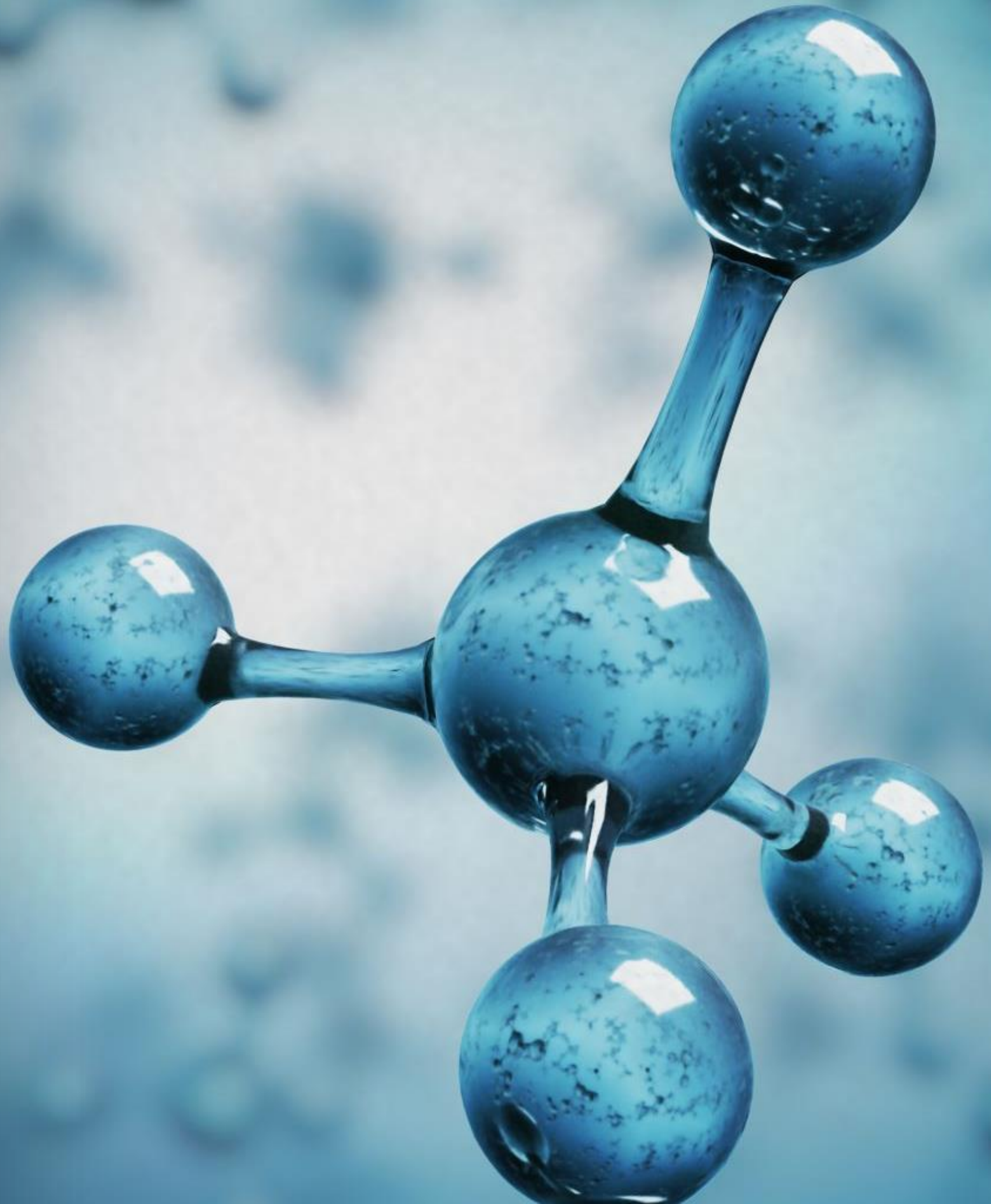
Silicates



Dr. Tapabrato Sarkar

Why silicates?

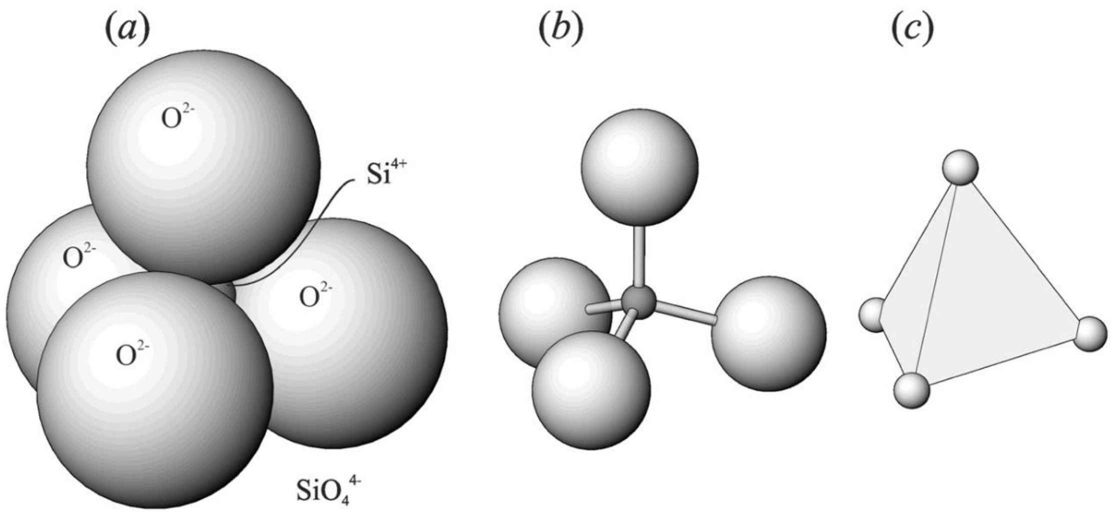
Table 3.6 The Eight Most Abundant Elements in the Earth's Crust

		Proportion of Earth's Crust				
Element	**Common Oxidation State**	**(wt %)**	**(atom %)**	**(vol %)**	**Oceanic Crust (wt %)**	**Total Earth (wt %)**
O	−2	46.6	62.5	91.7	40.9	29.5
Si	+4	27.7	21.2	0.2	23.1	15.2
Al	+3	8.1	6.5	0.5	8.5	1.1
Fe	+2/+3	5.0	1.9	0.5	8.2	34.6
Ca	+2	3.6	1.9	1.5	8.1	1.1
Na	+1	2.8	2.6	2.2	2.1	0.6
K	+1	2.6	1.4	3.1	1.3	0.1
Mg	+2	2.1	1.8	0.4	4.6	12.7
Total		98.5	99.8	~100	96.8	94.9

Source: Adapted from Mason and Moore (1982).

Oxygen and Silicon are the most abundant minerals on the Earth's crust

Coordination	**Radius Ratio**	**Minimum Radius (Å)**	**~Maximum Radius (Å)**	**Common Cations**
12	~1.00	1.26	N/A	K^+, Ca^{2+}, Na^+
8	0.732–1.00	0.92	1.26	Fe^{2+}, Ca^{2+}, Na^+, Mg^{2+}
6	0.414–0.732	0.52	0.92	Al^{3+}, Fe^{2+}, Fe^{3+}, Mg^{2+}
4	0.225–0.414	0.28	0.52	Si^{4+}, Al^{3+}, S^{6+}, P^{5+}
3	0.155–0.225	0.20	0.28	C^{4+} [a]
2	<0.155	N/A	0.20	None



Silicate classification

Orthosilicates = Nesosilicates

Disilicates = Sorosilicates

Ring silicates = Cyclosilicates

Chain silicates = Inosilicates

Sheet silicates = Phyllosilicates

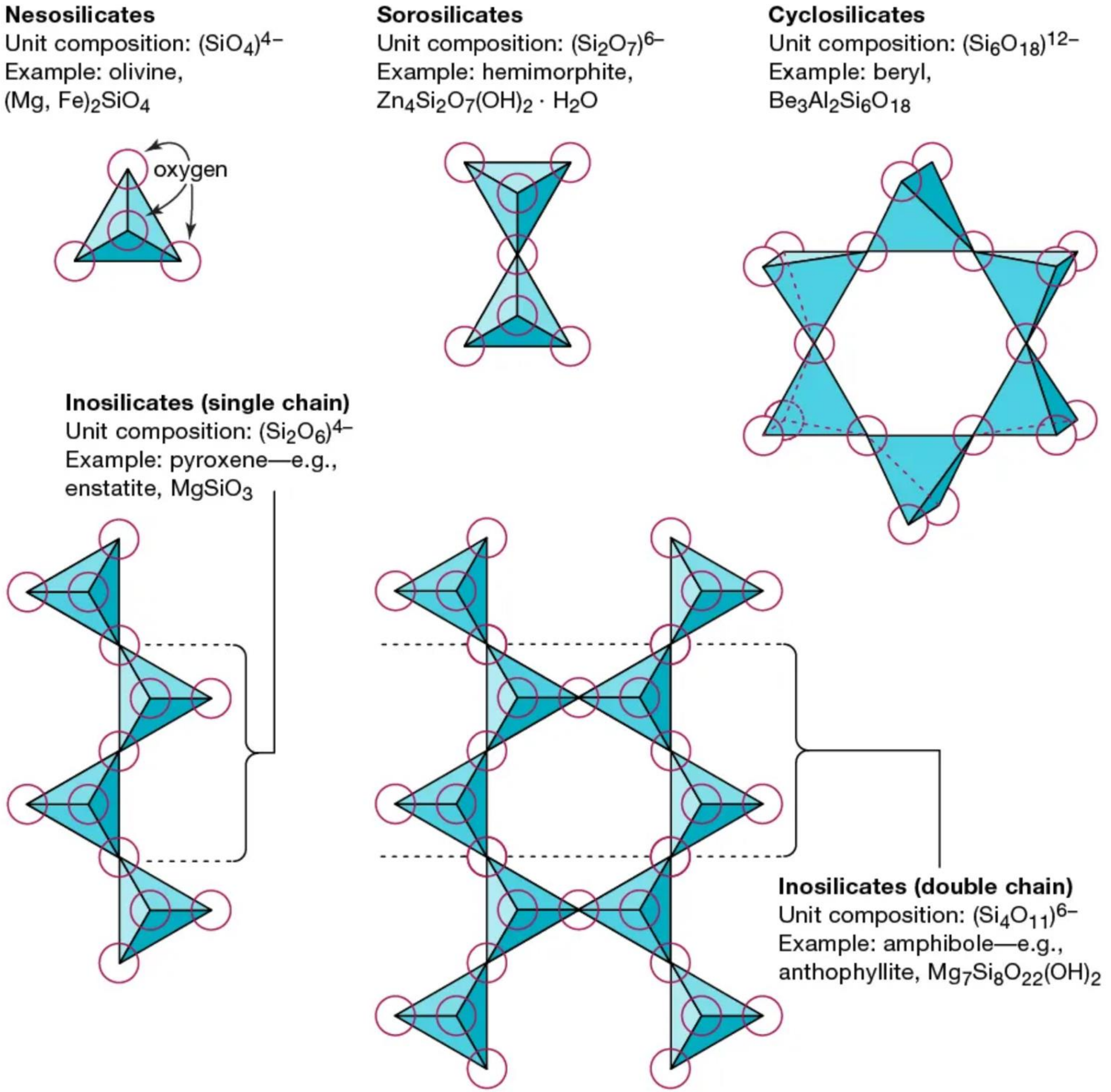
Framework silicates = Tectosilicates

Table 11.1 Silicate Classification[a]

Silicate Class	Number of O^{2-} Shared per Tetrahedron	Z:O Ratio	Structural Configuration
Orthosilicates	0	1:4	Isolated tetrahedra
Disilicates	1	2:7	Double tetrahedra
Ring silicates	2	1:3	Rings of tetrahedra
Chain silicates			Chains of tetrahedra
Single chain	2	1:3	
Double chain	2 or 3	4:11	
Sheet silicates	3	2:5	Sheets of tetrahedra
Framework silicates	4	1:2	Framework of tetrahedra

[a] Z refers to the cation(s), usually Si^{4+}, and also Al^{3+}, that occupy the tetrahedral sites.

Structural linkage schemes among silicates



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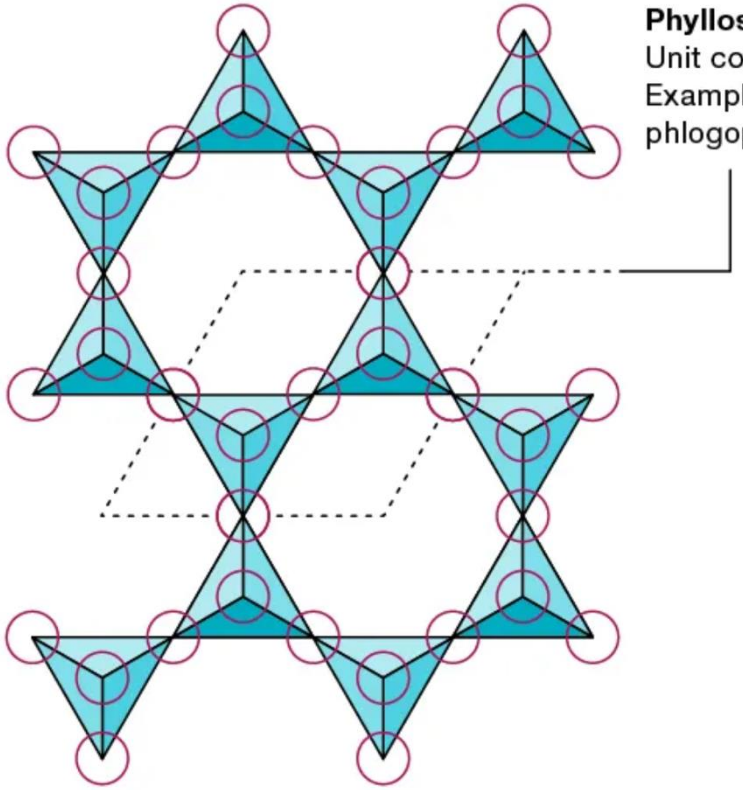
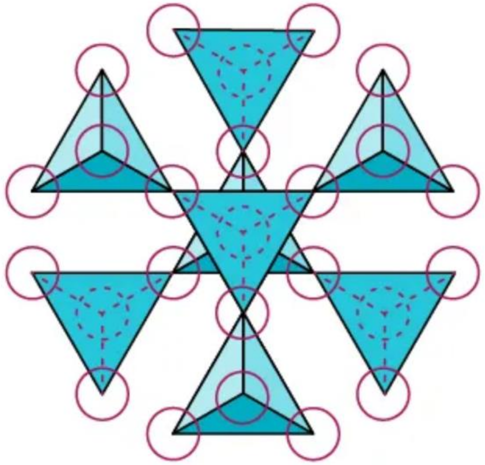
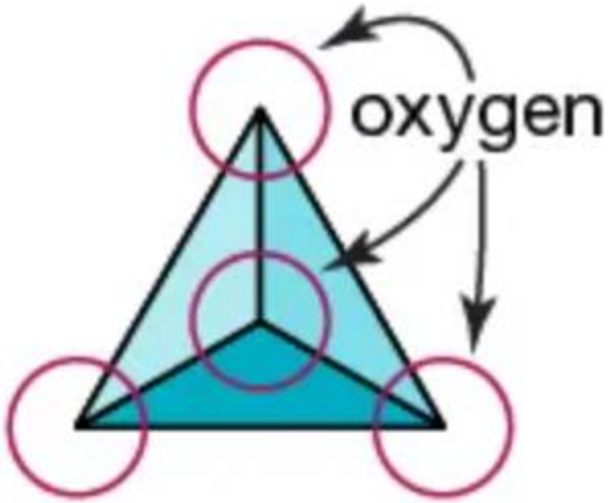


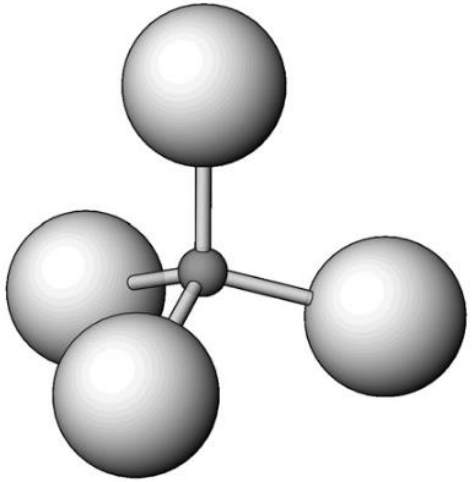
Phyllosilicates
Unit composition: $(Si_2O_5)^{2-}$
Example: mica—e.g., phlogopite, $KMg_3(AlSi_3O_{10})(OH)_2$



Tectosilicates
Unit composition: $(SiO_4)^{4-}$
Example: high cristobalite, SiO_2

Orthosilicate (Nesosilicate)





Orthosilicates

Olivine	$(Mg,Fe)_2SiO_4$
Zircon	$ZrSiO_4$
Garnet	$X_3Y_2(SiO_4)_3$
Aluminum silicates	$AlAlOSiO_4$
Staurolite	$Al_9Fe_2(SiO_4)_4O_6(OH)_2$
Chloritoid	$(Fe^{2+},Mg,Mn)_2(Al,Fe^{3+})$ $Al_3O_2(SiO_4)_2(OH)_4$
Topaz	$Al_2(SiO_4)(F,OH)_2$
Titanite	$CaTiOSiO_4$

Olivine: Composition

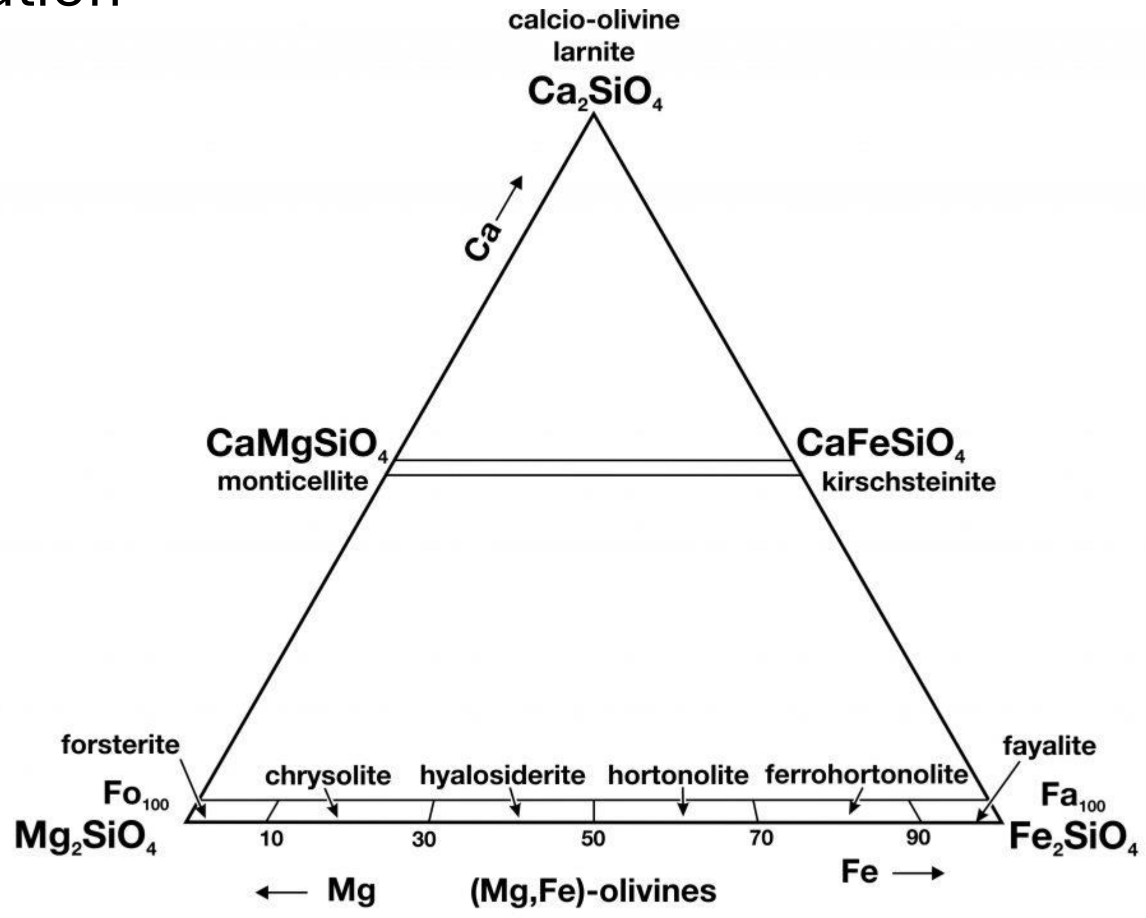
General formula: [$M2M1SiO_4$]
M2 and M1 are octahedral sites (6 coordination number)

M2>M1
M2= Ca^{2+}, Mg^{2+}, Fe^{2+}, Fe^{3+}, Mn^{2+}
M1= Mg^{2+}, Fe^{2+}, Fe^{3+}, Mn^{2+}

Important members:

Forsterite: Mg_2SiO_4

Fayalite: Fe_2SiO_4



Simple substitution

Olivine: Distinguishing features

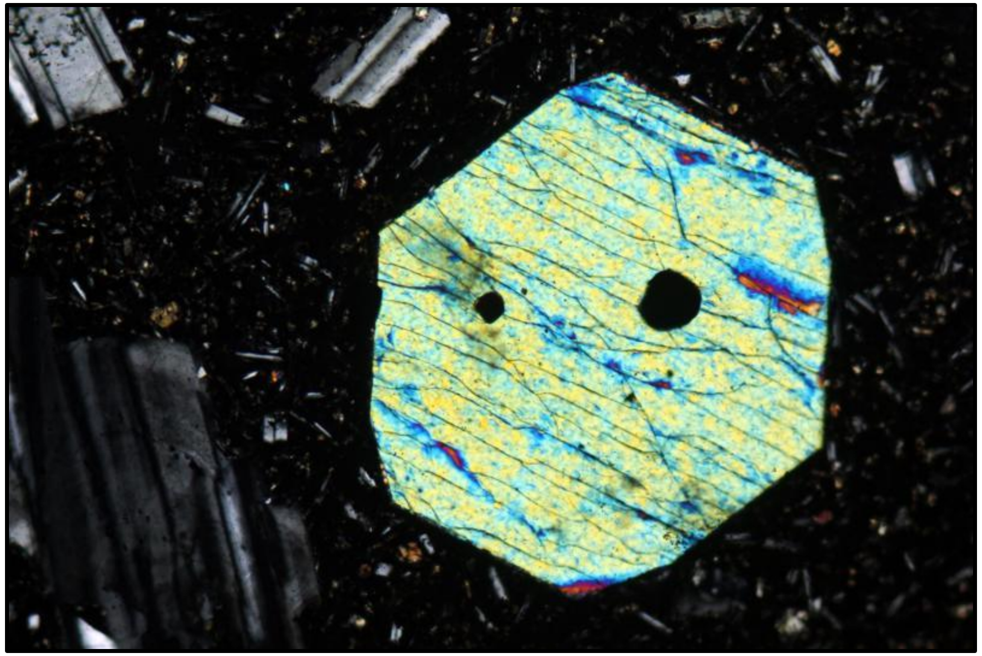
Common occurrence in rocks

Distinguishing features in hand specimen:

- Color: Olive to yellowish green, darker with increasing Fe
- Vitreous luster
- Conchoidal fracture
- Granular nature

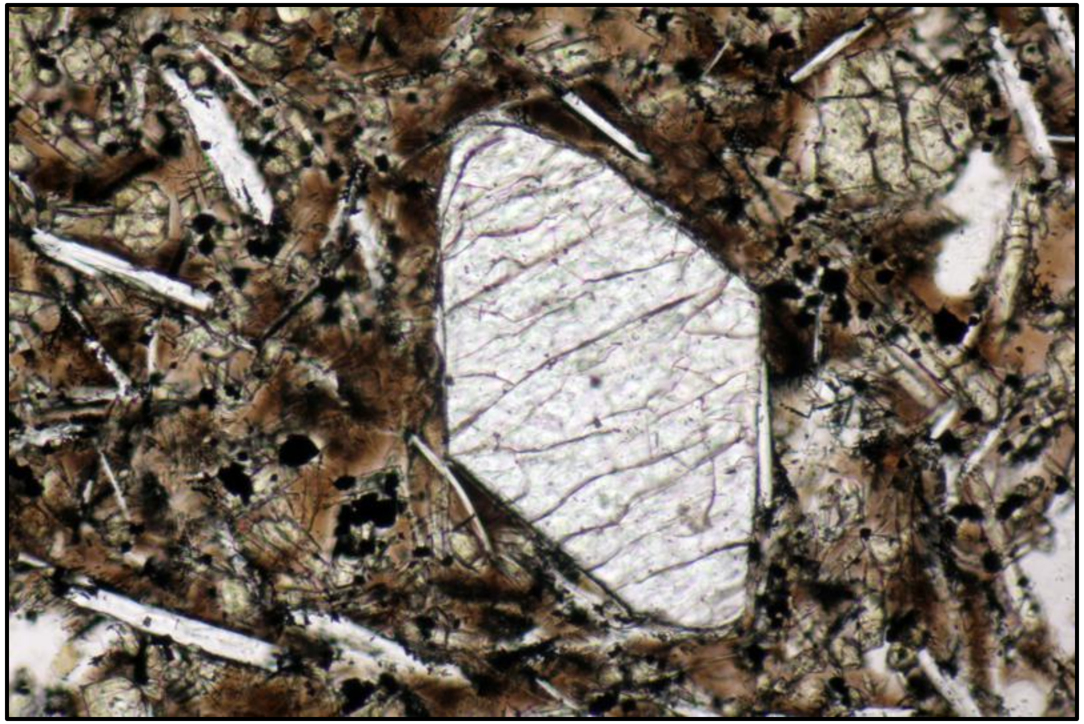
https://www.mindat.org/a/best_fayalite

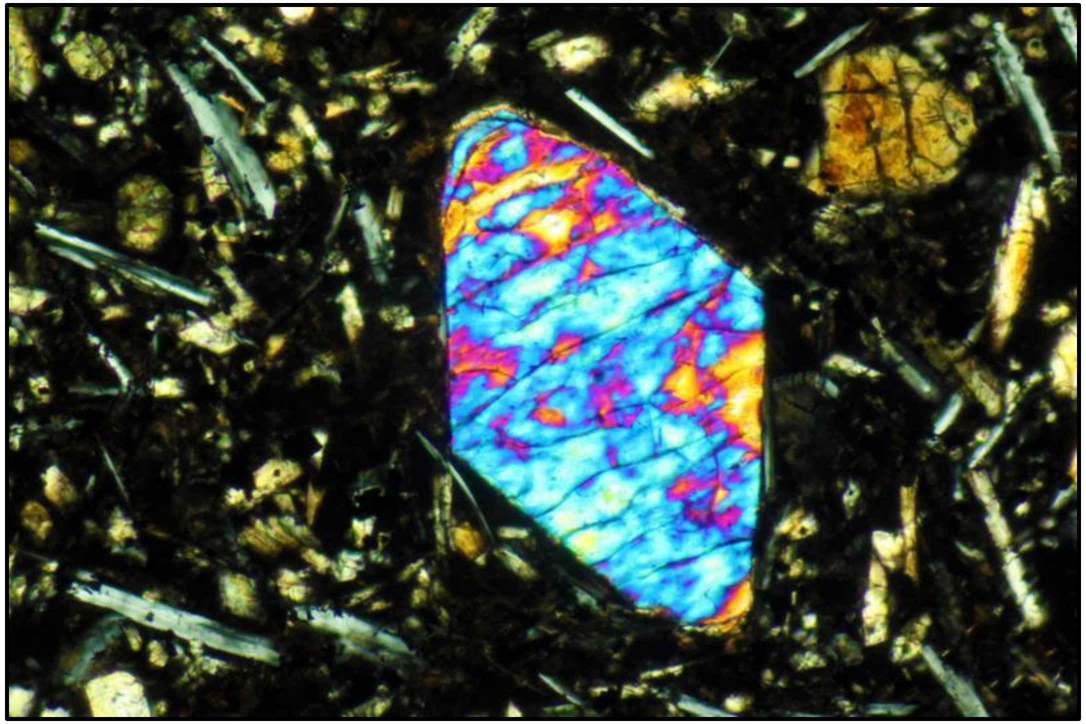
Olivine: Distinguishing features



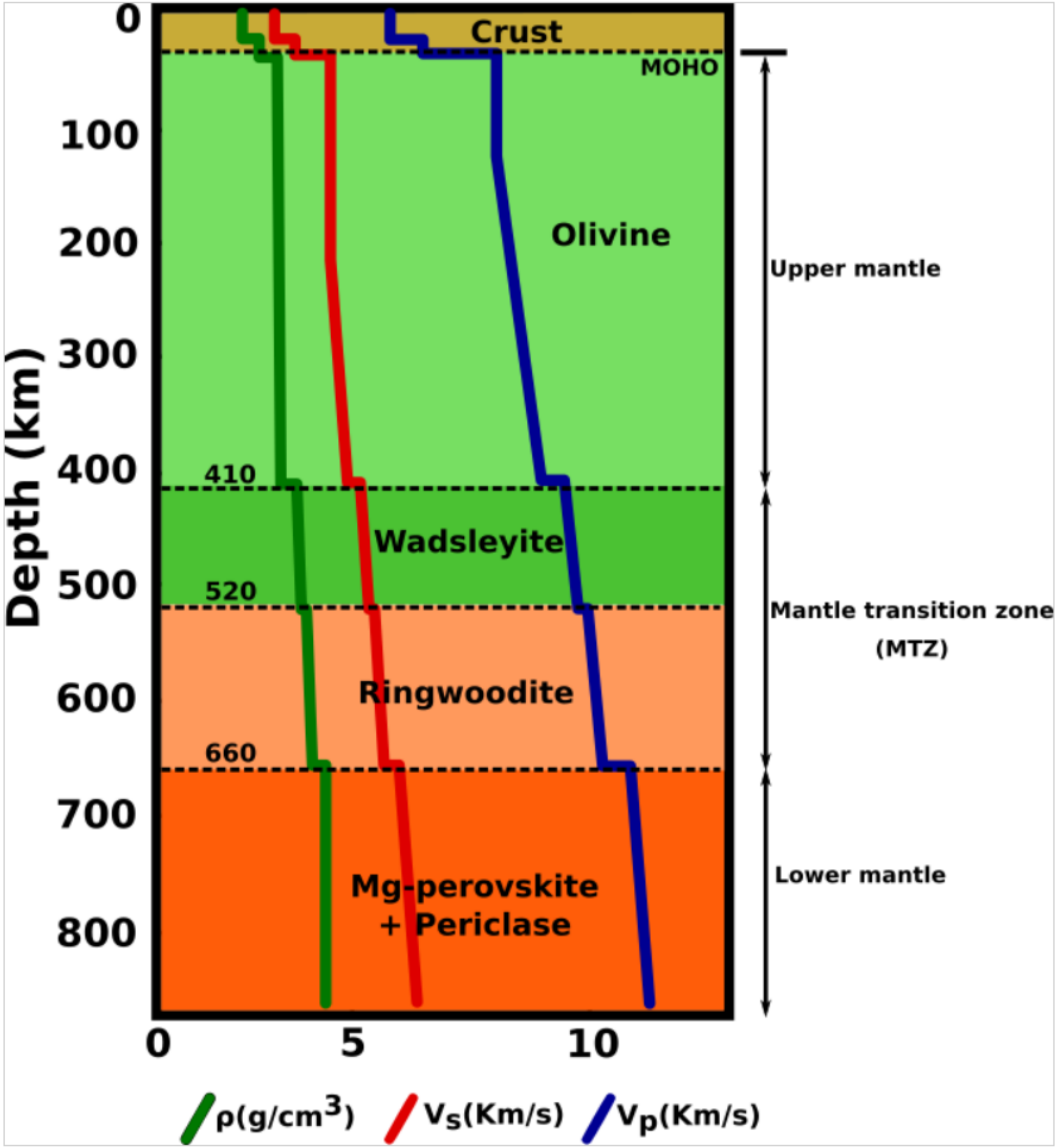
Optical properties

- ✓ Color: Colorless or pale green-yellow with increasing Fe.
- ✓ Relief: High.
- ✓ Birefringence: High
- ✓ Interference colors: Strong, III order colors.
- ✓ Cleavage: None
- ✓ Distinctive fractures





Olivine: Occurrence



Olivine: Uses

- Clear green olivine, known as ***peridot*** is a minor gemstone
- Some of the finest material comes from the island of Zebirget in the Red Sea.
- Peridot has historically been used to treat gastrointestinal problems (however, efficacy not been proven scientifically)
- Some dental ceramics contain forsterite as a strengthening agent.

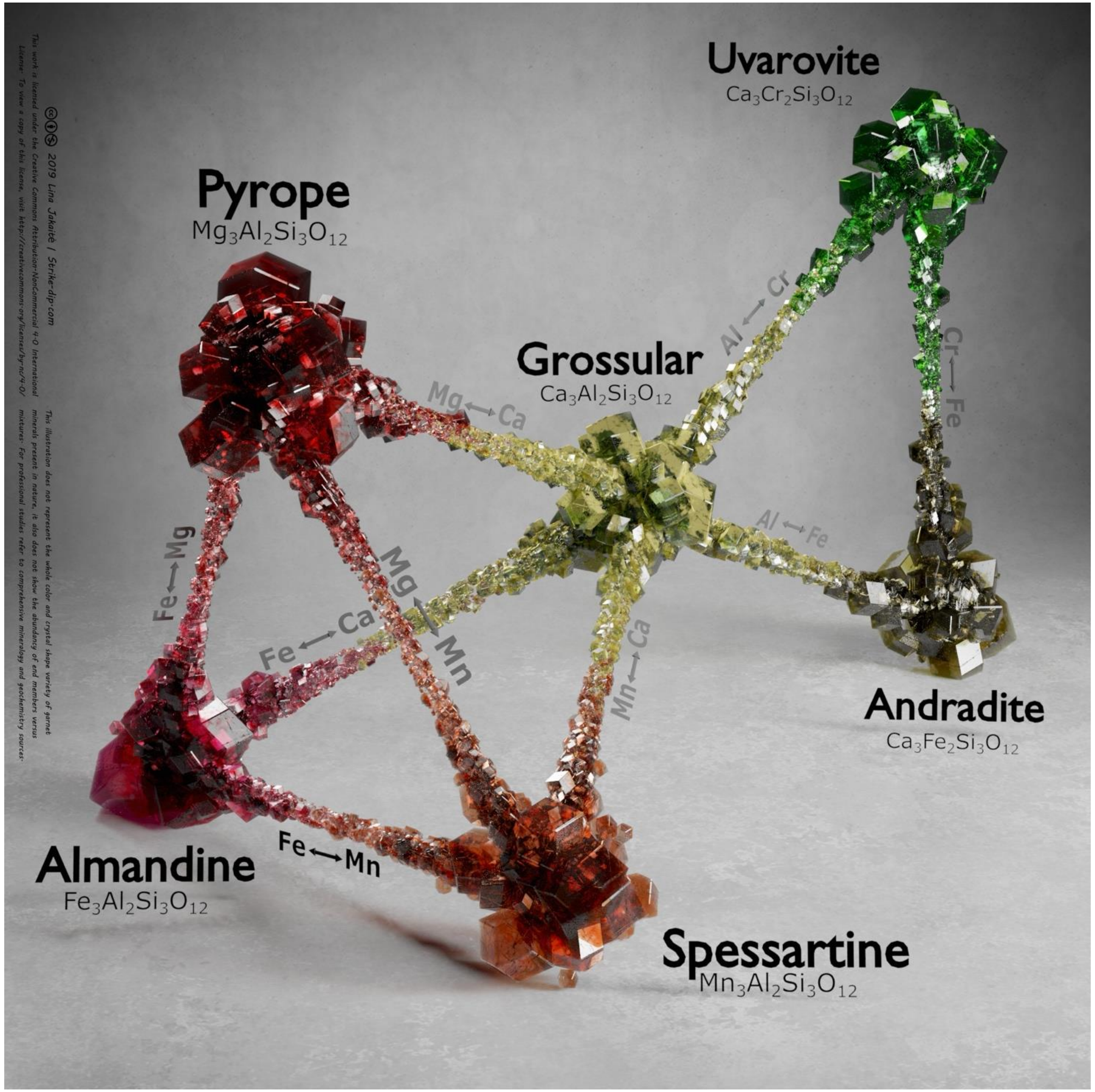
Olive to yellowish green, darker with increasing Fe

Garnet: Composition

General formula: $X_3Y_2(SiO_4)_3$

$X = Ca^{2+}, Mg^{2+}, Fe^{2+}, Mn^{2+}$
(divalent cations)
$Y = Al^{3+}, Fe^{3+}$ (trivalent cations)

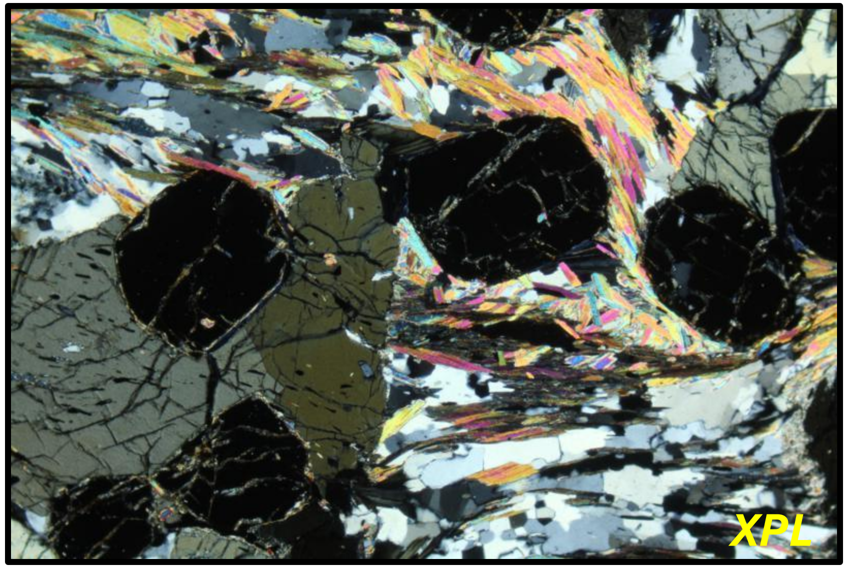
Group	End Member	Composition
Pyralspite	Pyrope	$Mg_3Al_2(SiO_4)_3$
	Almandine	$Fe_3Al_2(SiO_4)_3$
	Spessartine	$Mn_3Al_2(SiO_4)_3$
Grandite	Grossular	$Ca_3Al_2(SiO_4)_3$
	Andradite	$Ca_3Fe_2^{3+}(SiO_4)_3$

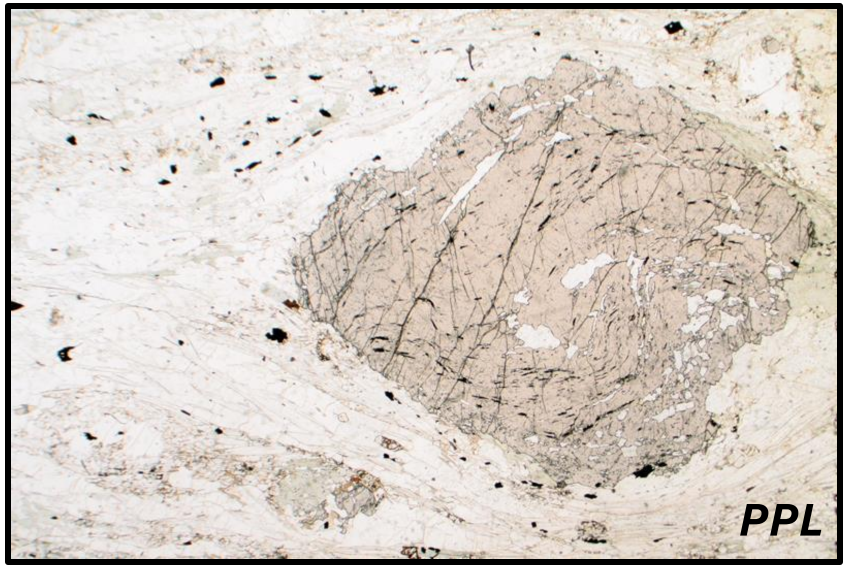


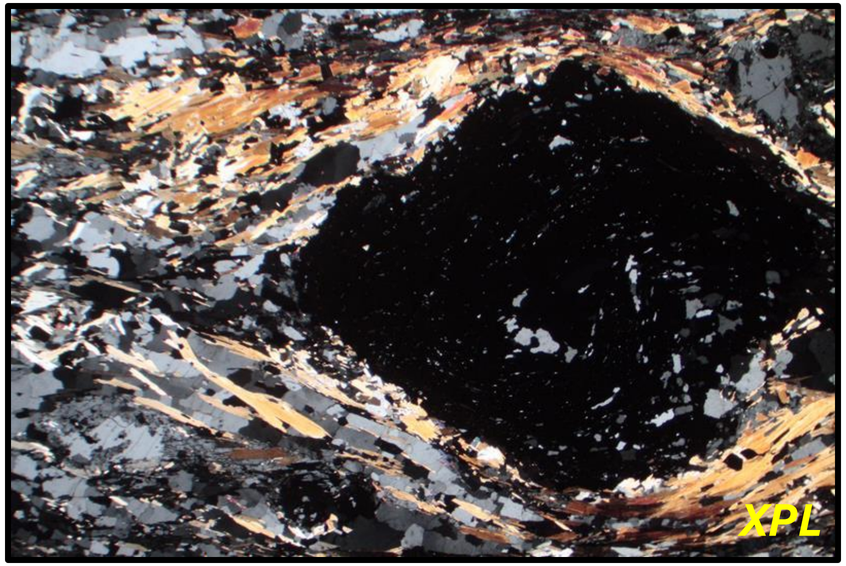
Garnet: Distinguishing features

The diversity of color is controlled mostly by the presence of chromophore elements (Fe, Mn, Cr, etc.) in the X and Y structural sites.

Garnet: Distinguishing features







Optical properties

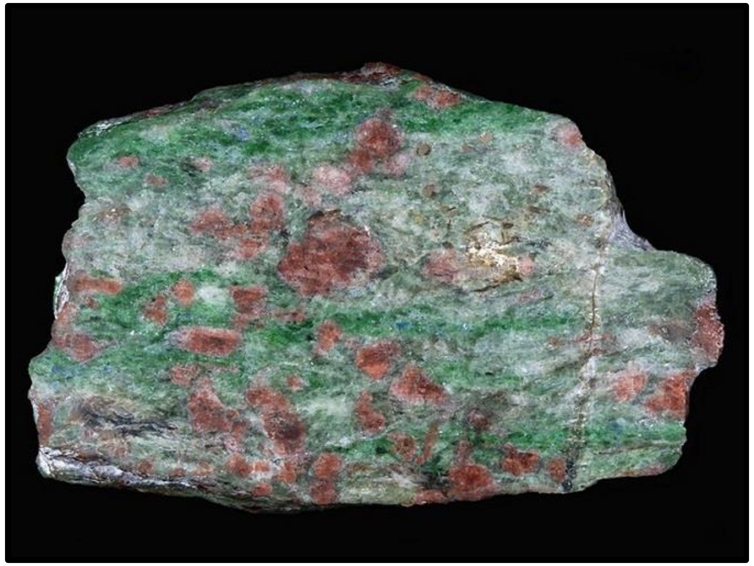
- ✓ Color: Colorless to pinkish.
- ✓ Relief: High.
- ✓ Birefringence: Isotropic
- ✓ Interference colors: Isotropic
- ✓ Cleavage: None
- ✓ Distinctive fractures
- ✓ Commonly contains a lot of inclusions.

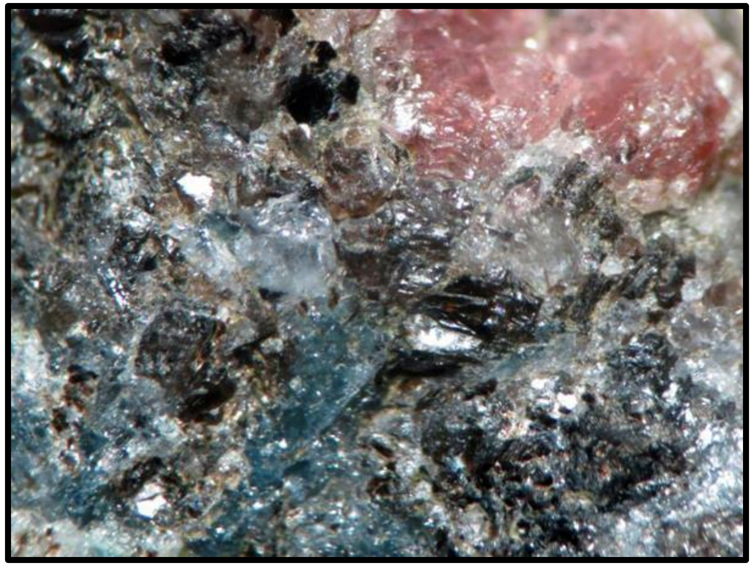
Garnet: Occurrence

- ✓ Common mineral found in crustal rocks
- ✓ Commonly found in a variety of metamorphic rocks

(details will be discussed in petrology)

- ✓ Garnet composition is strongly dependent on the pressure and temperature condition during the formation of the mineral.





Garnet: Uses

- ✓ Used as a semiprecious gemstone.
- ✓ The irregular fracture makes garnet valuable as an abrasive, particularly for sandpaper.
- ✓ Also used in filters to help purify water in wastewater treatment plants.

- ✓ In petrology, garnet has a large importance in reveling the history and evolution of rocks
- ✓ Commonly found in a variety of rocks formed in a wide range of physicochemical conditions
- ✓ It can have a wide range of chemical compositions, which are related to the physicochemical conditions in which they formed.
- ✓ Resistant to weathering and erosion.