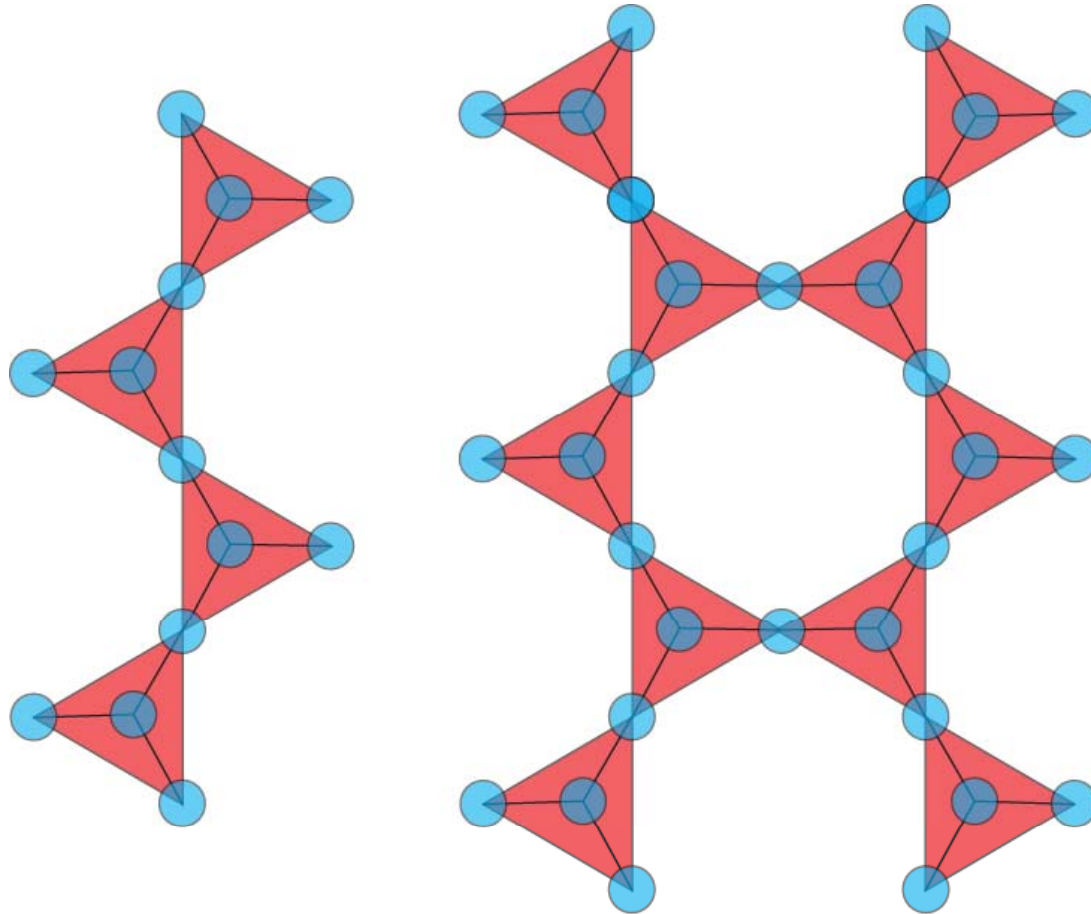


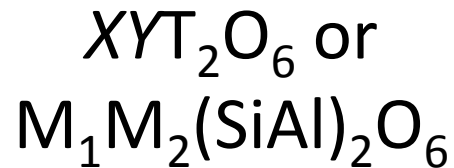
Inosilicates (chain silicates)



The most important two mineral groups are the pyroxenes and the amphiboles.

Pyroxenes

General Formula

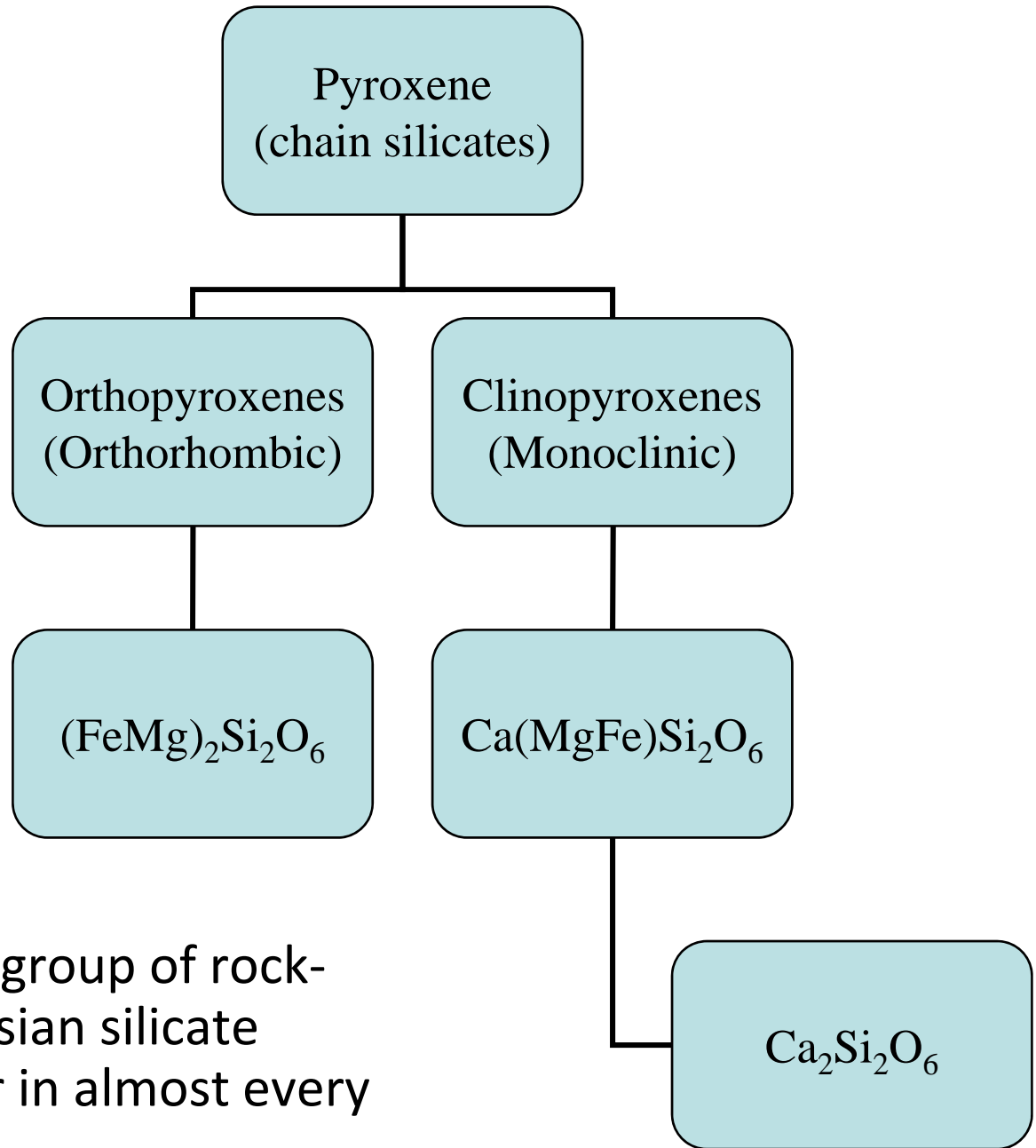


$X(M_2) = \text{Na, Ca, Mn Fe, Mg and Li}$

$Y(M_1) = \text{Mn, Fe, Al, Cr and Ti.}$

$T = \text{Si and Al.}$

- The most important group of rock-forming ferromagnesian silicate minerals. They occur in almost every type of igneous rock.

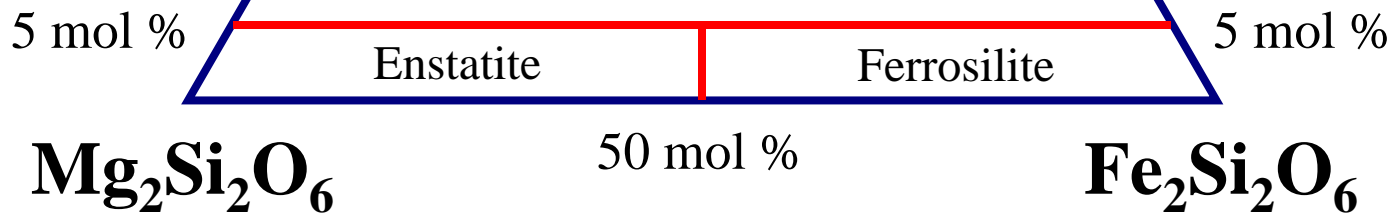


Orthopyroxenes



Magnesium-iron pyroxenes in which other cations occupy less than 10% of the M_1 - M_2 sites.

The M_1 and M_2 sites are essentially somewhat distorted octahedrally coordinated cations. (M_1 is more regular than M_2)



Clinopyroxenes

Wollastonite $\text{Ca}_2\text{Si}_2\text{O}_6$

Magnesium-iron pyroxenes in which Ca cations occupy 50% of octahedral sites. (All of the M_2 sites).

The grey areas represent miscibility gaps.

50 mol % $\text{CaMgSi}_2\text{O}_6$

Diopside Hedenbergite
Augite

55 mol % $\text{CaFeSi}_2\text{O}_6$

5 mol %

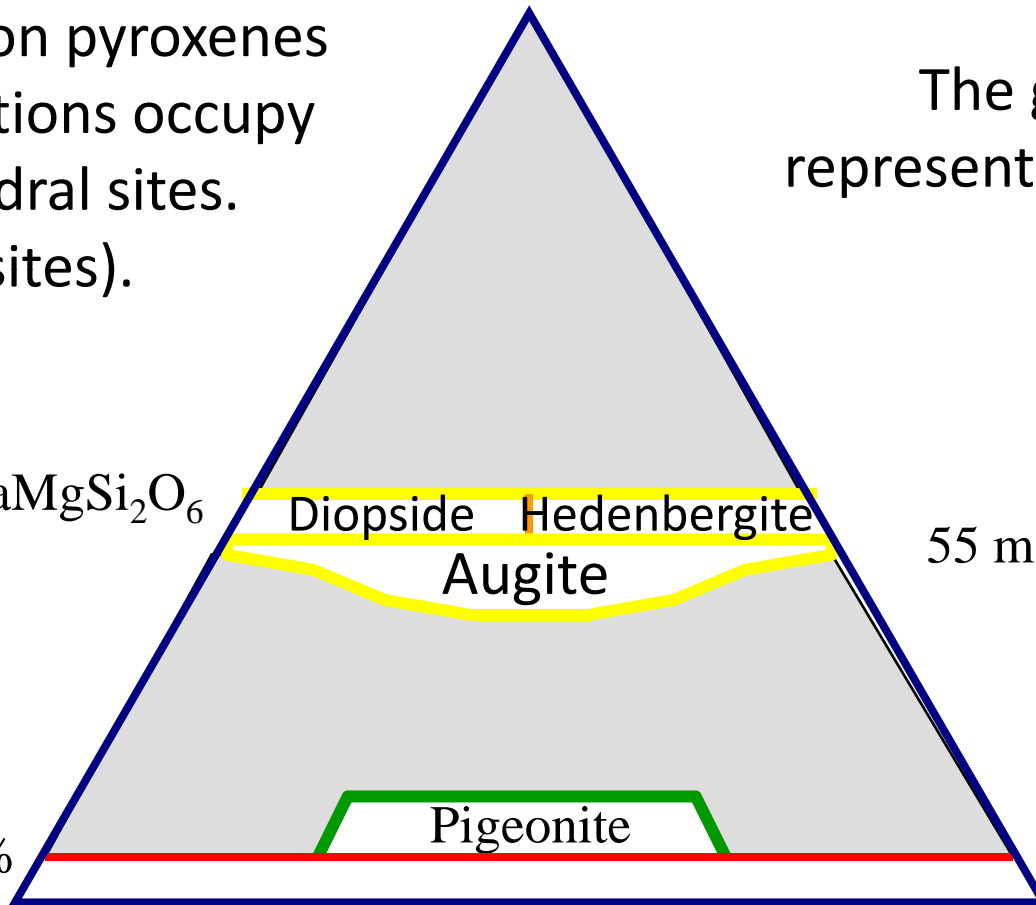
Pigeonite

10 mol %

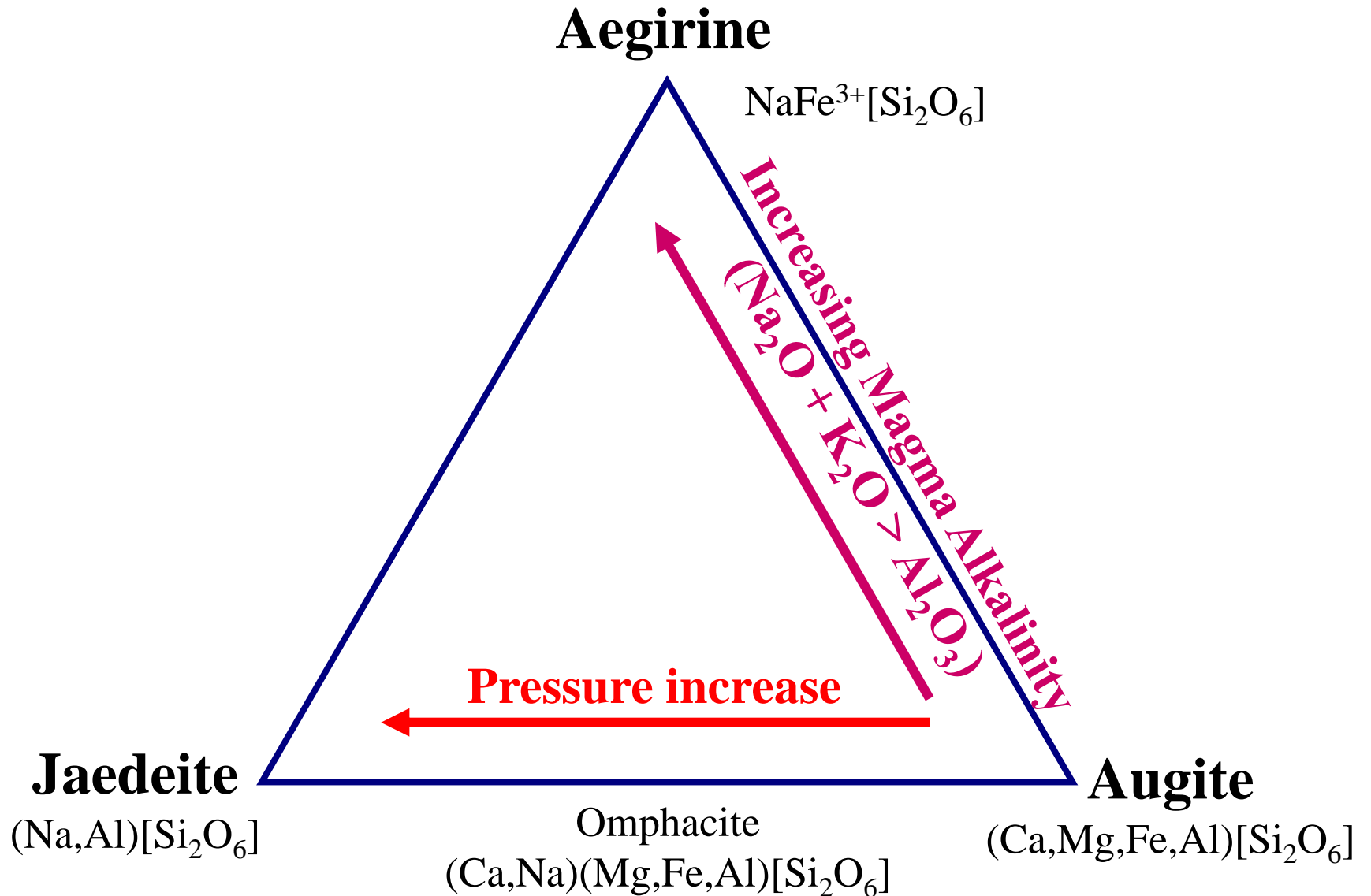
$\text{Mg}_2\text{Si}_2\text{O}_6$

50 mol %

$\text{Fe}_2\text{Si}_2\text{O}_6$



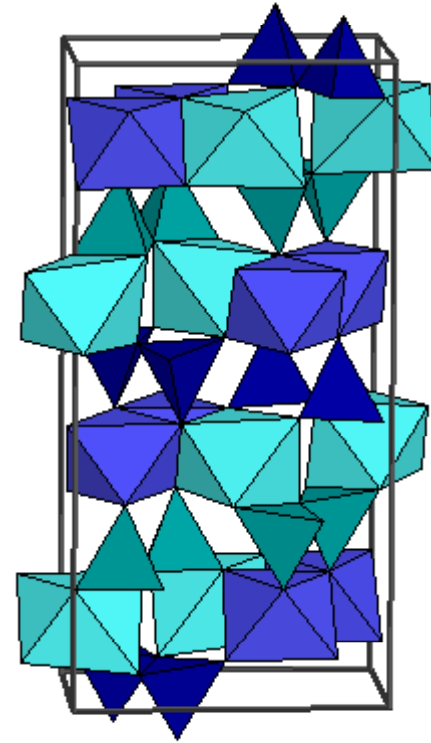
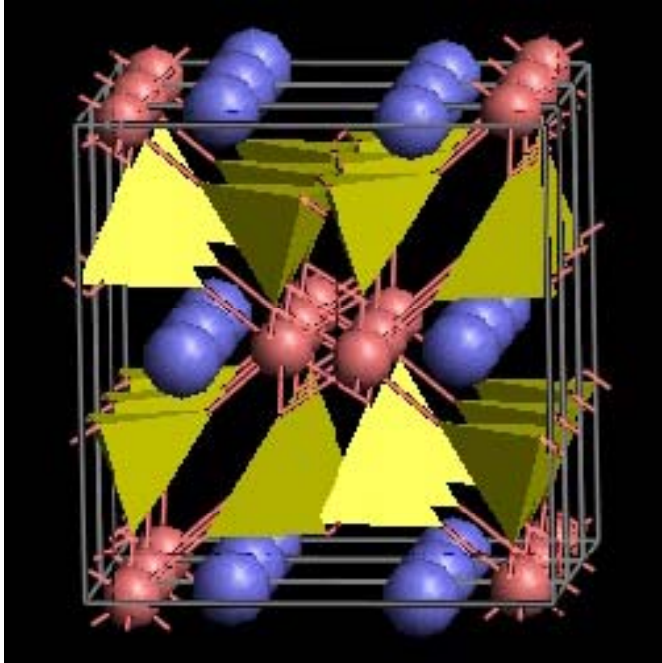
In special circumstances a complex coupled substitution involving both of the M-sites will occur.



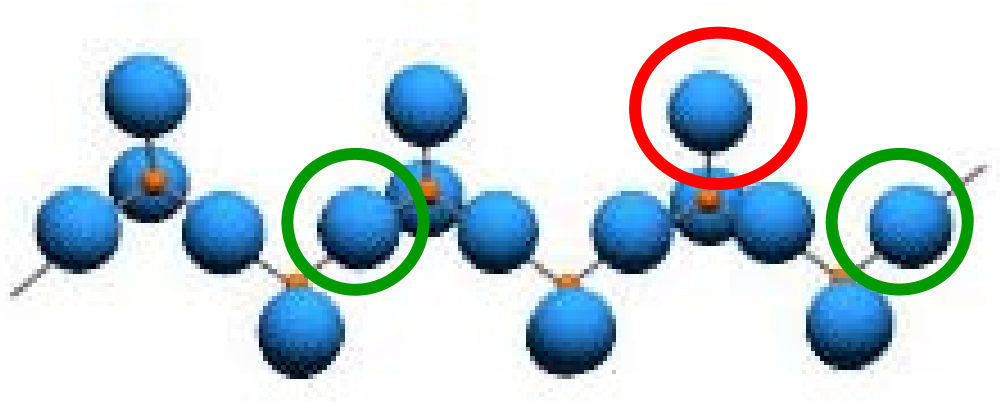
Structure of the pyroxenes

Pyroxene group minerals are made up of silicon-oxygen tetrahedral linked at corners to form infinite chains parallel to the c axis.

The chains are laterally linked by the 6-coordinated polyhedral M-sites. M_1 atoms lie at apices, whereas M_2 sites lie between silica tetrahedral bases.



Corner-to-corner and edge-to-edge.



All oxygen atoms in the pyroxene structure are bonded to at least 1 silica atom.

Some oxygen atoms belong to only 1 tetrahedron and coordinate the M_1 site.

Non-Bridging atoms

Some oxygen atoms belong to 2 tetrahedron and coordinate the M_2 site.

Bridging atoms

How does the pyroxene structure vary over that of olivine?

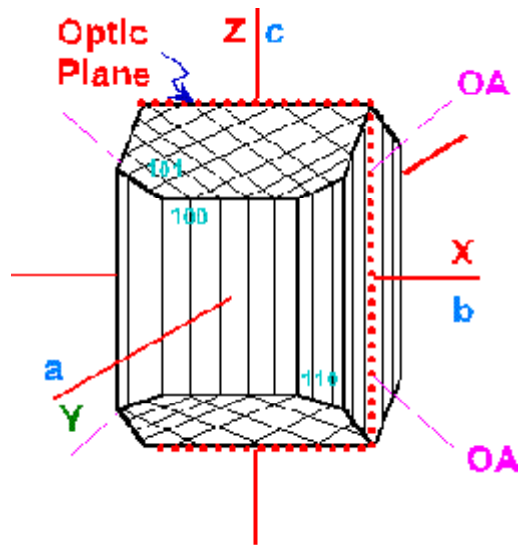
Rather than simple $\text{Mg}^{2+} \leftrightarrow \text{Fe}^{2+}$ substitution, ~50% of the M-site atoms may be replaced by Ca^{2+} .
Ionic radii = 0.72, 0.78 and 0.99Å respectively.

How does the structure adapt to accommodate the larger cation?

The flexing of the structure results in a change in crystallographic system between the ortho- and clinopyroxenes.

Orthorhombic to Monoclinic.

Identifying Orthopyroxene

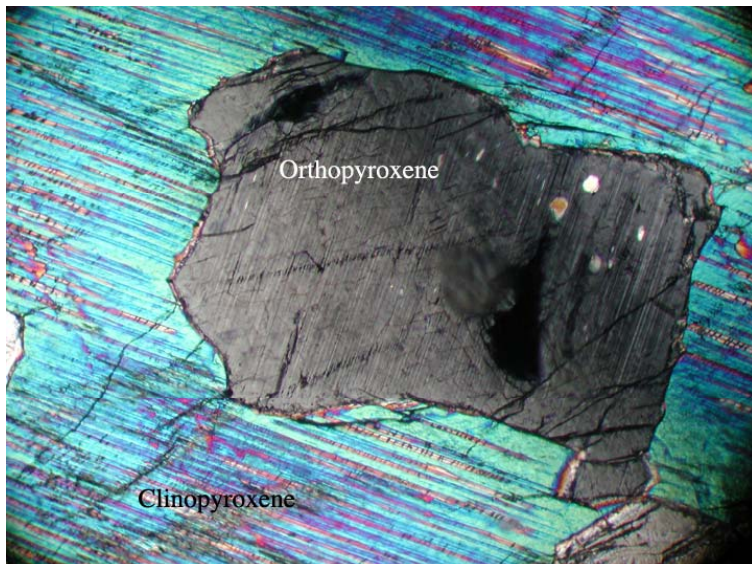


All pyroxenes are biaxial.

Opx has low birefringence (first order red maximum) and good cleavage.

- Section parallel to $c = 1$ cleavage.
- Section perpendicular to $c = 2$.

Weakly coloured (pink or green), generally colourless.

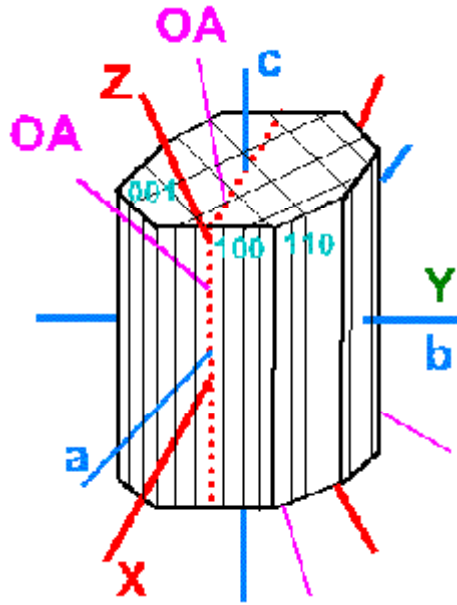


Weak pale green, pale red, or pale purple pleochroism in some grains.

$2V_z$ between 50° and 132° - “+ve” & “-ve”.
(most natural opx is negative).

Optical properties change with $Mg^{2+} \leftrightarrow Fe^{2+}$.

Identifying Clinopyroxene



All pyroxenes are biaxial.

Cpx has lower-middle 2nd birefringence (blues to yellow maximum) and good cleavage.

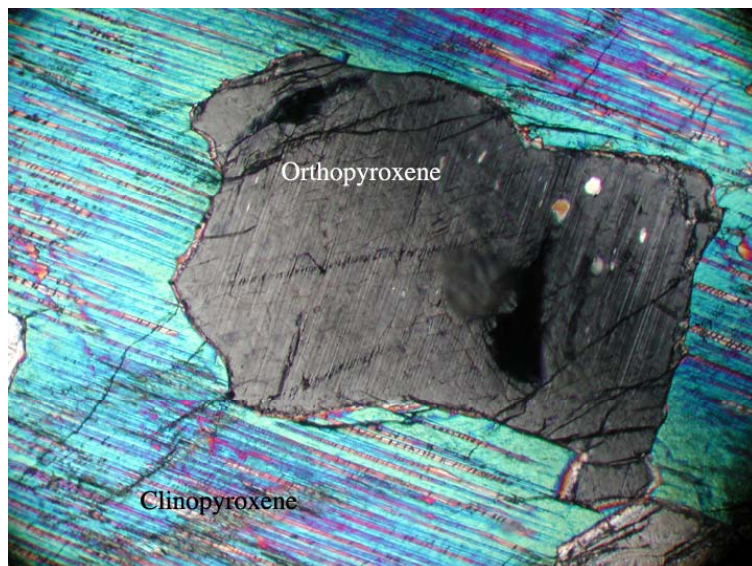
- Section parallel to c = 1 cleavage.
- Section perpendicular to c = 2.

Colourless to grey, or pale green/brown, with variation associated with pleochroism. More Fe-rich species – higher pleochroism.

$2V_z$ between 25° and 70° - Cpx is positive.

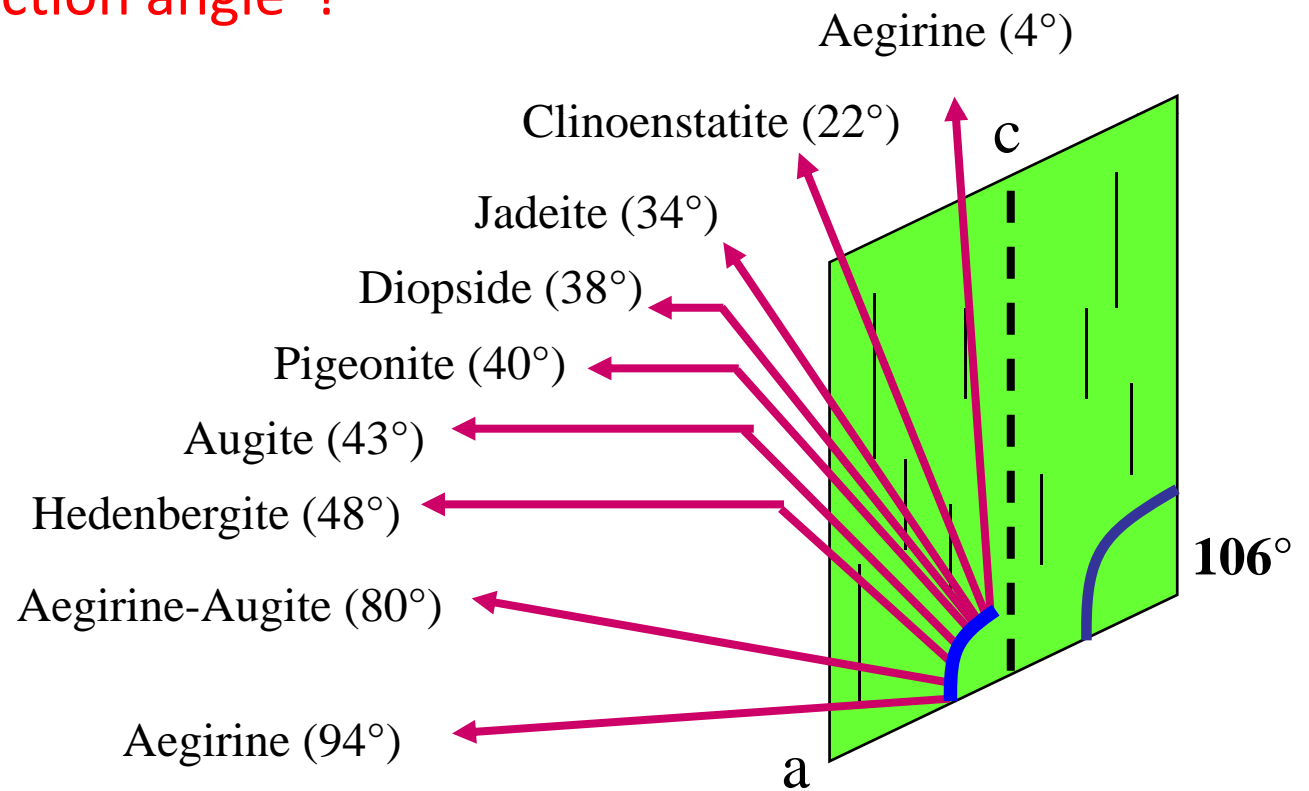
Cpx has medium-high relief.

Optical properties change with $Mg^{2+} \leftrightarrow Fe^{2+}$.

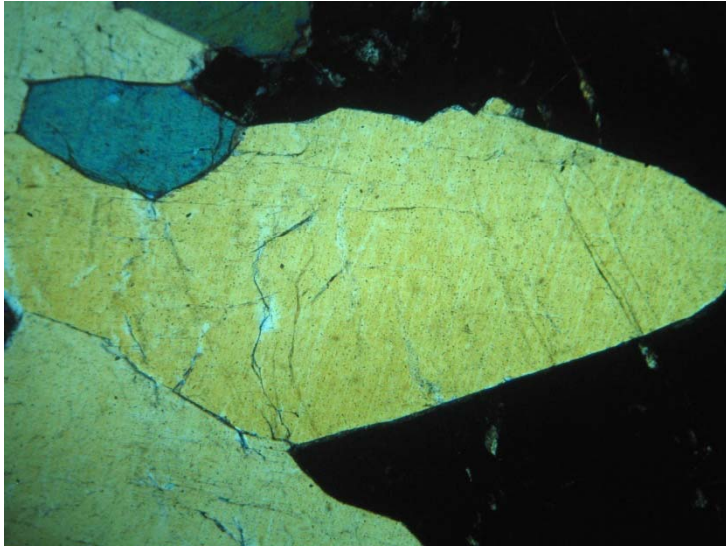


After using the criteria listed previously to identify *Cpx*, an estimation of composition can be made on the basis of extinction angle.

What is an “extinction angle”?



Wollastonite – Calcic-pyroxene



$\text{Ca}_2\text{Si}_2\text{O}_6$ occurs chiefly in contact metamorphic mineral assemblages.

Middle 1st order birefringence (yellow maximum).

Has three cleavages, of which 2 are intersect at about 84° . When looking in thin-section:

- Section parallel to c = 1 cleavage.
- Section perpendicular to c = 2.

Colourless to grey, or very pale green.

$2V_z$ between 36 and 60° - and is negative.

Medium relief.

Wollastonite is a triclinic mineral.



Occurrence, uses and applications

- Ferrosilite rarely occurs and the Fe:Mg ratio of Opx is rarely > 1 .
- Cpx is an important constituent of the mantle.
- Opx is an important constituent of many basic to ultramafic rocks.
- Both occur in high-grade metamorphic rocks as a function of T, P and rock composition.
- Neither have special economic importance.
- Wollastonite, by far and away, most common in contact metamorphic environments.
- Where it makes up a major proportion of the rock it can be exploited for manufacturing ceramics.