Classification of Minerals

Minerals may be classified according to chemical composition. They are here categorized by anion group. The list below is in approximate order of their abundance in the Earth's crust. The list follows the Dana classification system which closely parallels the Strunz Classification.

Classification of Minerals

I	Silicate	Quartz, feldspar, mica etc.
II	Carbonate	Calcite, aragonite, dolomite
III	Sulfate	Anhydrite, gypsum, barite, zaherite*
IV	Halide	Fluorite, halite, sylvite
V	Oxide	Hematite, magnetite, chromite
VI	Sulfide	Pyrite, chalcopyrite, galena
VII	Phosphate	Monazite, apatite
VIII	Native/Element	Gold, silver, copper
IX	Organic	Oxalates, mellite, hydrocarbons

SILICATES

Introduction

- most abundant class of minerals (40% of all common minerals)
- of the common rocks, the essential and accessory minerals of all igneous rocks, many sedimentary rocks, and all but one metamorphic rock are comprised of silicate minerals
- polymerization occurs in silicates because of the presence of the mesodesmic bond type—this bond allows linkages of the basic building block, the silicon tetrahedron and results in the formation of the silicate subclasses

General Chemical Formula

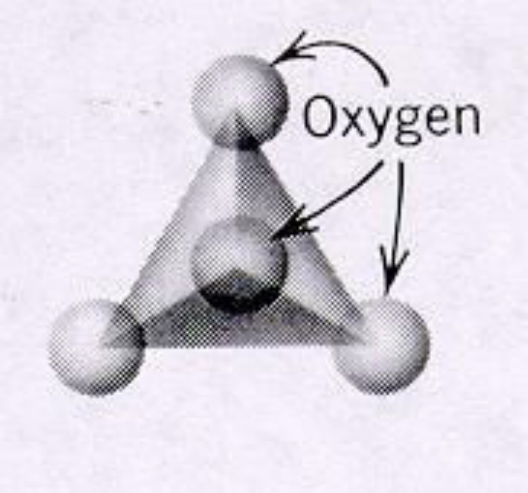
- $X_mY_n(Z_pO_q)w_r$
  - X = cations with valence of 1 or 2 and CN of 6, 8 or 12 with O
  - Y = cations with valence of 2-4 and CN of 6 with O
  - Z = Al^{+3}, Si^{+4}
  - w = usually OH^{-1}, F^{-1}, Cl^{-1}
  - p, q, m, n ,r = used for electroneutrality and p:q defines subclasses
  - yH_2O present in silicates is not shown in formula
  - many minerals may not have all symbols represented in their formula

- Common elements representing symbols are:
    - X = K^{+1}, Na^{+1}, Ca^{+2}
    - Y = Mn^{+2}, Fe^{+2}, Mg^{+2}, Fe^{+3}, Ti^{+4}, Al^{+3}
    - Z = Al^{+3}, Si^{+4}

- **(Structural) Subclasses**
    - Kind of subclass based on the kind or degree of polmerization involving the tetrahedron linkage

1. Nesosilicate

- **units of independent tetrahedra in which all 4 O in each tetrahedron are free to directly connect to other cation polyhedra which in turn will connect with other independent silicate tetrahedra**
- **p:q = 1:4 (where p=1 or 3 and q=4 or 12 in Si_pO_q)**
- **crystal habit of minerals is equidemensional and pronounced cleavage is absent**



OLIVINE

These three specimens are of an igneous rock consisting almost exclusively of crystals of olivine that are approximately 1mm across.

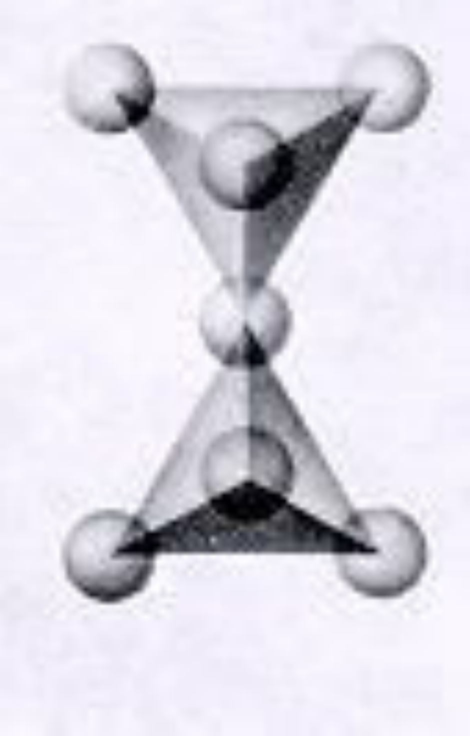
Olivine exhibits its classic glassy, olive green appearance in these specimens, as well as its common granular [somewhat like sugar] habit. There is no cleavage, only conchoidal fracture, so that there are no plane surfaces reflecting light.

Nesosilicates

- ***olivine*** ***(solid solution series)*****--important rock forming mineral**
- ***garnet*** ***(isomorphic group)***
  - **minerals often occur in dodecahedron crystal form**
  - **form abundantly in metamorphic rocks**
  - **pyrope, almandine, grossularite**
- **zircon**
  - **can form metamict structure**
- ***kyanite (belongs to a polymorphic group)***

2. Sorosilicates

- unit of 2 silica tetrahedra sharing one common O
- the other 6 O are free to connect with other cation polyhedra and in turn more of the soro- units can connect with these
- p:q = 2:7 (where p=2 and q=7 in Si_pO_q)

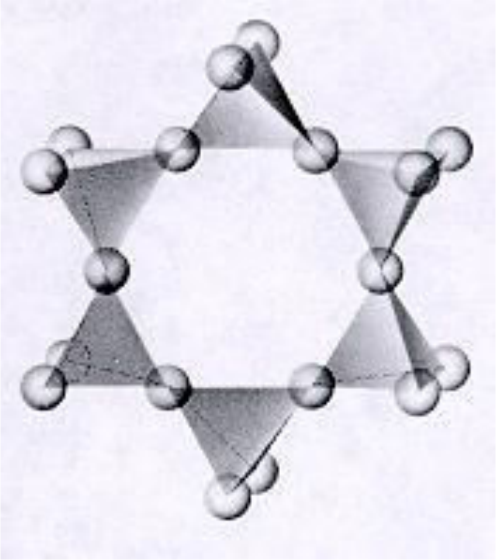


Sorosilicates

- **hemimorphite**
  - often found as clear hard bladed crystals
- ***epidote***
  - belongs to an isomorphic group
  - an important rock forming mineral
- **allanite**
  - black and no cleavage—can have metamict form

3. Cyclosilicates

- closed rings of of tetrahedra each sharing 2 O
- the remaining 12 O in the unit are free to connect with cations of other polyhedra which in turn can connect with more cyclo-units
- p:q = 1:3 (where p=6 and q=18 in Si_pO_q)
- atoms can be physically trapped in the open spaces

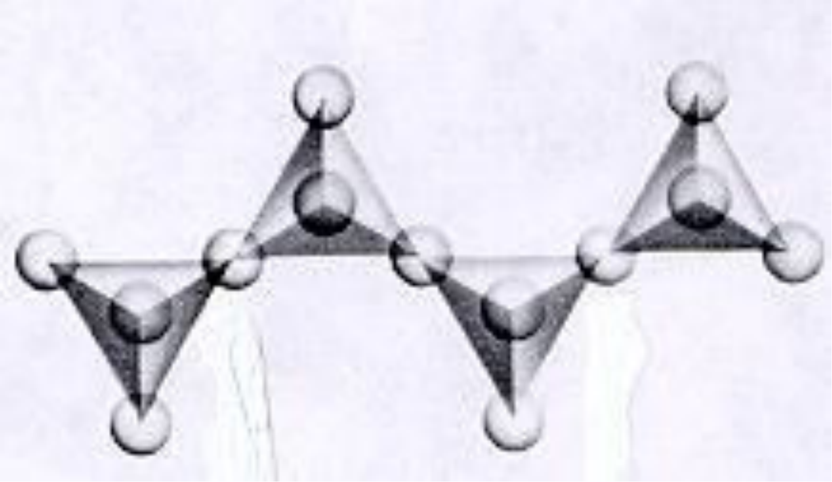


Cyclosilicates

- **minerals have high hardness, there are many examples of gemstones, and cleavage is poor**
- **examples are:**
  - **<u>beryl</u>**
    - **emerald (green transparent), aquamarine (pale green-blue transparent) and morganite (rose transparent)**
  - **<u>cordierite</u>**
    - **often displays dichroism**
  - **<u>tourmaline</u>**
    - **<u>Shorl (black</u>) variety, <u>rubellite (red-pinkish)</u> variety, indicolite (blue)**

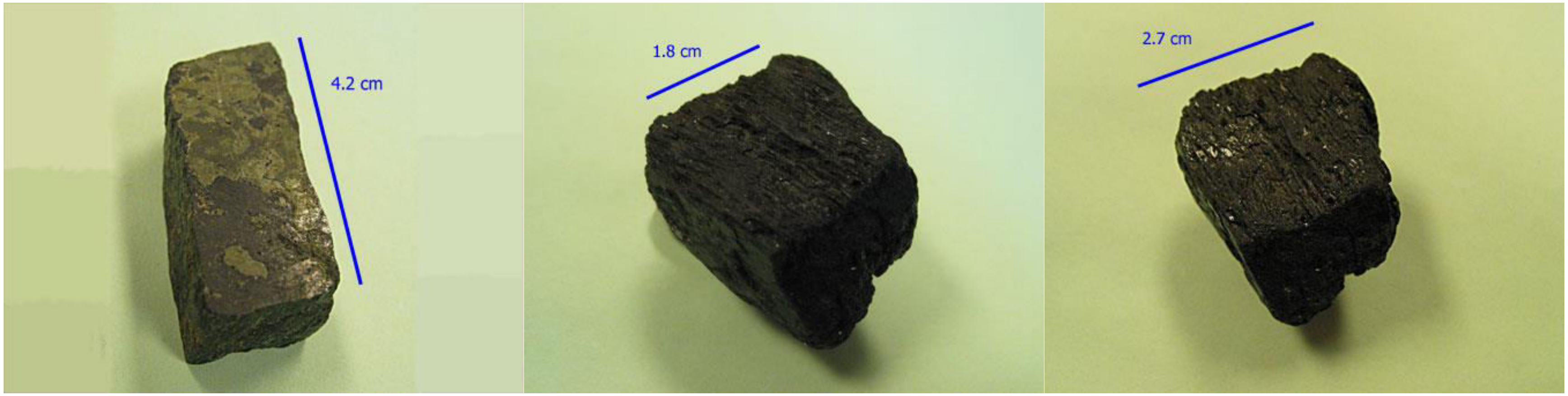
4. Inosilicates

- 1 .<u>continuous chain unit</u>, each sharing 2 O
- free O in each tetrahedron available to connect to other cation polyhedra which in turn will connect with other ino-single chain units
- p:q = 1:3 (where p=1or 2 and q=3 or 6 in Si_pO_q)
- cleavage along connected polyhedra results in a typical 90 degree 2 directional cleavage



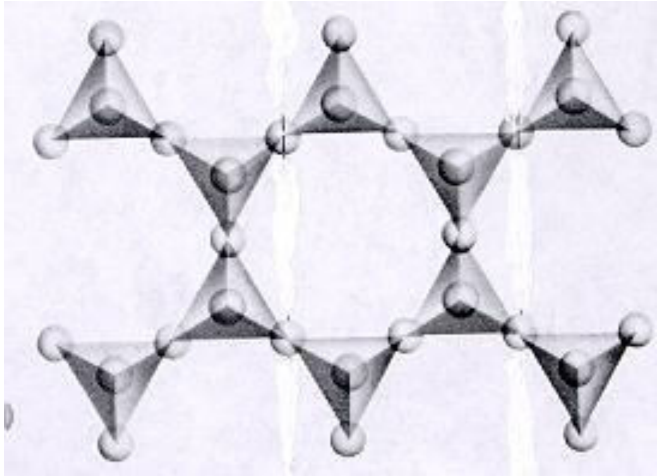
Pyroxene [e.g. augite]

In these three views of two specimens, the upper face and left side vertical face meet at right angles, a common characteristic of the single chain silicates. Note how irregular the faces are on the two images on the right, yet how these small steps are parallel to each other. The hardness, around 5 ½ to 6, white streak, and typical dark colour make this otherwise very similar to amphibole, a double chain silicate. The square cross-sections of pyroxene crystals distinguishes them from amphiboles.

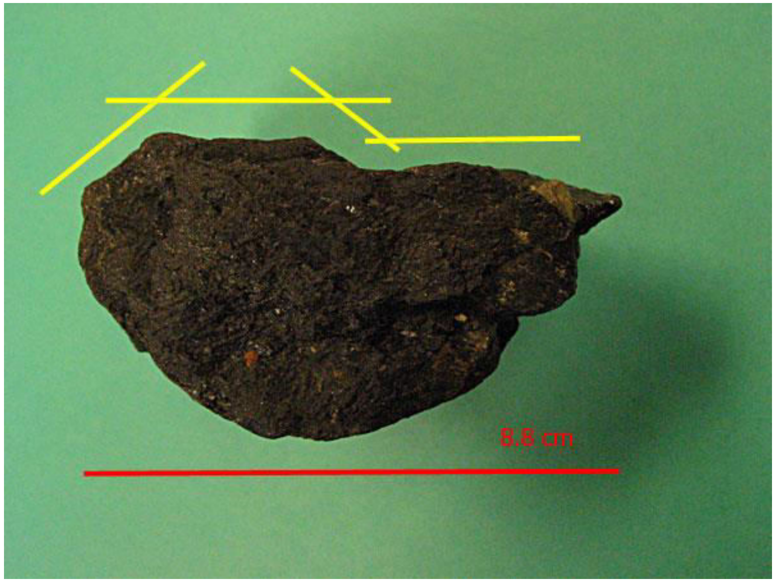


Inosilicate

- **2. <u>double chain unit</u> of tetrahedra each sharing 2 and 3 O alternately**
- **free O in tetrahedra available to connect to other cation polyhedra which in turn connect to other ino-double chain units**
- **p:q = 4:11 (where p=8 and q=22 in Si_pO_q)**
- **cleavage along connected polyhedra forms a 124-56 degree 2 directional cleavage**



Amphibole [e.g. hornblende]



In the double chain silicates, the extra width of the double chain skews the intersection angle between cleavage faces, so that they meet to form hexagonal cross sections to the crystals, as highlighted by the yellow lines in the right-hand image. In this case, we are sighting along the length of the chains. Other major properties are as for pyroxene.

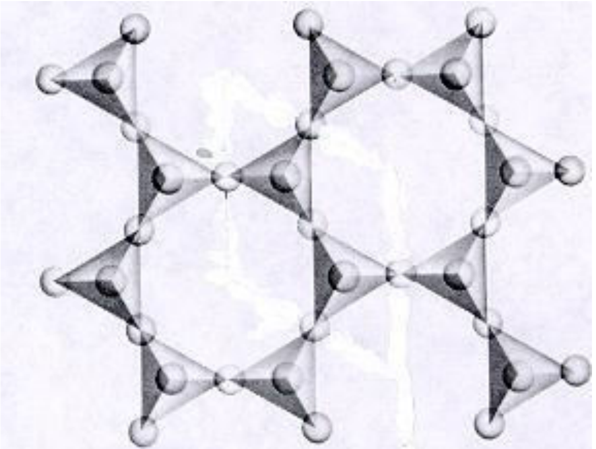
Inosilicates

- **includes the <u>pyroxene</u> and <u>pyroxenoid</u> groups which are single chain silicates and <u>amphibole</u> group which are double chain silicates**
- **pyroxene and pyroxenoid minerals lack $(OH)_x$ and display 2 directional 90 degree cleavage and the pyroxenes are very important rock forming minerals**
- ***pyroxenes***
  - **<u>enstatite-ferrosilite</u> (solid solution series)**
  - **<u>diopside-hendenbergite</u> (solid solution series)**
  - **<u>augite--</u>most common pyroxene**
  - **<u>spodumene</u>**
    - **important source of Li-kunzite=gemstone**

- *pyroxenoid group*
  - **minerals commonly display splintery cleavage**
  - **an example is:**
    - **<u>wollastonite</u> can resemble albite but has no striation twinning**
- *amphibole group*
  - **double chain minerals with $(OH)_x$ present**
  - **minerals display 2 directional cleavage intersecting at 124 and 56 degrees**
  - **important rock forming minerals**
  - **examples are:**
    - **<u>actinolite-tremolite</u>(solid solution series)**
    - **<u>hornblende</u>—most common amphibole**

5. Phyllosilicates

- **continuous sheet units of tetrahedra each sharing 3 of its O**
- **free O are available to connect to other cation polyhedra which in turn connect to other phylo-units**
- **much Al substitutes for Si**
- **one directional sheet cleavage results in minerals and atoms and ions can be trapped in open spaces**
- **p:q = 2:5 (where p=2 or 4 and q=5 or 10 in Si_pO_q)**

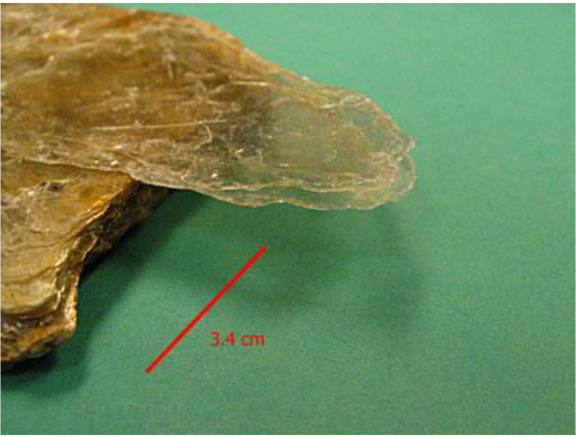


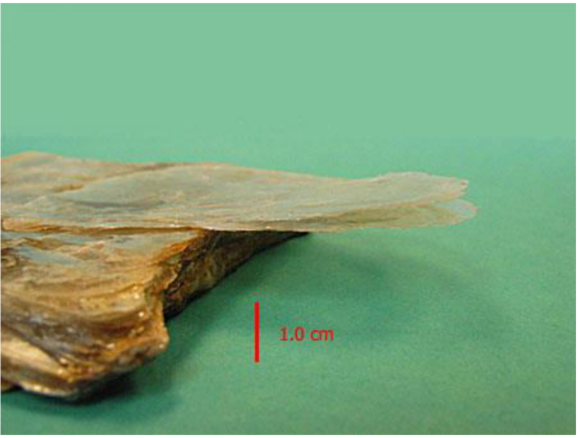
Biotite

As with all mica group minerals within the sheet silicates, biotite cleaves readily to produce flexible cleavage flakes whose surface has significant reflectance, such that small flakes or crystals within a rock typically glint. It is soft as well, and not readily confused with anything else. You may rely on the colour to be this consistent, almost black or very dark brown shade, to distinguish from other micas, such as muscovite.

Muscovite

Soft, and with flexible, highly reflective cleavage flakes, the mica group mineral muscovite is distinguished consistently and reliably from the darker cousin biotite by its clear to silvery colour. Muscovite contains aluminum, whereas biotite has iron and/or magnesium in the same site in the crystal struture, which accounts for the consistent colour difference.





Chlorite

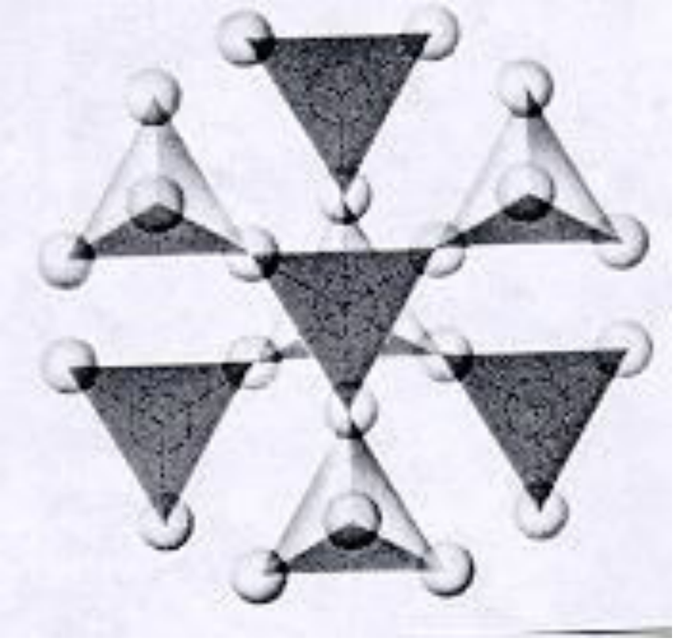
Belonging to a different group of sheet silicates than the micas, chlorite has brittle rather than flexible cleavage flakes.

Chlorite is also soft and readily flakes along its perfect cleavage, and is highly reflective as well. Its characteristic dark green colour imparts a green tone to the rocks which most typically contain it – low grade metamorphic rocks that are called greenschists.

- **Phylosilicates**
  - **includes the clay and mica minerals**
  - **one directional sheet cleavage**
  - **very important rock forming minerals**
  - ***Serpentine group* (polymorphic group)**
    - **little or no ionic substitution of Al for Si**
    - **serpentine (massive) greenish**
    - **crysotile**
      - **fibrous or asbestos variety of serpentine**
  - ***Clay group***
    - **hydrous Al layered silicates and little Al for Si**
    - **kaolinite**
    - **talc**

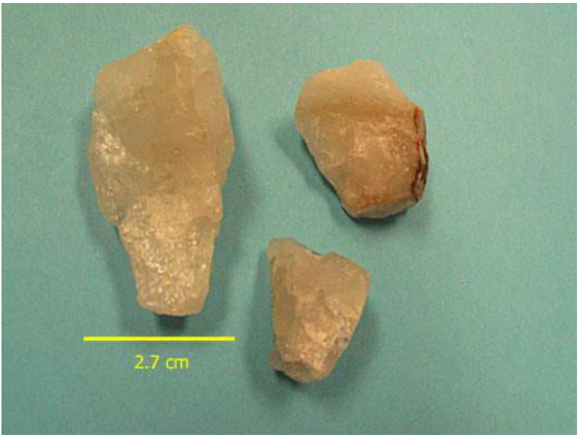
6. Tectosilicates

- continuous framework of tetrahedra all sharing 4 of its O
- large amounts of Al for Si substitutions allows other polyhedra to connect to the tecto-units
- p:q = 1:2 (where p=1, 2, 4 or 6 and q=2, 4, 8 or 12 in Si_pO_q)



Quartz

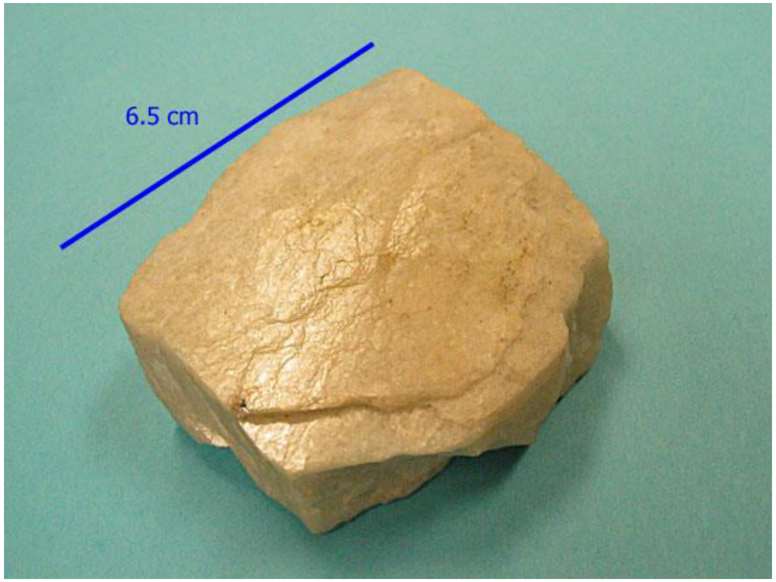
Among the most common rock-forming minerals, quartz is also among the easiest to identify. With a hardness of 7, it is not scratched by a knife blade, but ends up with a thin streak of metal on its surface. Most commonly it has a somewhat dull, grey glassy appearance. It has no cleavages to produce plane reflecting surfaces when incorporated in rocks (see right image), but rather exhibits conchoidal fracture. Its characteristic habit is as hexagonal prismatic crystals (see left view) with pyramid terminations, seen in the specimen under the scale bar in the left image, and in the middle image.

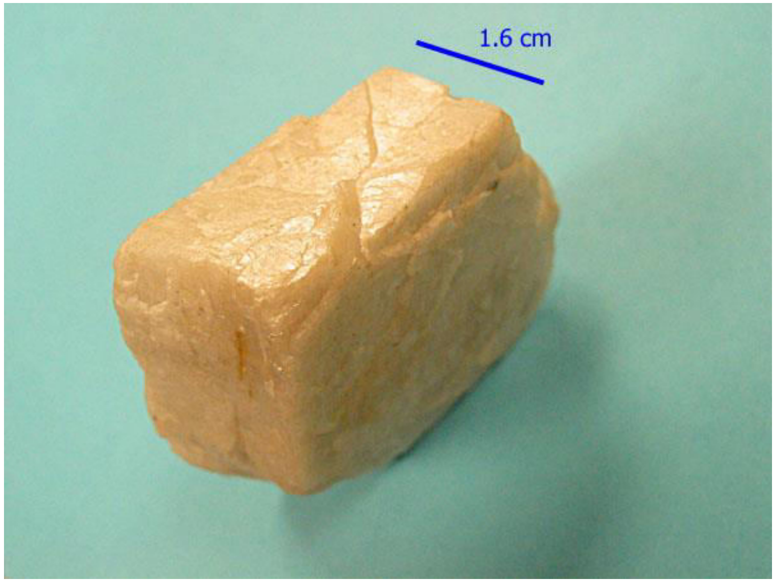


Potassium Feldspar

The most common variety of potassium feldspar is orthoclase, number 6 on Mohs hardness scale. Although it is commonly a salmon pink colour, this is not a diagnostic feature (see plagioclase feldspar images to confirm this point). It has two cleavages that meet at right angles, to produce square edges as seen in these specimens. Streak is white. This mineral may have simple twinning, but never exhibits the multiple twinning that plagioclase feldspar may show.

Potassium Feldspar

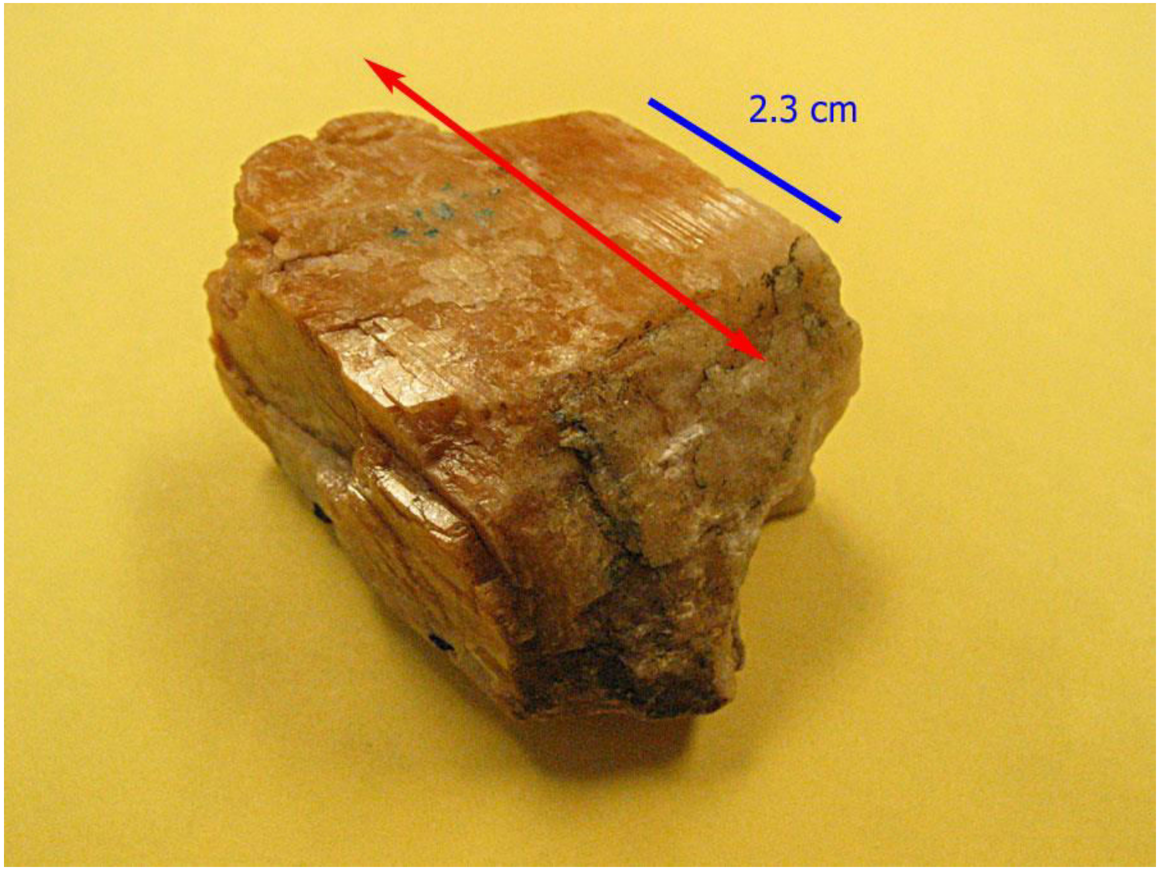




This specimen is included to emphasize the fact that one can not say with confidence that potassium feldspar is pink, and plagioclase white, although this is often the case. In the left-hand image, the upper face and lower left faces are cleavages, and in the right-hand image, the upper face and shaded lower right face are cleavages. Note again that cleavages tend to be expressed in a somewhat discontinuous fashion.

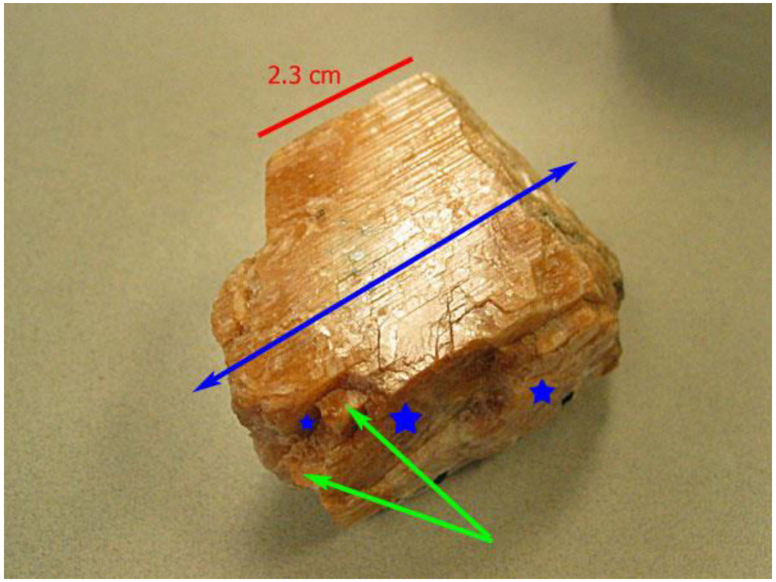
Plagioclase Feldspar

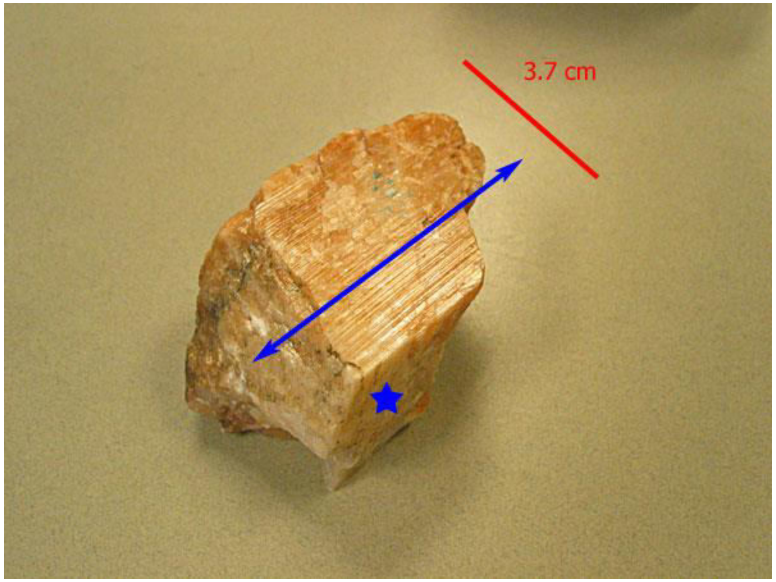
This mineral has many properties in common with potassium feldspar, which we emphasize on this slide.



The hardness is 6, colour is variable, including salmon pink as seen here, and the streak is white. Two excellent cleavages meet at right angles (upper and left-facing surfaces in the image above). However, plagioclase feldspar may have multiple (or polysynthetic) twinning striations, as seen on the upper face parallel to the red arrow.

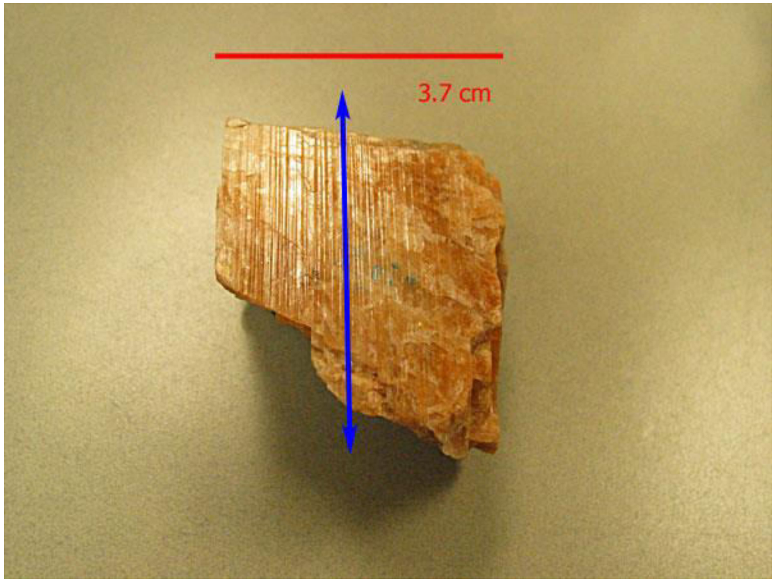
Plagioclase Feldspar

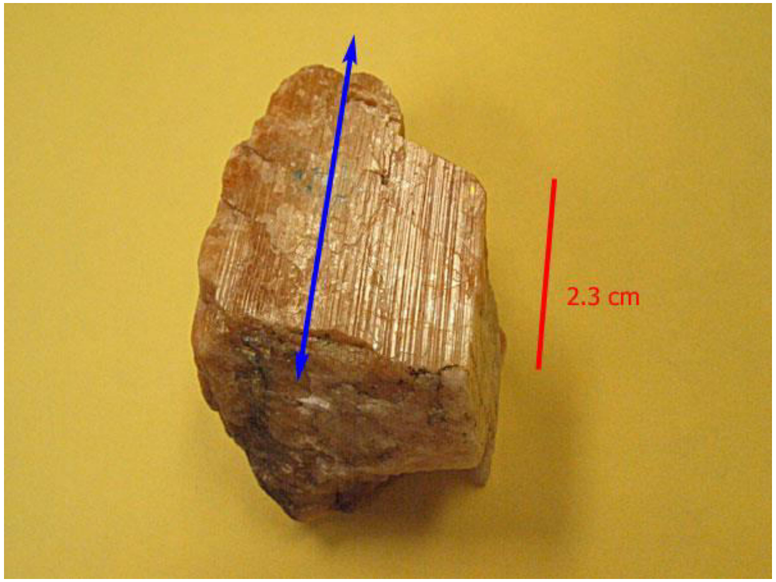




This reoriented specimen exhibits the twinning striations more clearly, parallel to the blue arrows. Resembling very fine scratches, they represent the intersection between twin planes and the upper surface of the crystal, and are flush with that surface. They are not seen on the faces marked with blue stars, because they are parallel to those faces, but could be seen on the faces highlighted by green arrows.

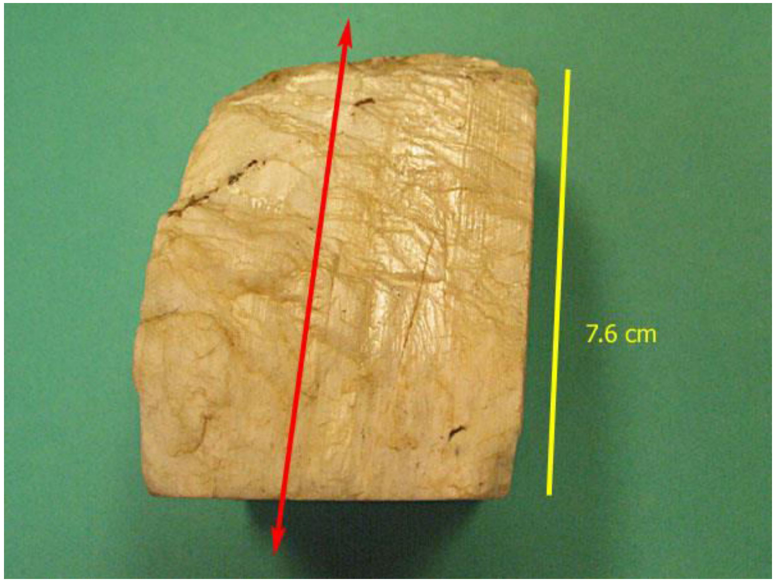
Plagioclase Feldspar

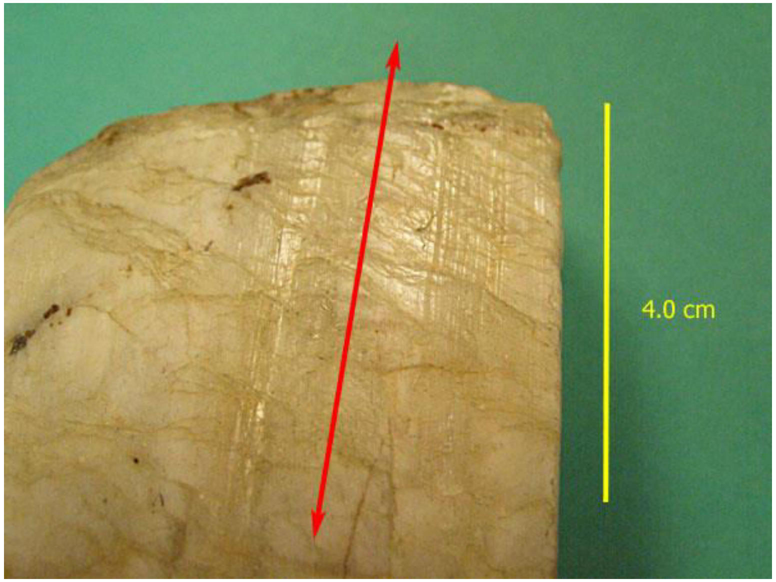




The same crystal yet again conveys the idea that the twinned crystal consists of slices with alternating orientation of the crystal structure. As a result, some slices catch the light in such a way as to reflect it, and others do not, showing up salmon pink rather than being washed out. We stress that the striations are an optical effect produced by the fact that crystal structure controls the interaction of light with a specimen.

Plagioclase Feldspar





This white specimen, with twinning striations running parallel to the red arrows, illustrates the fact that portions of the twinned crystal are not necessarily all of the same thickness, although they tended to be nearly so in the specimens in the earlier slides. Note the broad uniform band, almost 1 cm wide, sandwiched between twins whose planes are less than 1 mm apart.

- **Tectosilicates**
  - **framework structure and much substitution of Al for Si**
  - **very important rock forming minerals**
    - ***SiO_2 polymorphic group***
      - **quartz varieties include <u>smoky quartz,</u> <u>amethyst</u>, <u>rose quartz</u>, <u>tiger's eye</u>, <u>jasper quartz</u>, <u>chalcedony</u>, <u>opal</u>, <u>flint-chert</u>**
    - ***K-feldspar polymorphic group***
      - **<u>orthoclase</u> pinkish-reddish to beige in color occurring often with perthite form**
      - **<u>microcloine</u> blue-green in color resulting from an <u>omission solid solution</u> effect caused by 1Pb^{+2} ionic substitution for every 2K^{+1}**

- *Plagioclase feldspar solid solution series*
  - **have twinning striations**
  - **albite—sodic variety white or light in color**
  - **labradorite—light-dark gray commonly displaying labradorescence**
  - **anorthite—calcic variety and black in color**
- *feldspathoid group*
  - **minerals containing about 2/3 the amount of silica resulting from a silica deficient magma**
  - **leucite—(2)$KAlSi_2O_6$ = K_2O + Al_2O_3 + $\underline{4SiO_2}$ compared to orthoclase (2)$KAlSi_3O_8$ = K_2O + Al_2O_3 + $\underline{6SiO_2}$**
  - **sodalite**

- *Zeolite group*
  - **hydrous silicates displaying ionic exchange and absorptive properties acting as water softeners by exchanging Na^{+1} for Ca^{+2}— $Na_2Al_2Si_3O_{10}.2H_2O$(natrolite) forming $CaAl_2Si_3O_{10}.2H_2O$**
  - **<u>stilbite–</u> occurs often in tabular or sheaflike aggregates**