Rock forming minerals

The Mineral Olivine

- **Chemistry:** (Mg, Fe)2SiO4, Magnesium Iron Silicate.
- **Class:** Silicates
- **Subclass:** Nesosilicates
- **Group:** Olivine
- **Uses:** As gemstones, industrial uses as refractory sands and abrasives, an ore of magnesium and as mineral specimens.
- **Group:** Olivine is actually a name for a series between two end members, fayalite and forsterite. Fayalite is the iron rich member with a pure formula of Fe2SiO4.
- Forsterite is the magnesium rich member with a pure formula of Mg2SiO4.
- the series includes:
  - Ca_2SiO_4 - larnite
  - Mn_2SiO_4 - tephroite
  - $CaMgSiO_4$ - monticellite (which is commonly found in metamorphosed dolomites)

Physical properties for hand sample

- **Color** is a light near emerald green to the more common pale yellowish green; also found colorless, greenish brown to black.
- **Luster** is vitreous.
- **Transparency:** Crystals are transparent to translucent.
- **Crystal System** is orthorhombic;
- **Habits** include flatten tabular to box shaped crystals, but good crystals are rare. More commonly found as grains in alluvial gravels and as granular xenoliths in magnesium rich volcanic rock. Also massive. **Twinning** is rare, but has produced star shaped trillings.
- **Cleavage** is poor in two directions at 90 degrees, is more distinct in fayalite.
- **Fracture** is conchoidal.
- **Hardness** is **6.5 - 7.**
- **Specific Gravity** is approximately **3.2** for **forsterite** - **4.3** for **fayalite** (above average for non-metallic minerals).
- **Streak** is white.
- **Associated Minerals** are pyroxene group minerals, ca-felspars, amphiboles.
- **Common rocks: ultramafic**, **mafic** rocks (Dunite, peridotite, basalt, gabbro). It is also found in **metamorphic** rocks and Serpentine deposits as a primary mineral. Olivine may also occur in **meteorites**.
- It weathers to iddingsite (a combination of clay minerals, iron oxides and ferrihydrites) readily in the presence of water.

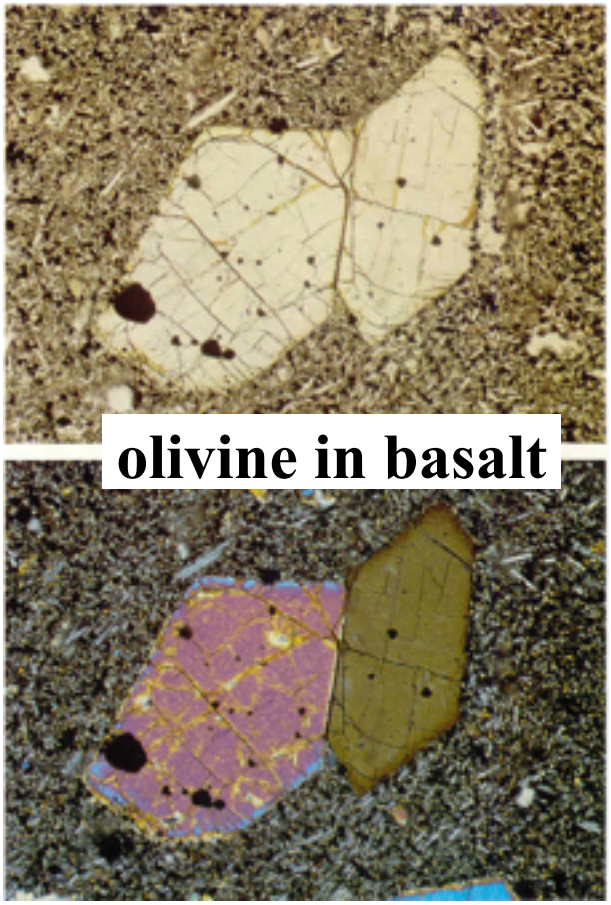
Optical properties for thin section

Plane-Polarized Light

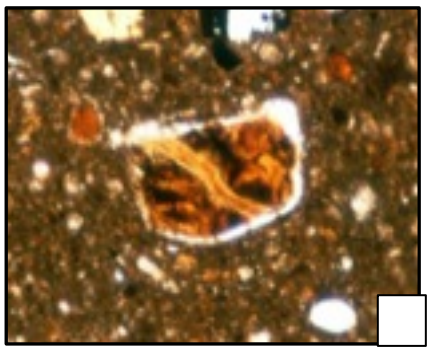
- Moderately high relief
- colorless
- Clear, occasionally very light yellowish or greenish
- No cleavage
- Commonly rimmed with greenish alteration products to iddingsite mineral
- Internal fracturing of grains common
- Never occurs with quartz

Crossed Polarizers

- Parallel extinction
- Bright second-and third-order interference colors.
- Alteration products tend to have low interference colors.



olivine in basalt



Alteration of olivine to iddingsite

Pyroxene Group

olivine in gabbro

Chemical Formula: $(NaCa)(Mg,Fe,Al)(Al,Si)_2O_6$– Sodium Calcium Magnesium Iron Aluminum Silicate.

Pyroxenes have the general formula $XY(Si,Al)_2O_6$ (where X represents calcium, sodium, iron^{+2} and magnesium and more rarely zinc, manganese and lithium and Y represents ions of smaller size, such as chromium, aluminium, iron^{+3}, magnesium, manganese, scandium, titanium, vanadium and even iron^{+2}).

- **Class:**Silicates
  - **Subclass/ structure:** Inosilicates **consisting of single chains of silica tetrahedra**
  - **Crystal system:** Monoclinic or orthorhombic
  - **Interference figure:** Biaxial
  - **Group:**The pyroxenes can be divided up into **3 subgroup:**

1- Calcium-rich pyroxenes are **Augite** is a dark green to black and **Diopside** is a white to light green

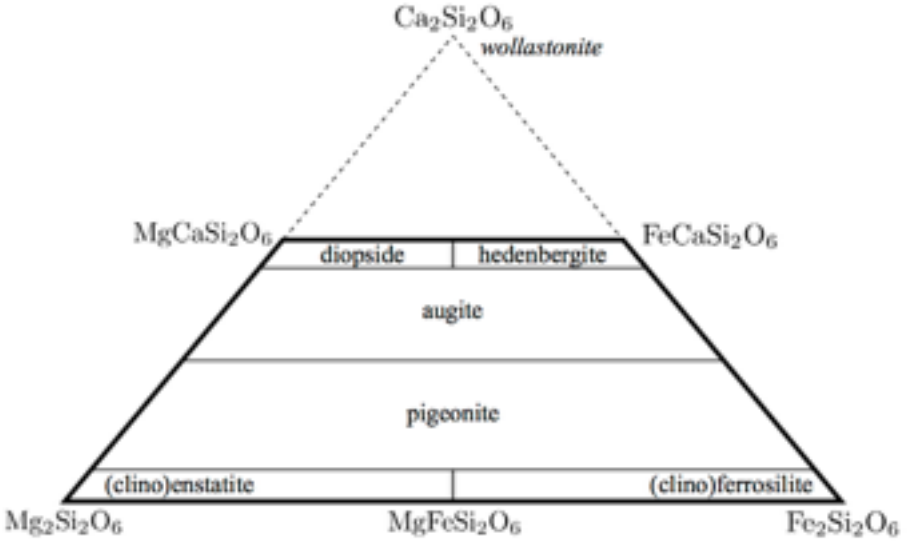
2- Magnesium-rich pyroxenes form a continuous replacement series between **enstatite**, an iron-free magnesium pyroxene, and **hypersthene**, an iron-bearing magnesium pyroxene.

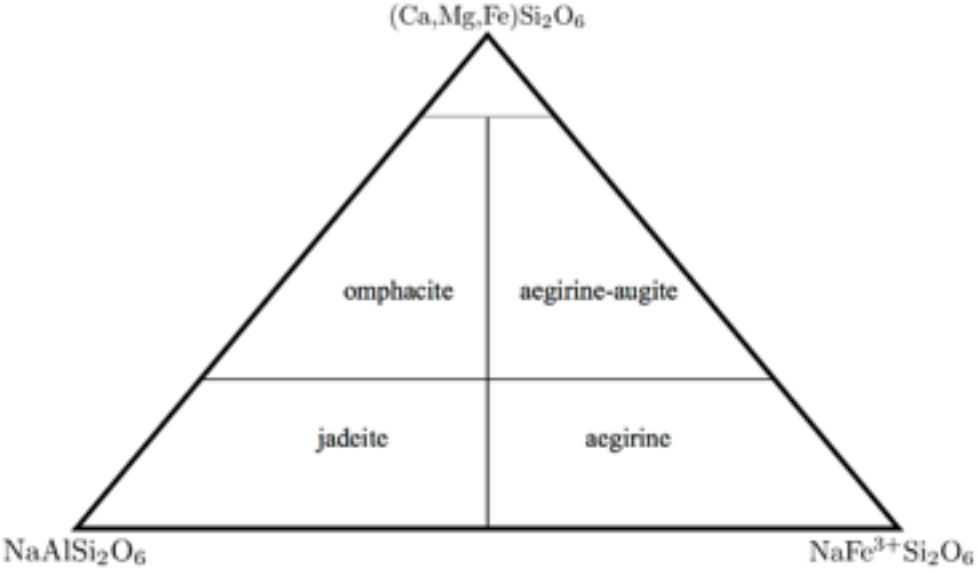
3- Sodium-rich pyroxenes include a dark green to black iron-bearing form known as **aegirine** and a green iron-free variety known as **jadeite**

- **Uses:** Pyroxenes are an important component of many decorative building stones, where their dark green to black colors contribute to the stones' decorative pattern.

Physical properties for hand sample

- **Color:** Usually dark green, dark brown or black, but some varieties are white to light green
- **Cleavage:** Two directions, that meet at nearly right angles (87° and 93°)
- **Hardness:** 5 to 6 (harder than glass)
- **Specific** Gravity: 3.2 to 3.5 (average), increases with iron content
- **Luster:** Vitreous (glass-like), in dark colored samples can be mistaken as metallic
- **Habit**: stubby prismatic with nearly square cross sections perpendicular to cleavage directions
- **Streak:** White, greenish white or gray
- **Associated minerals:**Olivine, Ca-feldspares, amphiboles
- **Common rocks: Mafic, ultra-mafic, intermediate igneous rocks**(basalt, gabbro, peridotite, diorite, andesite,dacite,).
- although they are also common in some medium-grade to high-grade **metamorphic rocks (gneiss).**





Optical properties for thin section

A. Orthopyroxene

-**Enstatite**- Thin section: Pale colored with greenish to pinkish pleochroism. Pure enstatite can be colorless,. High relief. Euhedral crystals will be stubby prisms.

First order yellow or below. parallel extinction.

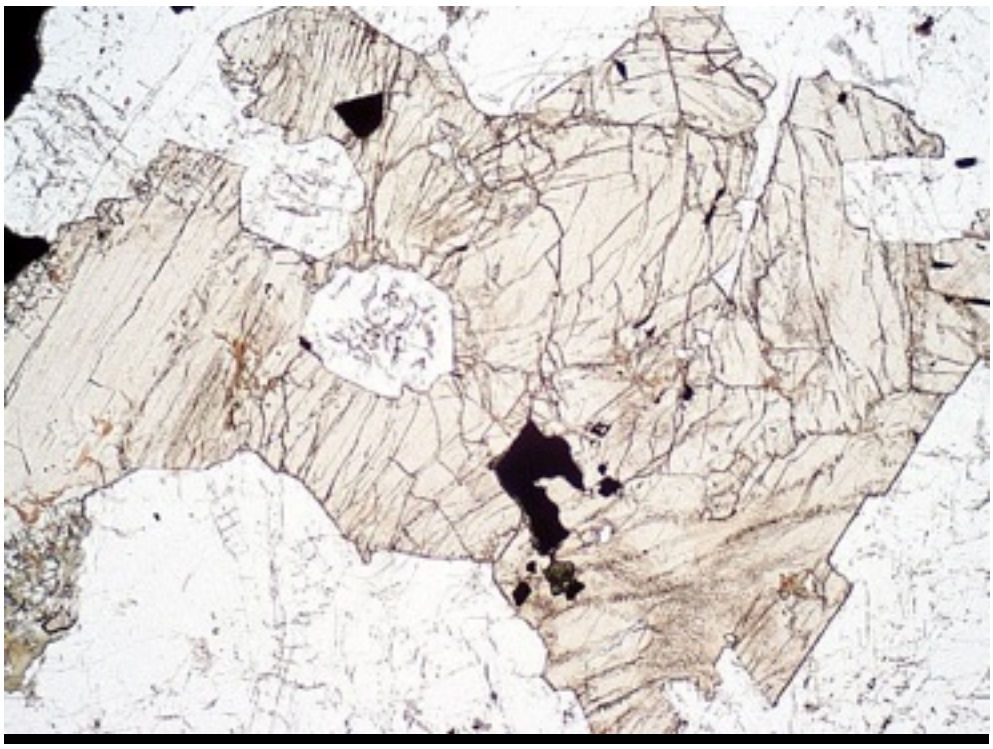
B. Clinopyroxene

-**Pigeonite**-Thin section: Colorless to pale brownish green. Generally not pleochroic. High relief. two cleavages at 87°.

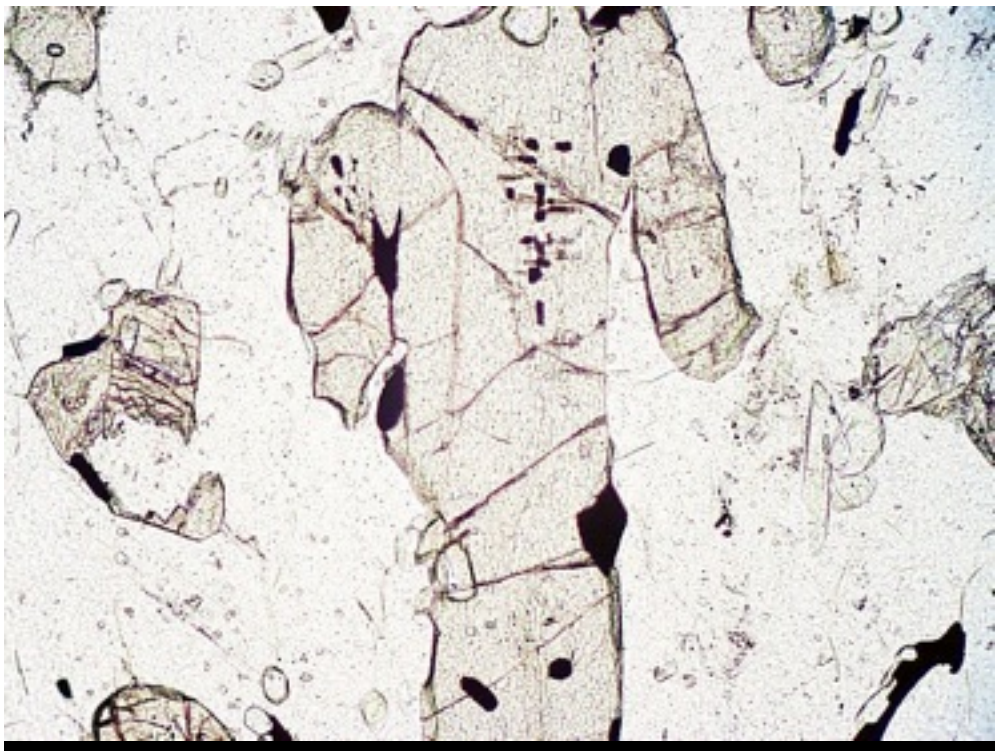
First order yellow or red common, up to lower second order is possible. inclined extinction.

-**Augite**- Thin section: Colorless, grey, pale green, pale brown, or brownish green. Can be weakly pleochroic. High relief. Typical pyroxene cleavage.

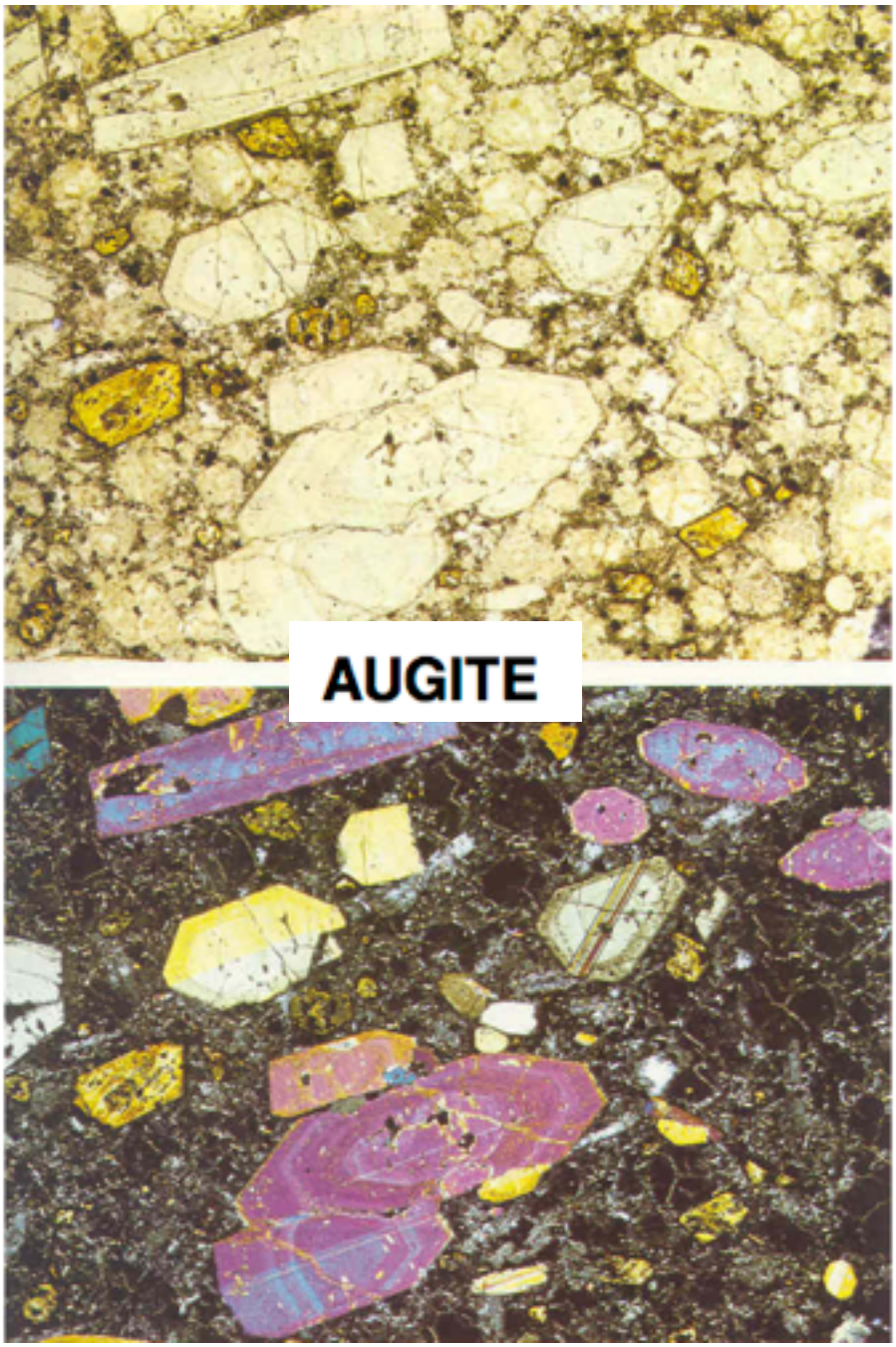
Lower to middle second order colors. inclined extinction.



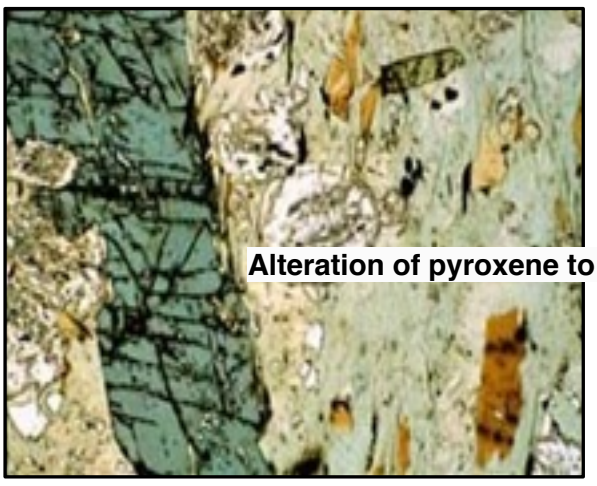
Augite (clinopyroxene, CPX), gabbro.



Enstatite (orthopyroxene, OPX) in gabbro



AUGITE



Alteration of pyroxene to chlorite

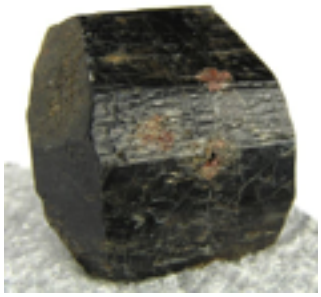
CLINOPYROXENE & ORTHOPYROXENE INTERGROWTH

PP light, the dark crystals are **pyroxenes** and the light crystals **plagioclase feldspars**. In some of the pyroxene crystals a lamellar structure can be seen but this is more clearly visible in the lower photograph, taken under crossed polars.

Pyroxene minerals (22 minerals)

- **Clinopyroxenes (monoclinic)**
  - Aegirine (Sodium Iron Silicate)
  - Augite (Calcium Sodium Magnesium Iron Aluminium Silicate)
  - Clinoenstatite (Magnesium Silicate)
  - Diopside (Calcium Magnesium Silicate, $CaMgSi_2O_6$)
  - Esseneite (Calcium Iron Aluminium Silicate)
  - Hedenbergite (Calcium Iron Silicate)
  - Jadeite (Sodium Aluminium Silicate)
  - Jervisite (Sodium Calcium Iron Scandium Magnesium Silicate)
  - Johannsenite (Calcium Manganese Silicate)
  - Kanoite (Manganese Magnesium Silicate)
  - Kosmochlor (Sodium Chromium Silicate)
  - Namansilite (Sodium Manganese Silicate)
  - Natalyite (Sodium Vanadium Chromium Silicate)
  - Omphacite (Calcium Sodium Magnesium Iron Aluminium Silicate)
  - Petedunnite (Calcium Zinc Manganese Iron Magnesium Silicate)
  - Pigeonite (Calcium Magnesium Iron Silicate)
  - Spodumene (Lithium Aluminium Silicate)
- **Orthopyroxenes (orthorhombic)**
  - Hypersthene (Magnesium Iron Silicate)
  - Donpeacorite, $(MgMn)MgSi_2O_6$
  - Enstatite, $Mg_2Si_2O_6$
  - Ferrosilite, $Fe_2Si_2O_6$
  - Nchwaningite (Hydrated Manganese Silicate)

Amphibole Group



Chemical Composition: $XY_2Z_5(Si, Al, Ti)_8O_{22}(OH, F)_2$
$NaCa_2(Mg,Fe,Al)_5(Al,Si)_8O_{22}(OH)_2$
The X represents large ions such as sodium or potassium and this site can be left vacant. The Y can be populated by sodium, calcium, iron (+2), lithium, manganese (+2), aluminum and/or magnesium and more rarely zinc, nickel, or cobalt. The Z can be filled by ions such as Iron (+3), manganese (+3), chromium (+3), aluminum, titanium (+4), iron (+2), lithium and manganese (+2).

Class: Siicates
Subclass/ structure: Inosilicates- double chains
Group: Amphibole
Subgroups: Cummingtonite Subgroup, Anthophyllite Subgroup, Tremolite Subgroup, Richterite Subgroup, Glaucophane Subgroup
The formulas of the common amphiboles:

- Actinolite $Ca_2(Mg, Fe^{+2})_5 Si_8O_{22}(OH)_2$
- Anthophyllite $(Mg, Fe)_7 Si_8O_{22}(OH)_2$
- Grunerite $[Fe_7Si_8O_{22}(OH)_2]$
- Arfvedsonite $Na_3(Fe^{+2})_4Fe^{+3} Si_8O_{22}(OH)_2$
- Cummingtonite $Mg_7 Si_8O_{22}(OH)_2$
- Edenite $NaCa_2Mg_5 Si_8O_{22}(OH)_2$
- Fluorrichterite $Na(CaNa)Mg_5 Si_8O_{22}F_2$
- Glaucophane $Na_2(Mg_3Al_2) Si_8O_{22}(OH)_2$
- The Hornblende Series $Ca_2(Mg, Fe^{+2})_4 (Al, Fe^{+3})Si_7AlO_{22}(OH)_2$
- Riebeckite $Na_2Fe^{+2}{}_3 Fe^{+3}{}_2Si_8O_{22}(OH)_2$
- Tremolite $Ca_2Mg_5 Si_8O_{22}(OH)_2$

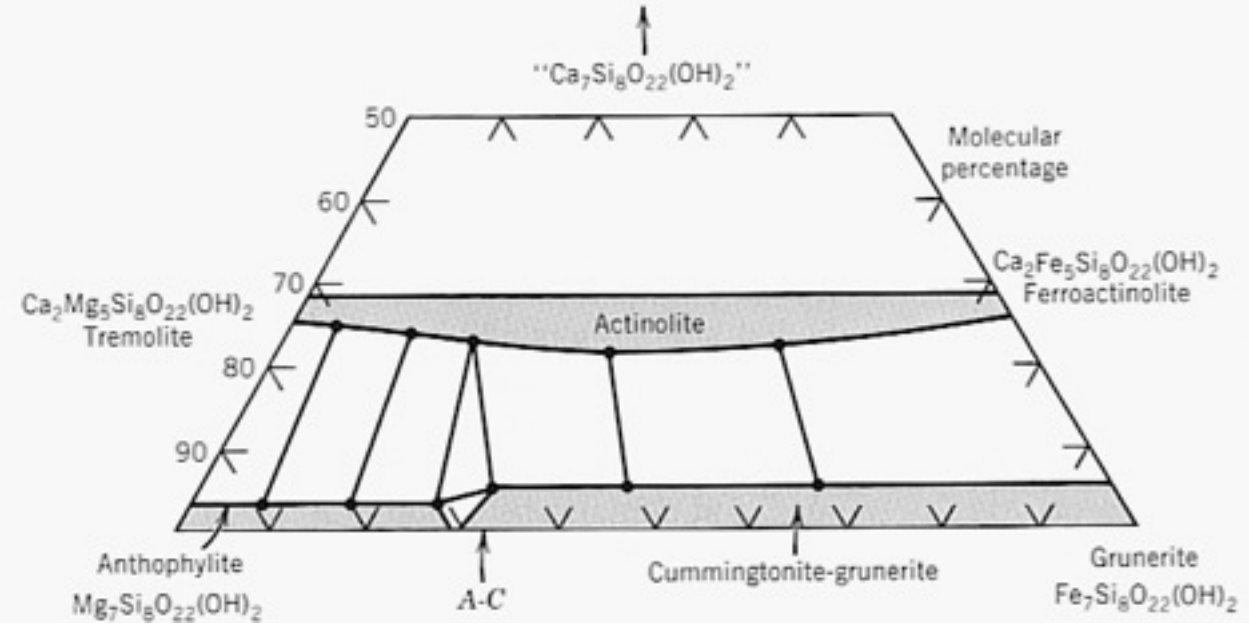
Crystal system: Most amphiboles are monoclinic, but members of the Anthophyllite Subgroup are orthorhombic
Uses: decorative building stones
Associated minerals: quartz, feldspars, augite, magnetite, micas and many medium grade metamorphic minerals.
Common rocks:igneous rocks (Intermediate, such as, diorite, andesite) and metamorphic rocks

Physical properties:

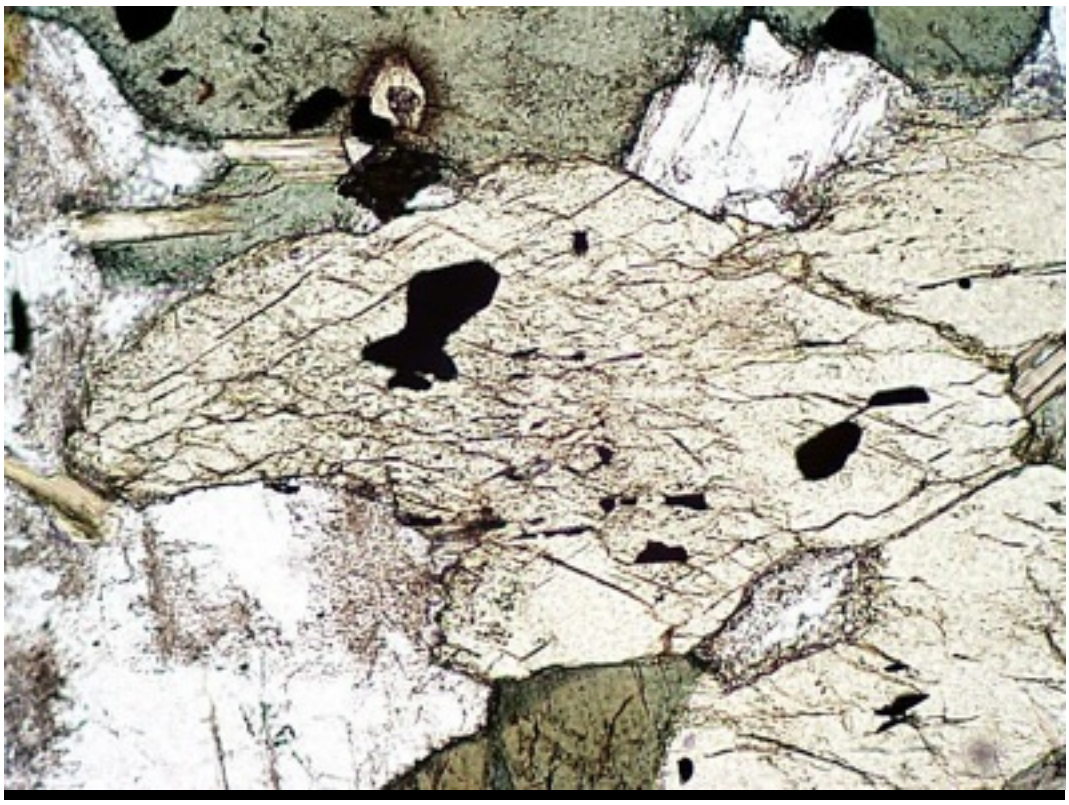
Color: Dark green, dark brown, black
Cleavage: Two directions that meet at 56 and 124 degrees
Hardness: 5 to 6 (harder than glass)
Specific Gravity: 3.0 to 3.4, increases with iron content (average)
Luster: Vitreous (glassy) to dull, opaque
Streak: White to gray
Habit: Typically amphiboles form as long prismatic crystals, radiating sprays, and fibrous aggregates;

Optical properties:

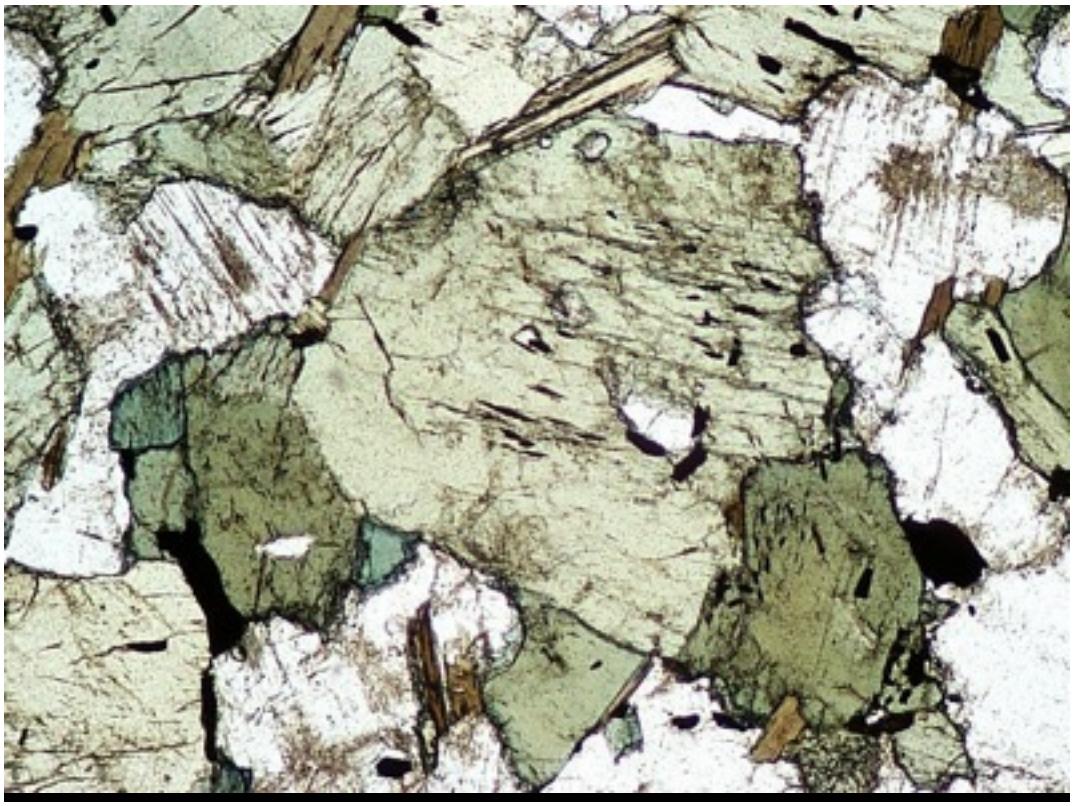
Optic: Biaxial
Relief: Moderate To High Pos
Color: Brown, Red, Yellow
Pleochroism: Yellow-Green, Brown
Cleavage: 2 Sets Intersect At 56 And 124
Extinction: Parallel Or Inclined
Alteration To: Biotite, Chlorite



HORNBLENDE



Green hornblende in a diorite.



These are the minerals of the Amphibole Group:

Cummingtonite Subgroup (Fe-Mg-Li Clinoamphiboles):

- Clinoferroholmquistite (Lithium Iron Aluminum Silicate Hydroxide)
- Clinoholmquistite (Lithium Magnesium Aluminum Silicate Hydroxide)
- Cummingtonite (Iron Magnesium Silicate Hydroxide)
- Dannemorite (Sodium Magnesium Aluminum Silicate Hydroxide)
- Grunerite (Iron Silicate Hydroxide)
- Holmquistite (Lithium Magnesium Aluminum Silicate Hydroxide)
- Magnesiocummingtonite (Magnesium Iron Silicate Hydroxide)
- Sodic-ferri-clinoferroholmquistite (Lithium Iron Magnesium Silicate Hydroxide)
- Tirodite (Manganese Magnesium Silicate Hydroxide)

Anthophyllite Subgroup (Fe-Mg-Li Orthoamphiboles):

- Anthophyllite (Magnesium Iron Silicate Hydroxide)
- Ferro-anthophyllite (Iron Silicate Hydroxide)
- Ferrogedrite (Iron Aluminum Silicate Hydroxide)
- Ferroholmquistite (Lithium Iron Aluminum Silicate Hydroxide)
- Gedrite (Magnesium Aluminum Silicate Hydroxide)
- Protoferro-anthophyllite (Iron Manganese Magnesium Silicate Hydroxide)
- Protomangano-ferro-anthophyllite (Manganese Iron Magnesium Silicate Hydroxide)
- Sodicanthophyllite (Sodium Magnesium Silicate Hydroxide)
- Sodic-ferro-anthophyllite (Sodium Iron Silicate Hydroxide)
- Sodic-ferrogedrite (Sodium Iron Aluminum Silicate Hydroxide)
- Sodicgedrite (Sodium Magnesium Aluminum Silicate Hydroxide)
-

Tremolite Subgroup (Ca Amphiboles):

- **Actinolite (Calcium Mag**nesium Iron Silicate Hydroxide)
- Edenite (Sodium Calcium Magnesium Iron Aluminum Silicate Hydroxide)
- Ferro-actinolite (Calcium Iron Silicate Hydroxide)
- Ferro-edenite (Sodium Calcium Iron Aluminum Silicate Hydroxide)
- Ferrohornblende (Calcium Iron Aluminum Silicate Hydroxide)
- Ferrokaersutite (Sodium Calcium Iron Titanium Aluminum Silicate Hydroxide)
- Ferropargasite (Sodium Calcium Iron Aluminum Silicate Hydroxide)
- Ferrotschermakite (Calcium Iron Aluminum Silicate Hydroxide)
- Fluorocannilloite (Calcium Magnesium Aluminum Silicate Fluoride)
- Hastingsite (Sodium Calcium Iron Aluminum Silicate Hydroxide)
- Hornblende (Calcium Sodium Magnesium Iron Aluminum Silicate Hydroxide)
- Kaersutite (Sodium Calcium Magnesium Titanium Aluminum Silicate Hydroxide)
- Magnesiohastingsite (Sodium Calcium Magnesium Iron Aluminum Silicate Hydroxide)
- Magnesiohornblende (Calcium Magnesium Aluminum Iron Silicate Hydroxide)
- Magnesiosadanagaite (Sodium Calcium Magnesium Aluminum Iron Silicate Hydroxide)
- Pargasite (Sodium Calcium Magnesium Aluminum Silicate Hydroxide)
- Potassic-magnesiosadanagaite (Potassium Sodium Calcium Magnesium Aluminum Iron Silicate Hydroxide)

- Potassicpargasite (Potassium Sodium Calcium Magnesium Iron Aluminum Silicate Hydroxide Fluoride)
- Potassicsadanagaite (Potassium Sodium Calcium Iron Aluminum Silicate Hydroxide)
- Tremolite (Calcium Magnesium Iron Silicate Hydroxide)
- Tschermakite (Calcium Magnesium Aluminum Iron Silicate Hydroxide)

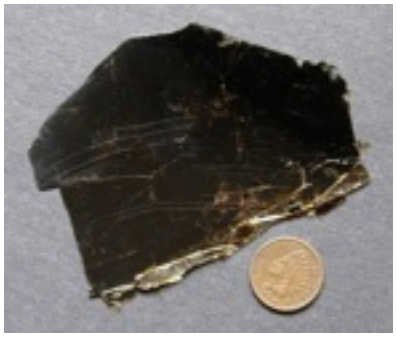
Richterite Subgroup (Ca-Na Clinoamphiboles):

- Barroisite (Calcium Sodium Magnesium Aluminum Iron Silicate Hydroxide)
- Ferrobarroisite (Calcium Sodium Iron Aluminum Silicate Hydroxide)
- Ferrorichterite (Sodium Calcium Iron Aluminum Silicate Hydroxide)
- Ferrowinchite (Calcium Sodium Iron Aluminum Silicate Hydroxide)
- Fluorrichterite (Sodium Calcium Magnesium Silicate Fluoride)
- Katophorite (Sodium Calcium Iron Aluminum Silicate Hydroxide)
- Magnesiokatophorite (Sodium Calcium Magnesium Aluminum Iron Silicate Hydroxide)
- Magnesiotaramite (Sodium Calcium Magnesium Aluminum Iron Silicate Hydroxide)
- Potassic-fluorrichterite (Potassium Sodium Calcium Magnesium Silicate Fluoride)
- Richterite (Sodium Calcium Magnesium Silicate Hydroxide)
- Taramite (Sodium Calcium Iron Aluminum Silicate Hydroxide)
- Winchite (Calcium Sodium Magnesium Aluminum Iron Silicate Hydroxide)

Glaucophane Subgroup (Alkali Amphiboles):

- Arfvedsonite (Sodium Iron Magnesium Silicate Hydroxide)
- Eckermannite (Sodium Magnesium Aluminum Silicate Hydroxide)
- Ferro-eckermannite (Sodium Iron Aluminum Silicate Hydroxide)
- Ferroglaucophane (Sodium Iron Aluminum Silicate Hydroxide)
- Fluoro-ferroleakeite (Sodium Iron Lithium Silicate Fluoride)
- Glaucophane (Sodium Magnesium Aluminum Silicate Hydroxide)
- Kornite (Sodium Potassium Magnesium Manganese Lithium Silicate Hydroxide)
- Kozulite (Sodium Manganese Iron Aluminum Silicate Hydroxide)
- Leakeite (Sodium Magnesium Iron Lithium Silicate Hydroxide)
- Magnesio-arfvedsonite (Sodium Magnesium Iron Silicate Hydroxide)
- Magnesioriebeckite (Sodium Magnesium Iron Silicate Hydroxide)
- Nyboite (Sodium Magnesium Aluminum Silicate Hydroxide)
- Riebeckite (Sodium Iron Silicate Hydroxide)
- Ungarettiite (Sodium Manganese Silicate Oxide)

Mica group



- **Chemical formula**: $X_2Y_{4-6}Z_8O_{20}(OH,F)_4$

in which

X is K, Na, or Ca or less commonly Ba, Rb, or Cs;
Y is Al, Mg, or Fe or less commonly Mn, Cr, Ti, Li, etc.;
Z is chiefly Si or Al, but also may include Fe^{3+} or Ti.

- **Class:** Silicates
- **Subclass/ structure: Phyllosilicates** two-dimensional sheet or layer structure
- **Crystal system**: monoclinic or triclinic
- **Group:** The mica group represents 37 phyllosilicate minerals that have a layered or platy texture, only 6 are common rock-forming minerals (Muscovite,biotite, phlogopite, paragonite, lepidolite, glauconite)
- **Uses:** As insulators in electronics
- **Associated minerals:** The Mica Group minerals are closely associated with the clay minerals
- **Common Rocks:** igneous, sedimentary, and metamorphic

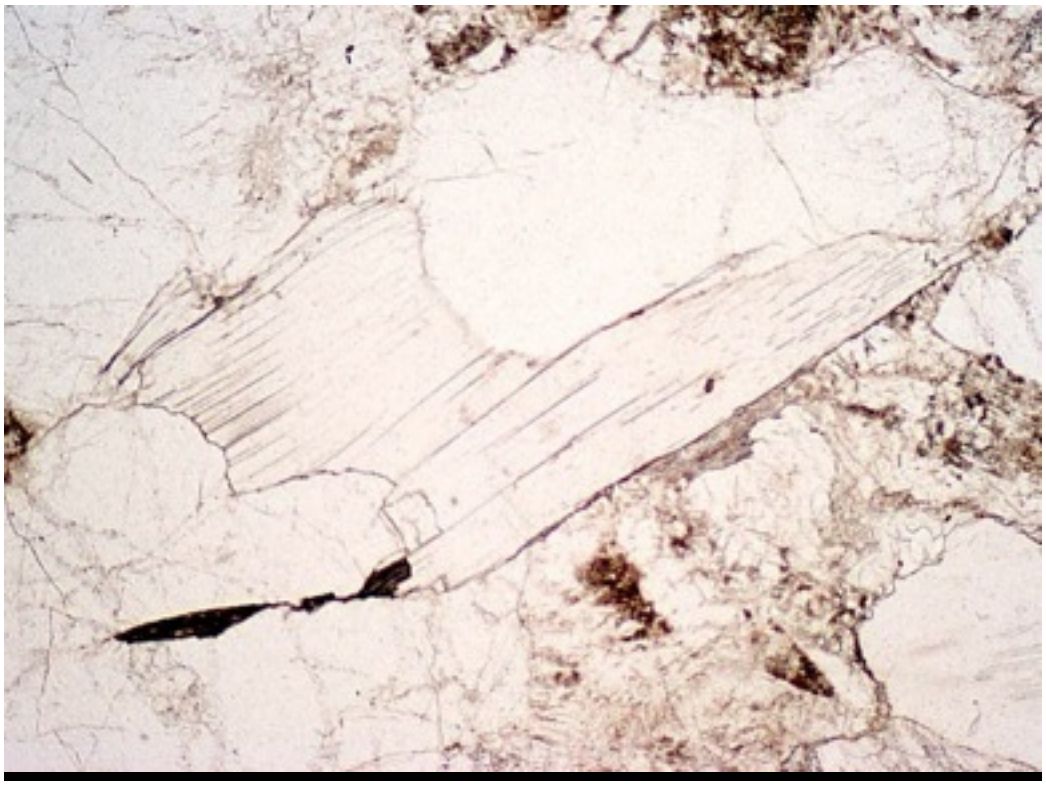
Physical properties:

- **Color(s):** white,yellowish,green, gray
- **Streak:** colorless
- **Luster:** vitreous to pearly
- **Transparency:** transparent, translucent, opaque
- **Specific Gravity:** 2.8
- **Hardness (Mohs):** 2.5 - 3
- **Cleavage**: 1 set
- **Habit**: layered or platy or sheet shape

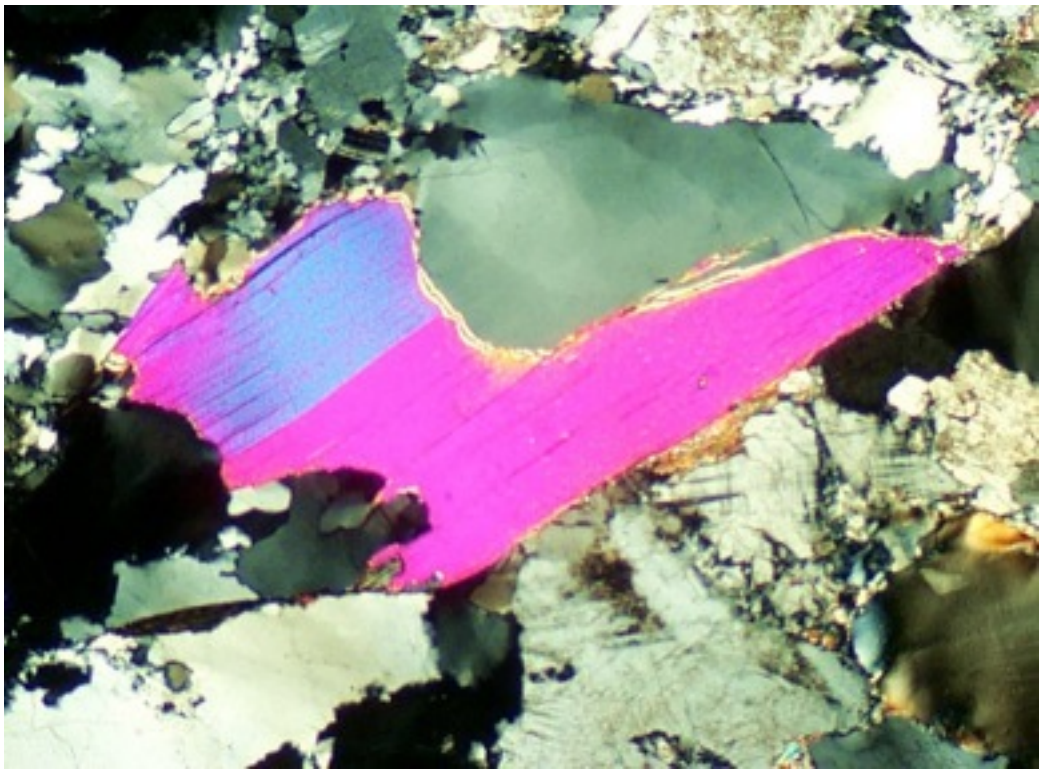
Optical properties:

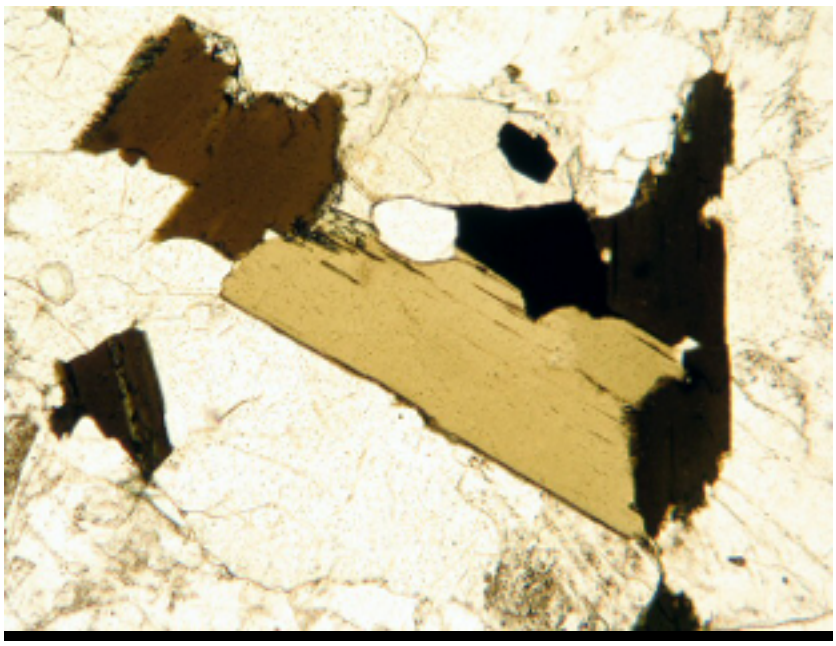
Plane-Polarized Light

- Moderate relief
- Orange, brown or dark green
- 1 set cleavage
- parallel extinction
- May be dark pleochroic halos around inclusions of zircon or other mildly radioactive minerals
- Second-and third-order interference colors usually not strikingly evident because of the strong natural coloration.
- altered to chlorite

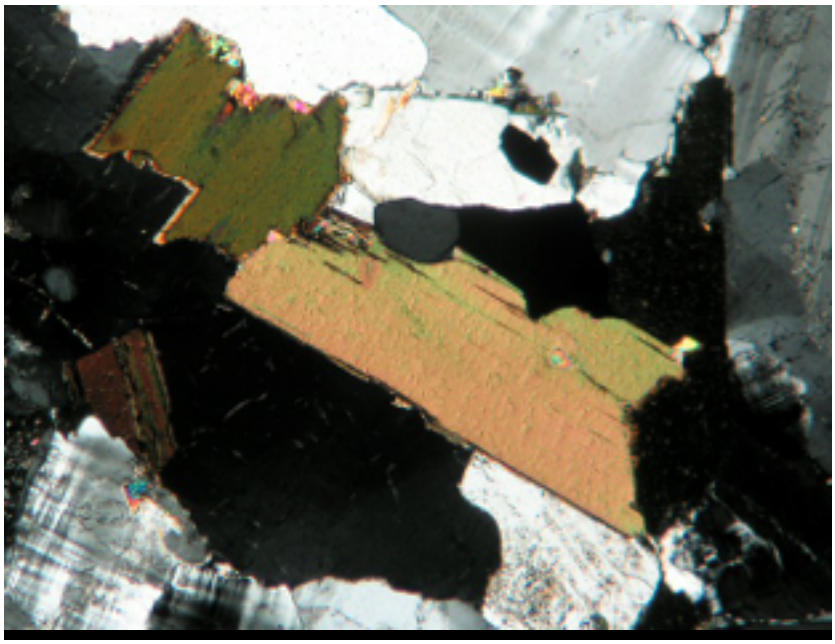


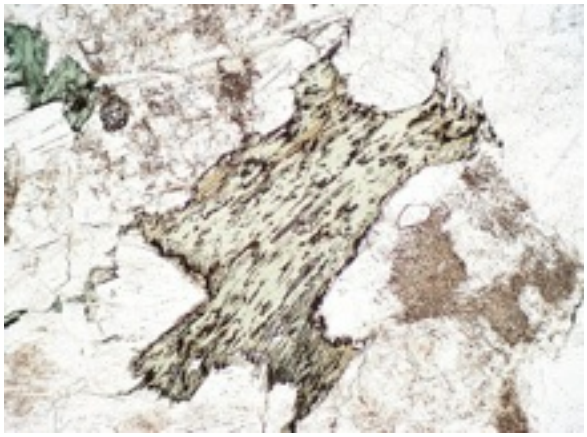
Muscovite





Biotite





Chlorite replacing biotite

Quartz group

Chemical Formula: SiO_2
Class: Silicates
Subclass/structure: Tectosilicates;
Crystal system: Hexagonal
Associated minerals: Mica, amphibole, and k- feldspars mineral
Common Rock: Igneous (granite and other felsic igneous rocks), Sedimentary (sandstone and shale), Metamorphic (schist, gneiss, quartzite)
Uses: several of which are semi-precious gemstones

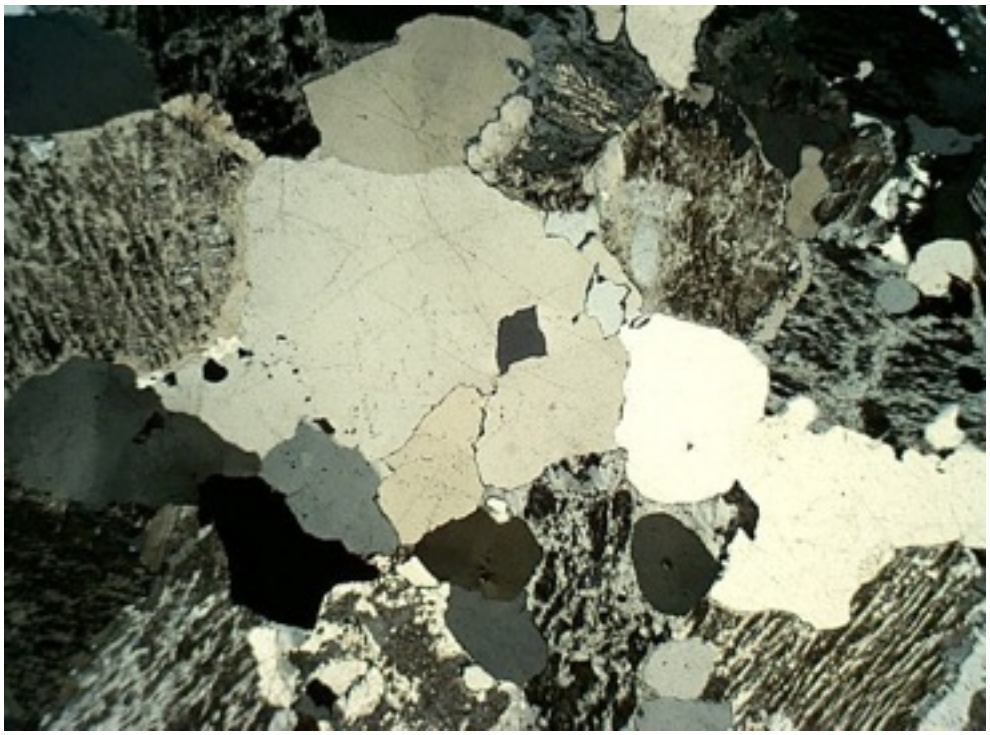
Physical properties:
Color Colorless, white, purple, pink, brown, and black. Also gray, green, orange, yellow, blue, and red. Sometimes multicolored or banded.
Streak White
Hardness 7
Crystal System Hexagonal
Transparency Transparent to opaque
Specific Gravity 2.6 - 2.7
Luster Vitreous. Transparent, colorless
Fracture: Conchoidal
Habit: Prism

Optical properties:
- Low relief
- fractured
- No cleavage
- Gray to white interference colors, sometimes to light yellowish white
- Wavy extinction common

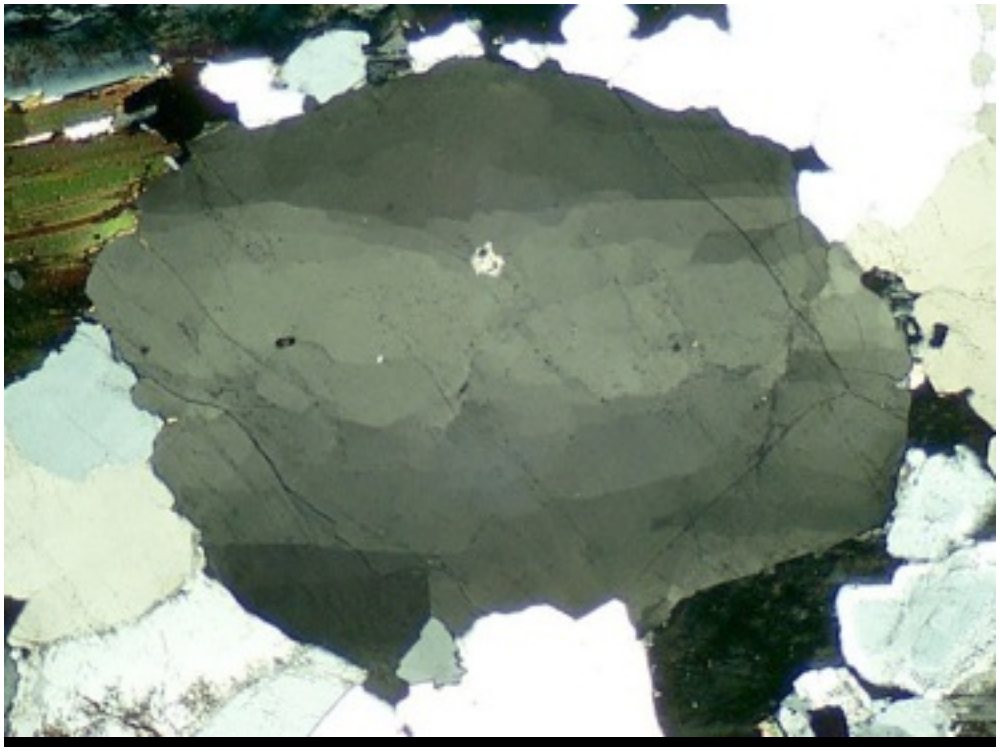
SiO_2 Minerals

There are nine known polymorphs of SiO_2, one of which does not occur naturally. These are:

Name	Crystal System	Density (g/cm^3)	Refractive Index (mean)
Stishovite	Tetragonal	4.35	1.81
Coesite	Monoclinic	3.01	1.59
Low (α) Quartz	Hexagonal	2.65	1.55
High (β) Quartz	Hexagonal	2.53	1.54
Kaetite (synthetic)	Tetragonal	2.50	1.52
Low (α) Tridymite	Monoclinic or Orthorhombic	2.26	1.47
High (β) Tridymite	Hexagonal	2.22	1.47
Low (α) Cristobalite	Tetragonal	2.32	1.48
High (β) Cristobalite	Isometric	2.20	1.48



Quartz crystals in alkali granite.



The Feldspar Group

($KAlSi_3O_8$ – $NaAlSi_3O_8$ – $CaAl_2Si_2O_8$) are a group of rock-forming minerals that make up as much as 60% of the Earth's crust.

Subclass: Tectosilicate (frameworks)
Crystal system: All feldspars have low symmetry, being only monoclinic, to triclinic.
parallel layers of twinned crystals.
They are slightly **hard** at around 6
density at 2.55 to 2.76.
vitreous **luster**.
They have t**wo directions of cleavage** at nearly right angles.
Common rocks: Feldspars also tend to crystallize in igneous enviroments, but are also present in many metamorphic rocks.

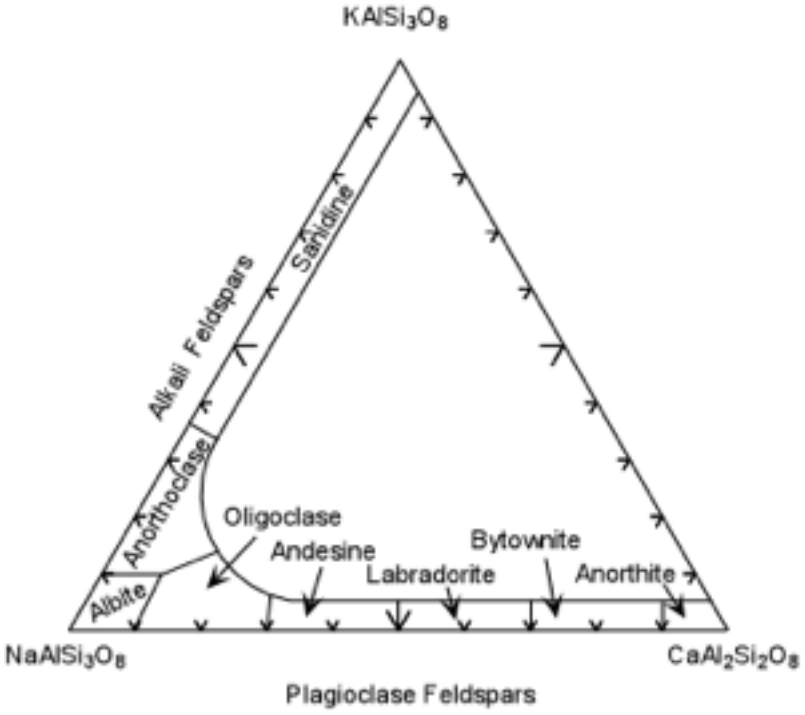
- The following are some of the more common feldspar minerals:

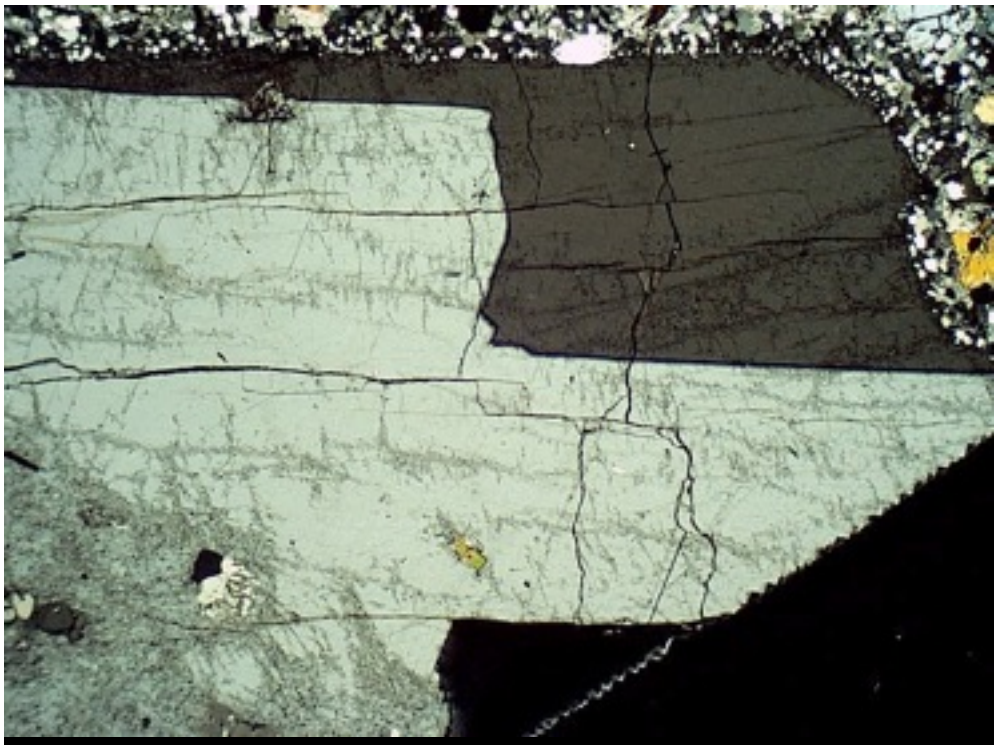
The plagioclase feldspars:

- albite (0 to 10) — $NaAlSi_3O_8$
- oligoclase (10 to 30) — $(Na,Ca)(Al,Si)AlSi_2O_8$
- andesine (30 to 50) — $NaAlSi_3O_8$ — $CaAl_2Si_2O_8$
- labradorite (50 to 70) — $(Ca,Na)Al(Al,Si)Si_2O_8$
- bytownite (70 to 90) — $(NaSi,CaAl)AlSi_2O_8$
- anorthite (90 to 100) — $CaAl_2Si_2O_8$

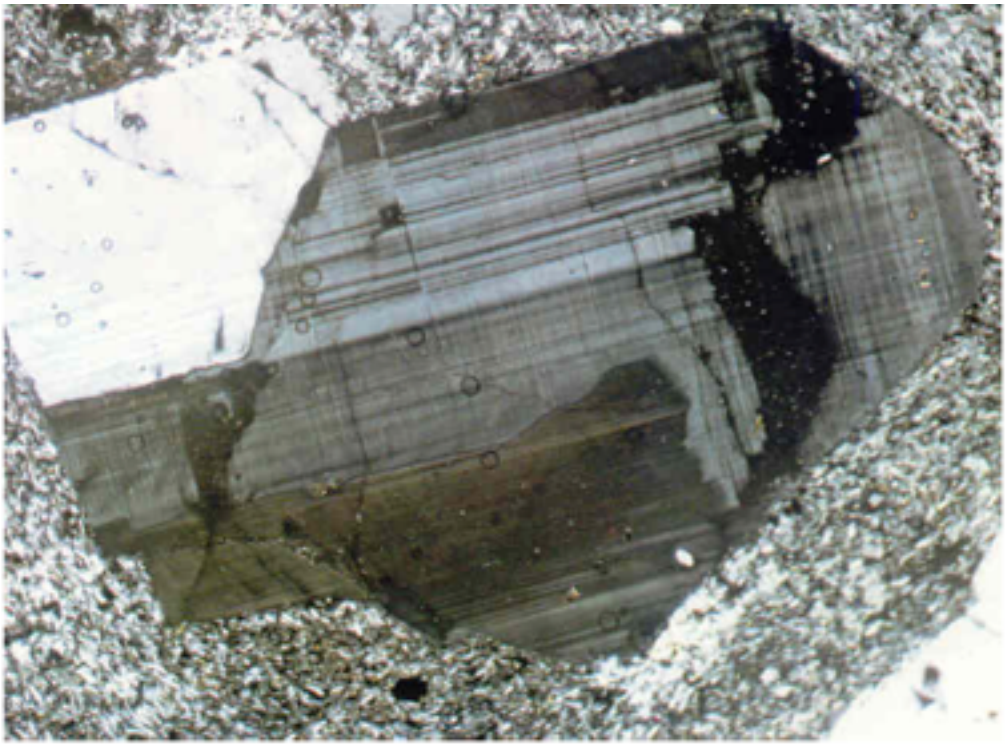
The alkali feldspars are as follows:

- orthoclase (monoclinic), — $KAlSi_3O_8$
- sanidine (monoclinic)—$(K,Na)AlSi_3O_8$
- microcline (triclinic) — $KAlSi_3O_8$
- anorthoclase (triclinic) — $(Na,K)AlSi_3O_8$

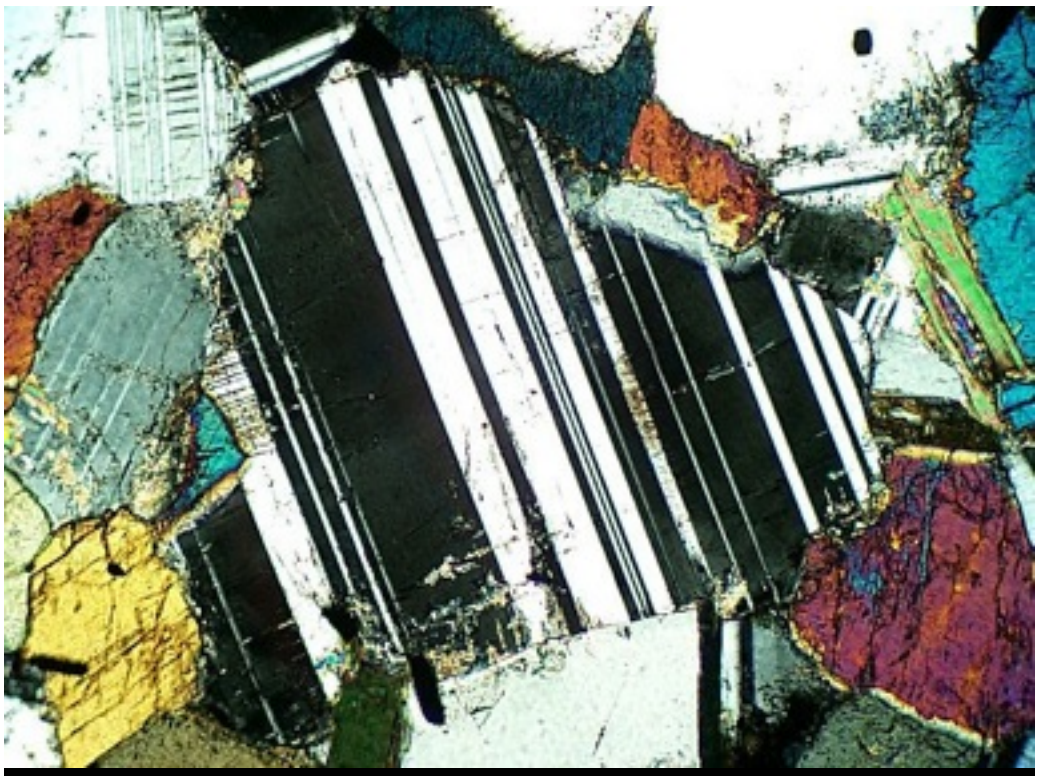




Orthoclase



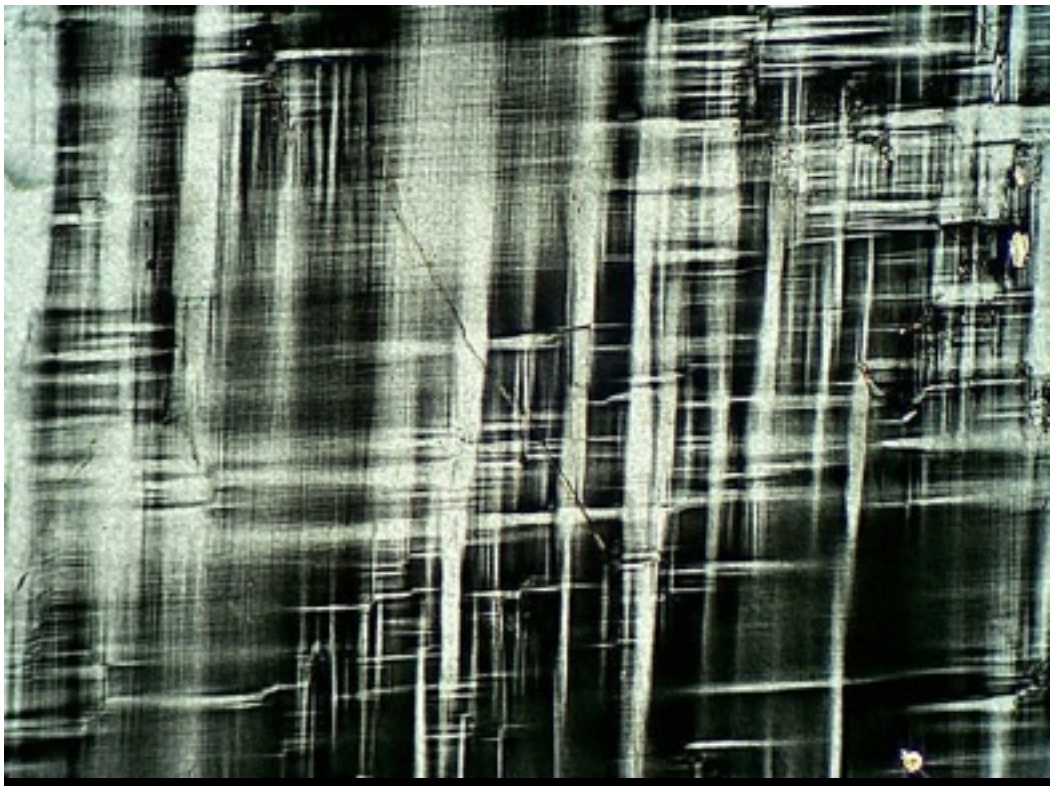
Anorthoclase



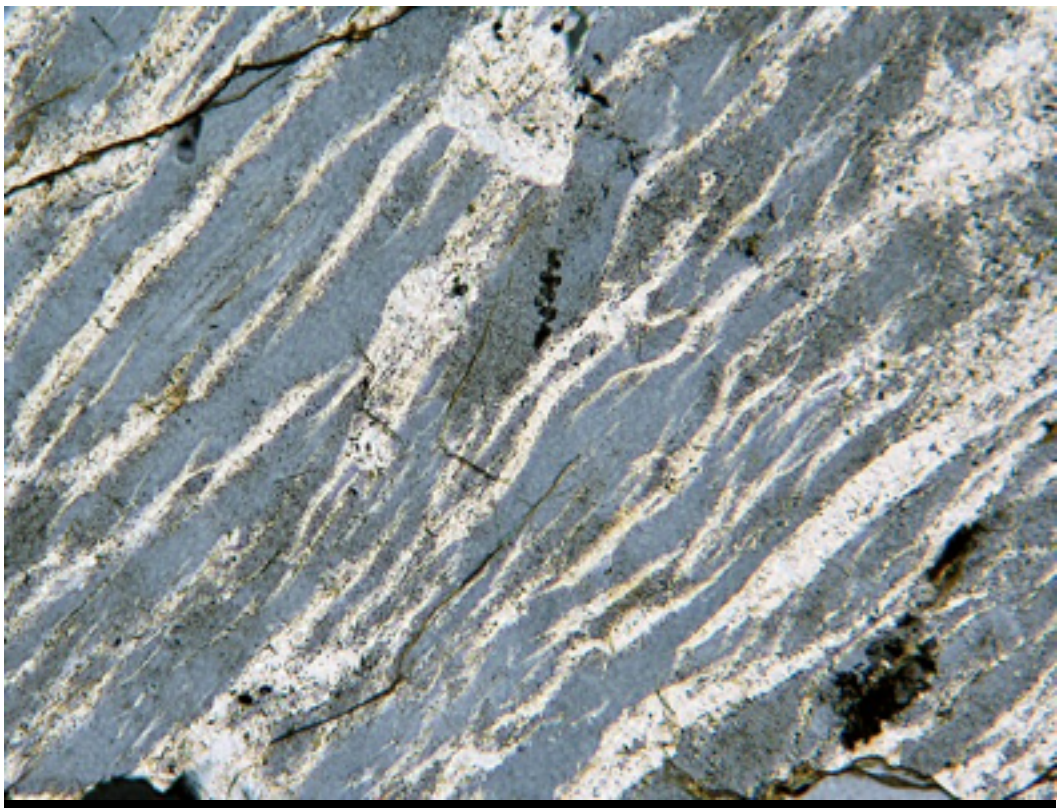
Multiple twining in Plagioclase

simple twining in sanidine

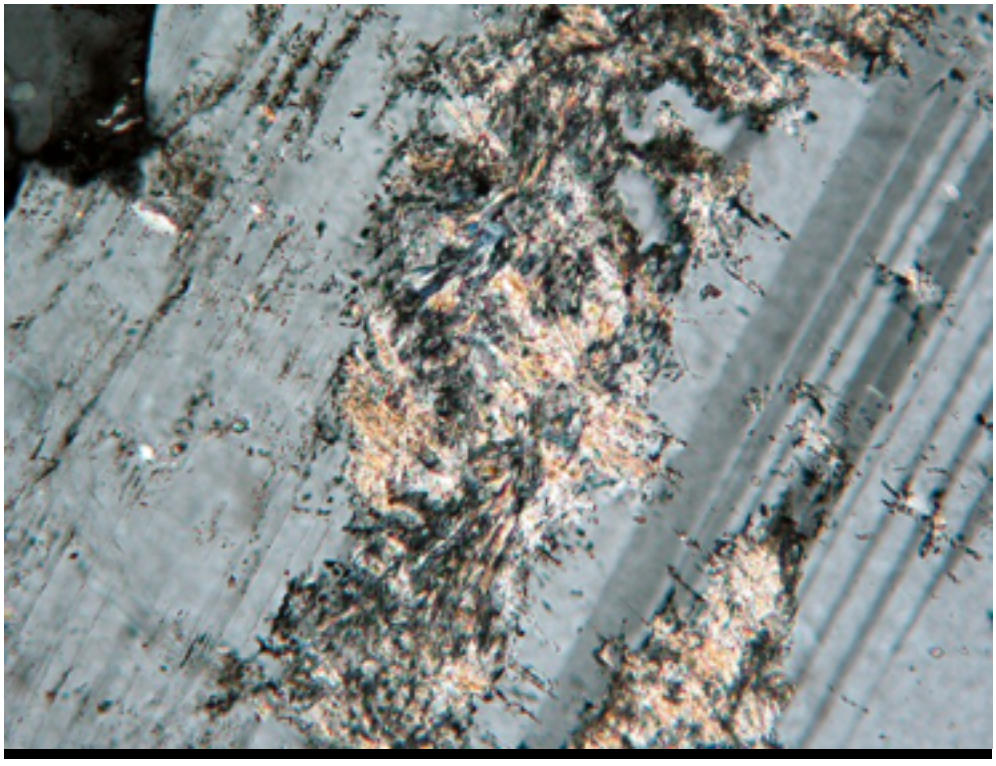
Plagioclase, zoned



Microcline cross hatch



Perthite The k-feldspar and plagioclase both exsolved



Sericite replacing or alteration of plagioclase