal fracture in quartz
Credits: Geology.com

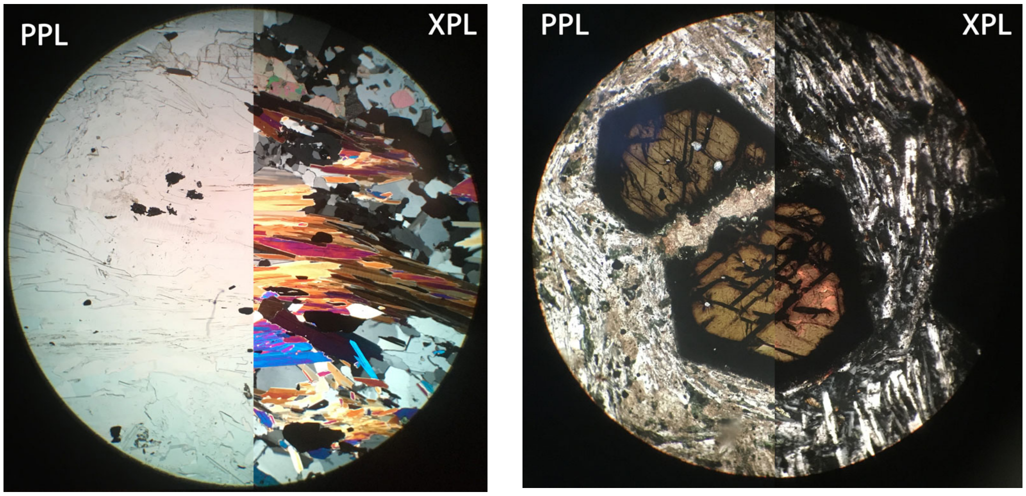
Minerals with **no cleavage** will show **conchoidal fractures** (random orientation, not necessarily parallel to each other).



Credits: Geologyin.com

Note that cleavages are also a diagnostic property in optical mineralogy (identification of the minerals in thin section) . However, thin section are basically a 2D cut of a crystal. Hence, the number of cleavages that can be see in thin section will depend on how the mineral has been cut.

Can you determine the **minimal** number of cleavages that can be seen in a thin section of muscovite? Of hornblende?



Left: Quartz micaschist (C-I). Muscovite is colorless in PPL and shows vivid interference color in XPL. FOV = 4mm; Right: oxyhonblende (UUOP17). Note the presence of two cleavages at ~120° on the basal section. FOV = 2.5mm. G&G teaching collection

2.7. Tenacity

Tenacity is the ability of a mineral to resist to plastic deformation under stress: Brittle> Sectile > Ductile
A lot of native metals are ductile (e.g., gold, platinum)

2.8. Density (or specific gravity)

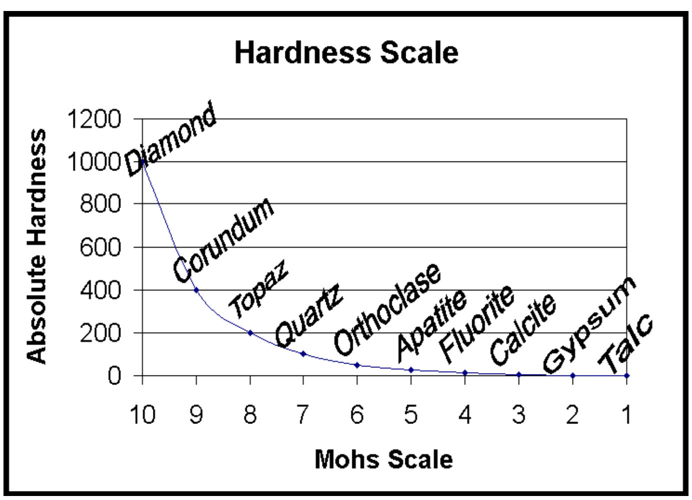
Density (ρ) is defined as mass per unit volume. The unit is kg/m^3 or g/cm^3.
Most silicates have a density between 2.6 and 3.5 g/cm^3 (2600-3500 kg/m^3)

The specific gravity is a dimensionless quantity defines as the ratio between the material density and the density of water at 4°C.

2.9 Hardness

Hardness is measure along a logarithmic scale named Mohs Scale.
It can also be define qualitatively using several object of reference (fingernail, copper cent, window glass, steel nail).

Fun fact: Pure copper was used to produce cents, but because of the price rise and the need of copper during war times, the composition changed and cents are now composed of a alloyed with copper and zinc. The result is that the hardness of the cent is slightly lower than 3 (close to 2.5 and similar to fingernail). Hence, you won't be able to scratch calcite with an american coin today (The quarter and dime are slightly softer than the cent and the nickel is slightly harder, but all are scratched by calcite).



1	**Talc**	
2	**Gypsum**	
2.5		*Fingernail Coin*
3	**Calcite**	
4	**Fluorite**	
5	**Apatite**	
5.5		*glass*
6	**orthoclase**	
6.5		*Steel*
7	**Quartz**	
8	**Topaz**	
9	**Corundum**	
10	**Diamond**	

2.10. Other properties

Other diagnostic properties can sometime be used to distinguish between a pair (or small subset) of minerals.

- Taste

Halite and sylvite are both salts that might look similar and are often associated on the field, but while halite is your table salt, sylvite is not use for consumption because it has a bitter taste

- Magnetism

Magnetite (Fe_3O_4)>ilmenite ($FeTiO_3$)>pyrolusite (MnO_2)

- Acid-test

When in contact with HCl, calcite shows a strong effervescent reaction. The reaction is due to the production of CO_2 such as:

$CaCO_3$ (calcite) + 2 HCl → CO2 + H2O + Ca^{2+} + 2 Cl^-

This reaction occurs with all carbonate minerals, however the kinetics of the reaction is much faster for calcite (or aragonite, a polymorph of calcite). Hence, if you place one drop of cold hydrochloric acid on a piece of dolomite ($CaMg(CO_3)_2$), the reaction is weak or not observed.

- Fluorescence and phosphorescence: minerals that glow when exposed to UV light.

Fluorescence: Fluorite (CaF2), calcite (CaCO3), nepheline

There are two classified ultraviolet wavelengths: longwave and shortwave. Some minerals fluoresce the same color in both wavelengths, others fluoresce in only one wavelength, and yet others fluoresce different colors in different wavelengths. We usually show several specimens of fluorescent minerals at the G&G Open House.

Phosphorescence (ie, continue to glow even after the UV light source has been removed)

e.g., Fluorite, selenite

- Radioactivity

e.g., uraninite (UO2), thorite (ThSiO4), carnotite

- Pleochroism: change of color depending on the orientation

e.g., tourmaline in hand sample.

While pleochroic minerals are relatively rare in hand sample, this property is quite common in thin section.

- Electrical properties: conduction, pyroelectricity (mineral that produces electricity when heated), piezoelectricity (mineral that produces electricity under stress)

L1 - Minerals: classification (part 3)

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3. Mineral classification

So far, we have identified about 5700 mineral species on Earth. We can use statistical analyses to have an idea of how many minerals are still to be discovered.
For instance, in 2015, there were 403 known C-bearing minerals. Statistics are telling us that there should be, at least, 548 C-bearing minerals on Earth. 145 were missing!!! The Deep Carbon Observatory launched The Carbon Mineral Challenge to discover as many as possible C-bearing mineral before September 2019. This initiative resulted in the discovery of 31 new C-minerals.

With that many minerals, we need to find a way to classify and name them. There are several factors that could be used to classify a minerals: chemistry, structure, environment.
The official classification is based on chemistry, most specifically, on the dominant anionic group and categorize all the minerals in 10 groups. Below, I present the 10 groups and give at least one common mineral example in each group. You should be able to remember, at least, these examples.

1) Sulfates: with SO_4^{2-}

Gypsum ($CaSO_4 \cdot 2H_2O$)

2) Phosphates: with PO_4^{3-} (or AsO_4^{3-}, VO_4^{3-})

Apatite ($Ca(PO_4)_3(OH)$)

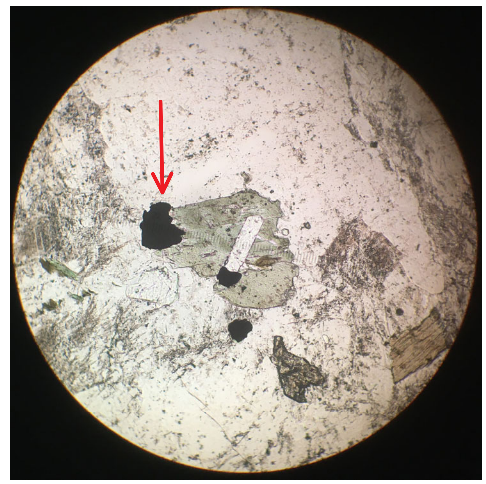
3) Borates: with BO_3^{2-} (or BO_4^{5-})

Borax ($Na_2B^{III}_2B^{IV}_2O_5(OH)_4 \cdot 8H_2O$)

4) Oxide: Cation + oxygen

Hematite (Fe_2O_3); Magnetite (Fe_3O_4); Rutile (TiO_2); Spinel ($MgAl_2O_4$)

Most oxides will appear opaque (red arrow) in PPL, making them almost impossible to identify with transmitted light. Rutile (TiO_2) is sometime dark red, spinel can be dark green



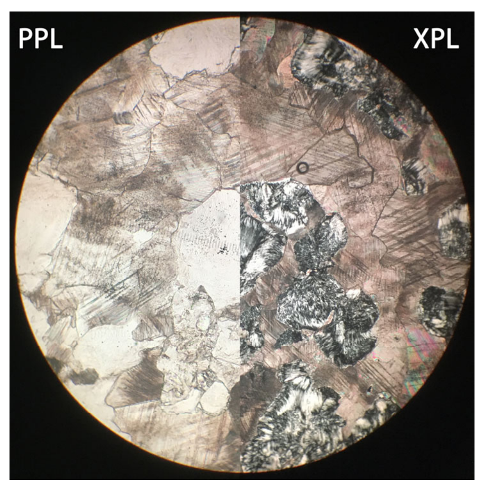
Apatite inclusion (prismatic, colorless, strong relief) in green biotite. FOV= 4.5mm - UUOP12

5) Hydroxides: with OH^-

Brucite ($Mg(OH)_2$); Gibbsite ($Al(OH)_3$)

6) Carbonate (CO_3^{2-}) and nitrates (NO_3^-)

Calcite ($CaCO_3$); Nitratite ($NaNO_3$)



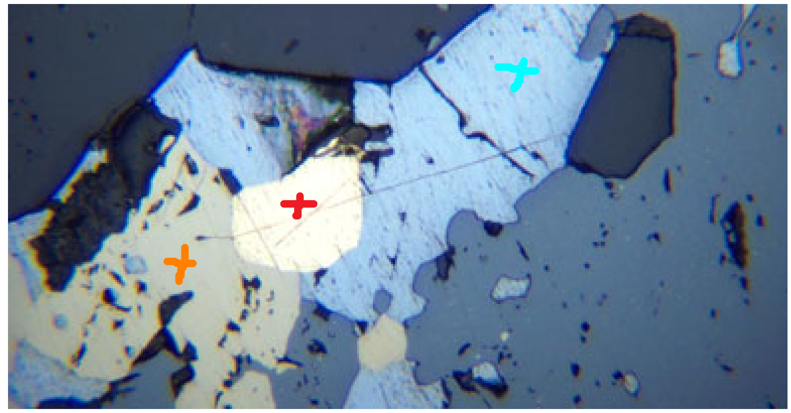
Brucite (colorless in PPL, low interference color in XPL) and calcite (brownish in PPL due to alteration and rhombohedral cleavage)- FOV=4.5mm - UUOP 13

7) **Native: no anion**

Gold (Au), Platinum (Pt), Copper (Cu), Graphite/Diamond (C)

8) **Sulfides: with S^{2-} (or As^{2-}, Te^{2-})**

Galena (PbS_2), Pyrite (FeS_2), Sphalerite (ZnS), chalcopyrite ($CuFeS_2$)

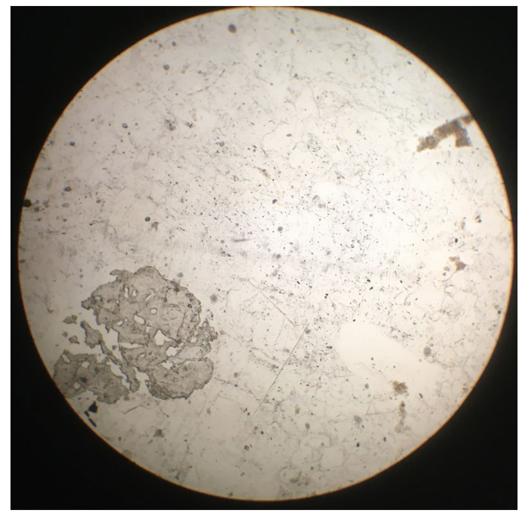


Reflected light image of a polished surface with gold, chalcopyrite and galena

9) **Halides: with halogens (F, CL, Br, I)**

Fluorite (CaF2), Halite (NaCl)

Fluorite shows a strong relief (= stand out), in lab 5, you will use the Becke line method to determine if the relief is positive or negative



Fluorite in PPL (FOV=4.5mm, UUOP 25)

10) **Silicates: with SiO_4^{4-}**

Silicate are by far the most common group of minerals on Earth. Silicates represent 600 of the 5700 minerals on Earth but also form 90% of the crust. Because of their importance, we developed a sub-classification for silicate based on the arrangement of the SiO4 tetrahedra in the crystal structure. Hence, the silicate classification is a **structural classification**.

L1 - Silicate classification (part 3.1)

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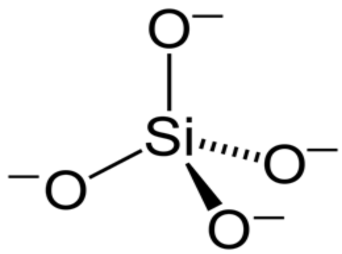
3.1. Silicate classification

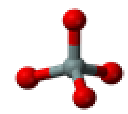


The silicate classification is based on the arrangement of the silica tetrahedra SiO4 in the crystal structure, or degree of polymerization: more the tetrahedra share oxygen, more the degree of polymerization increases.

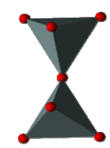
There are six groups of silicates. Most groups have two names (one descriptive and one with a latin root). You are welcome to use the one you prefer but you should know both are they are both used in the literature.
As for the mineral classification, you should know, at least one mineral in each group by the end of this lecture.

To visualize a silica tetrahedra in 3D and the various silica tetrahedra arrangements, open **SiO4.html** posted on Canvas-GEO3020-Lecture1-3D with your internet browser.

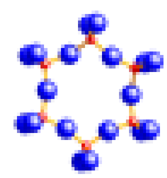
1) **Orthosilicate (or island silicate)**: isolated tetrahedra (they don't share any oxygen)
Olivine (Fe,Mg)2SiO4
Pyrope (Mg3Al2Si3O12)



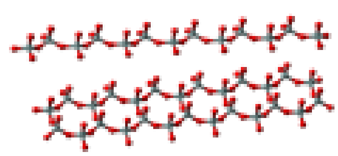
2) **Sorosilicate (or double island silicate):** Share one oxygen with another tetrahedra.
Sorosilicates are a small group of minerals. The most important one is Epidote ($Ca_2Al_2FeO(OH)SiO_4\ Si_2O_7$)



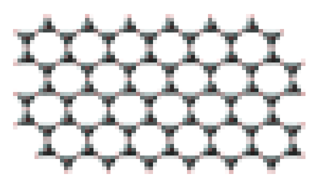
3) **Cyclosilicate (or ring silicate):**
Ring of 3, 4 or 6 tetrahedra.
Tourmaline, beryl, cordierite



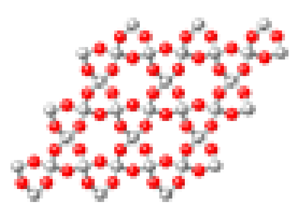
4) **Inosilicate (or chain silicate):**
Can be single (pyroxene) or double (Amphibole) chains.



5) **Phyllosilicate (or sheet silicate)**
Muscovite, biotite, chlorite, serpentine group



6) **Tectosilicate (or framework silicate)**
All the silica tetrahedra are connected with each other.
Quartz (SiO_2), felspars ($NaAlSi_3O_8$)



L1 - Personal assessment

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After reviewing the first lecture, you should be able to answer these questions:

****Multiple choices possible!****

1) **How effective is the physical property of color in identifying a mineral?**

A - Very effective: You can immediately identify it based only on the color.
B - It is one property and may not be used alone to identify a mineral.
C - It doesn't make a difference. Every mineral can be any color.
D - Color isn't a physical property.

2) **I collected a rock on the field and it contains calcite.**

A - This is a igneous rock
B - This is a metamorphic rock
C - This is a sedimentary rock
D - We don't have enough information

3) **Is mercury a mineral? Explain your answer.**

A - Yes
B - No
C - Yes and no

4) **Can an opaque mineral have a submetallic luster?**

A - Yes
B - No

5) **I can scratch this mineral with a coin. Hence this mineral is**

A - Calcite
B - Talc
C - Fluorite
D - Gypsum

6) **What physical property is used in Quartz Watches?**

7) **The mineral classification is a:**

A - Chemical classification
B - Structural classification

8) **What is the mineral group of this specimen? $Ca_2Na(Fe,Mg)_4Ti(Al_2Si_6O_{22}(OH)_2$?**

9) **Muscovite has a lower degree of polymerization than epidote.**

A - True
B - False
C - We don't have enough information