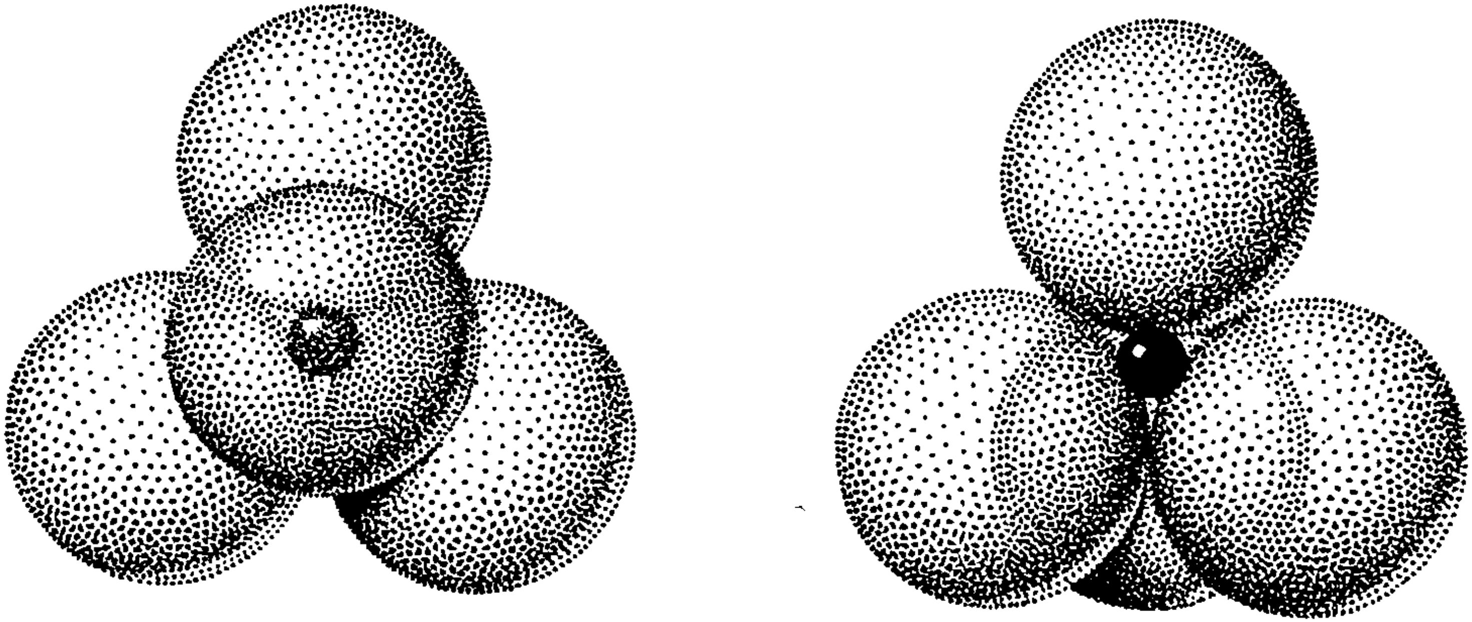
5.0 Silicates and silicate clay minerals, including poorly crystalline silicates

5.1 Silicates

(General)

- **Volumetrically the most important mineral group,**
- **Comprising over 90 % of the earth's crust,**
- **Next to silicates are oxygen containing oxides (Al, Fe) and carbonates, sulfate, phosphates etc.,**
- **Si Radius 0.34 Å (CN 4), 0.48 Å (CN 6),**
- **O radius 1.27 Å (CN), 1.30 Å (CN 4),**
- **Si CN 4 bond strong and 50 % ionic 50 % covalent,**
- **Si and O a tetrahedron, fundamental building block of silicates.**



Close packing representation of SiO_4 tetrahedron.

- **Bridging (polymerization) by shared oxygen to another Si-tetrahedron.**

- **Several types of sharing O give rise to a diversity of structural configurations like C in organic matter.**

COORDINATION OF COMMON ELEMENTS IN SILICATES[a]

	Coordination Number	Ion	Ionic Radius (Å)	$R_X : R_O$
Z	4	Si^{4+}	0.39	0.278
	4	Al^{3+}	0.51	0.364
Y	6	Al^{3+}	0.51	0.364
	6	Fe^{3+}	0.64	0.457
	6	Mg^{2+}	0.66	0.471
	6	Ti^{4+}	0.68	0.486
	6	Fe^{2+}	0.74	0.529
	6	Mn^{2+}	0.80	0.571
X	8	Na^{+}	0.97	0.693
	8	Ca^{2+}	0.99	0.707
X	8–12	K^{+}	1.33	0.950
	8–12	Ba^{2+}	1.34	0.957
	8–12	Rb^{+}	1.47	1.050

[a] See Table 4.3 for a complete listing of ionic radii.

SILICATE CLASSIFICATION

1. Neso (island), or ORTHO (true) SILICATES with independent SiO_4 group $(SiO_4)^{-4}$, Si/O=1/4,

2. SORO-SILICATES (group); two SiO_4 group are linked $(SiO_7)^{-6}$ Si/O=1/3.5,

3. CYCLO-SILICATES (ring) more than two SiO4 group are linked $(Si_6O_{18})^{-12}(Si_xO_{3x})$, Si/O=1/3,

4. INO-SILICATES (thread), they are like CYCLO but open: a- one thread; b- two threads $(SiO_3)^{-2}$ or $(Si_4O_{11})^{-6}$ Si/O or 1/2.75,

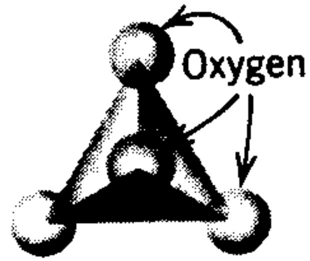
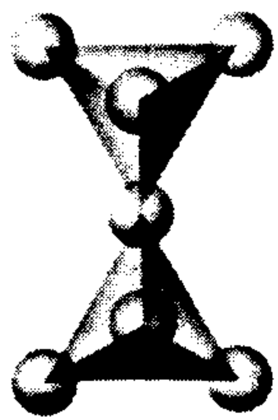
5. PHYLLO-SILICATES (leaf, sheet) three O is shared Si_2O_5, Si/O=1/2.5,

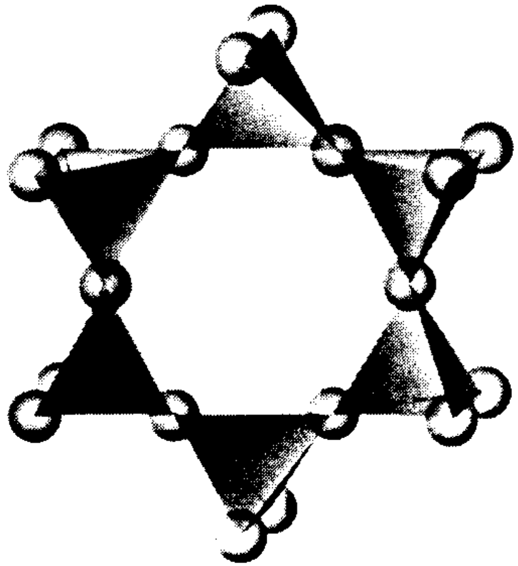
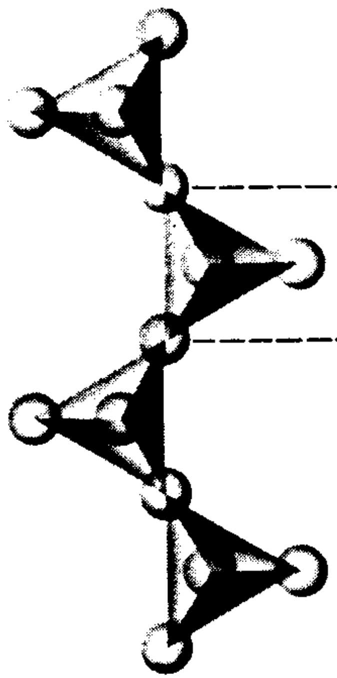
6. TECTO-SILICATES (framework) SiO_2, Si/O=1/2.

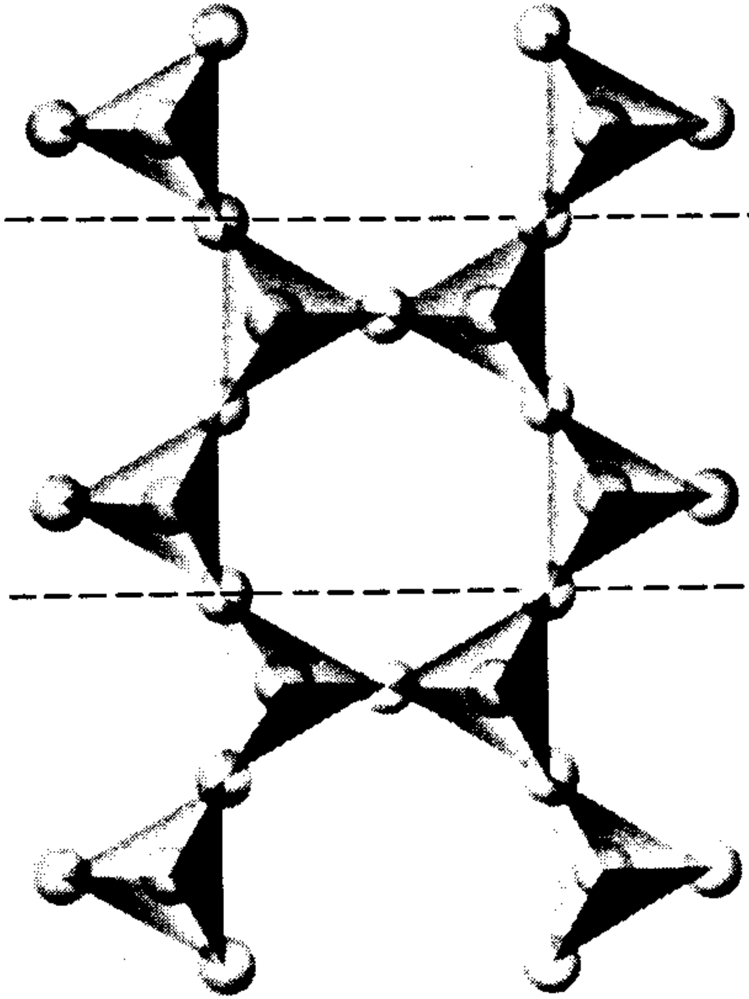
- Al is next abundant element to Si it may in 4 CN and substitute Si or may in 6 CN and link tetrahedron.

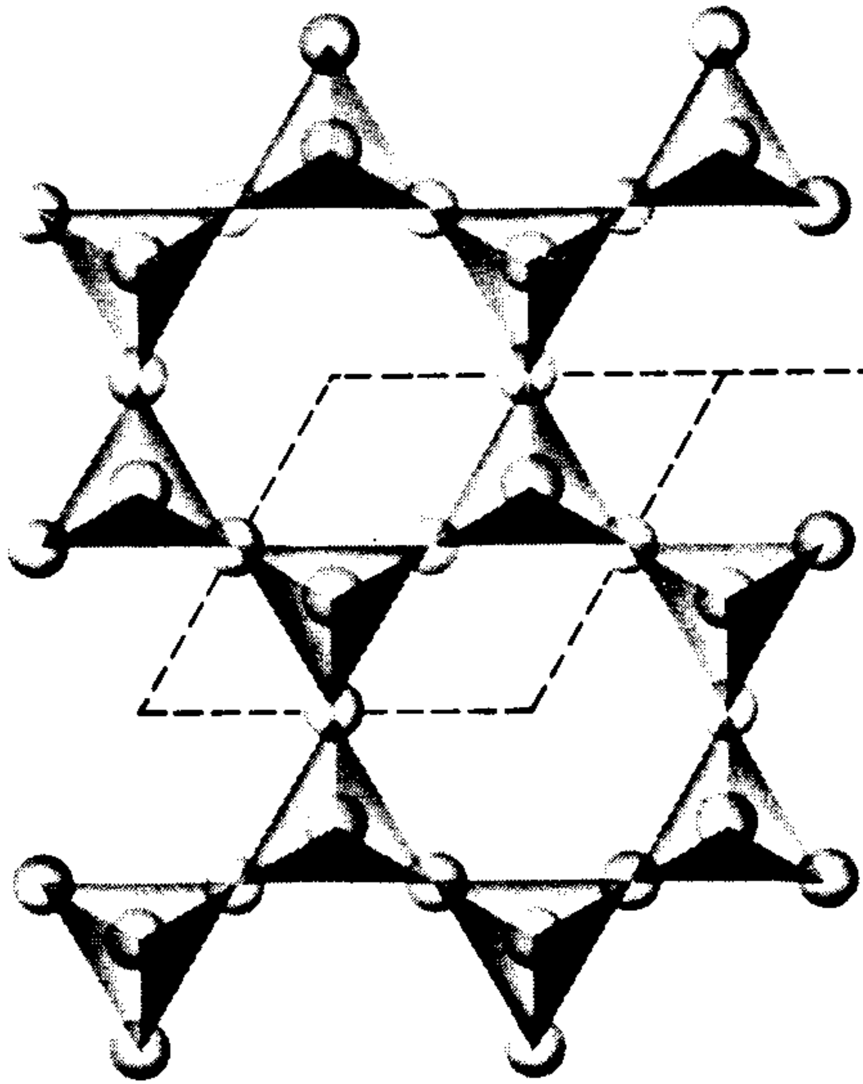
-In 6 CN they may be substituted with Fe, Mg; also Mn, Ti. (see Table).

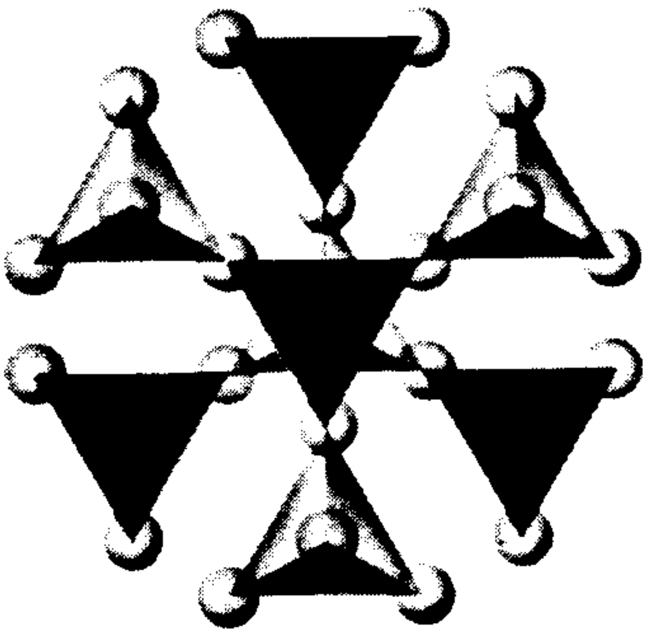
SILICATES

Class	Arrangement of SiO_4 tetrahedra (central Si^{4+} not shown)	Unit composition	Mineral example
Nesosilicates		$(SiO_4)^{-4}$	Olivine, $(Mg, Fe)SiO_4$
Sorosilicates		$(Si_2O_7)^{-6}$	Hemimorphite, $Zn_4Si_2O_7(OH) \cdot H_2O$

Cyclosilicates		$(Si_6O_{18})^{-12}$	Beryl, $Be_3Al_2Si_6O_{18}$
Inosilicates (single chain)		$(SiO_3)^{-2}$	Pyroxene e.g. Enstatite, $MgSiO_3$

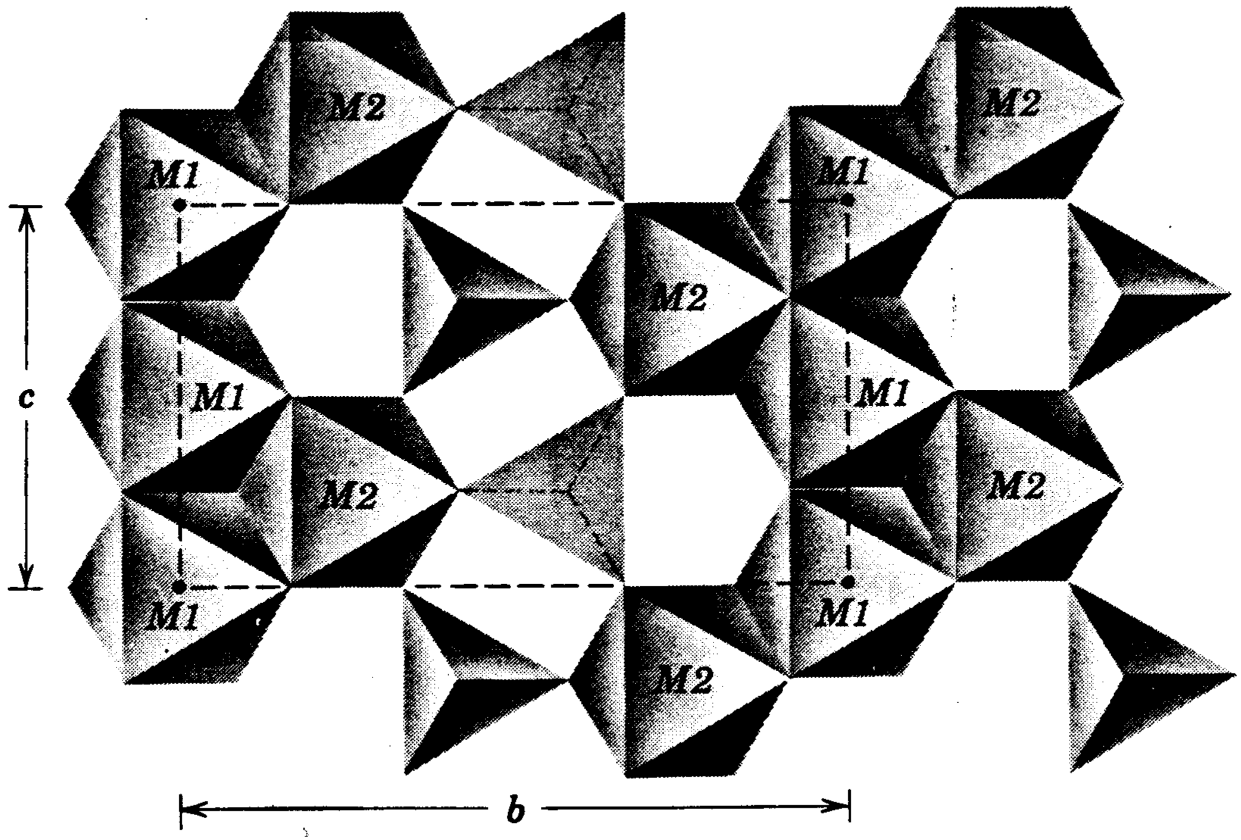
Inosilicates (double chain)		$(Si_4O_{11})^{-6}$	Amphibole e.g. Anthophyllite, $Mg_7Si_8O_{22}(OH)_2$

Phyllosilicates		$(Si_2O_5)^{-2}$	Mica e.g. Phologopite, $KMg_3(AlSi_3O_{10})(OH)_2$

Tectosilicates		$(SiO_2)^0$	High cristobalite, SiO_2

1. NESO (island), or ORTHO (true) SILICATES

SiO_4 are independent, cleavage direction are absent



Portion of the idealized structure of olivine projected on (100). M*1* and M*2* are octahedral sites. The M*1* octahedron is somewhat distorted in the real structure whereas M*2* is regular

Examples:

Olivines: **Forsterite $Mg_2\ SiO_4$**

Fayelite $Fe_2\ SiO_4$

Garnets: $Mg_3Al_2\ (SiO_4)$ (Fe, Mn)

O may be substituted by OH^-

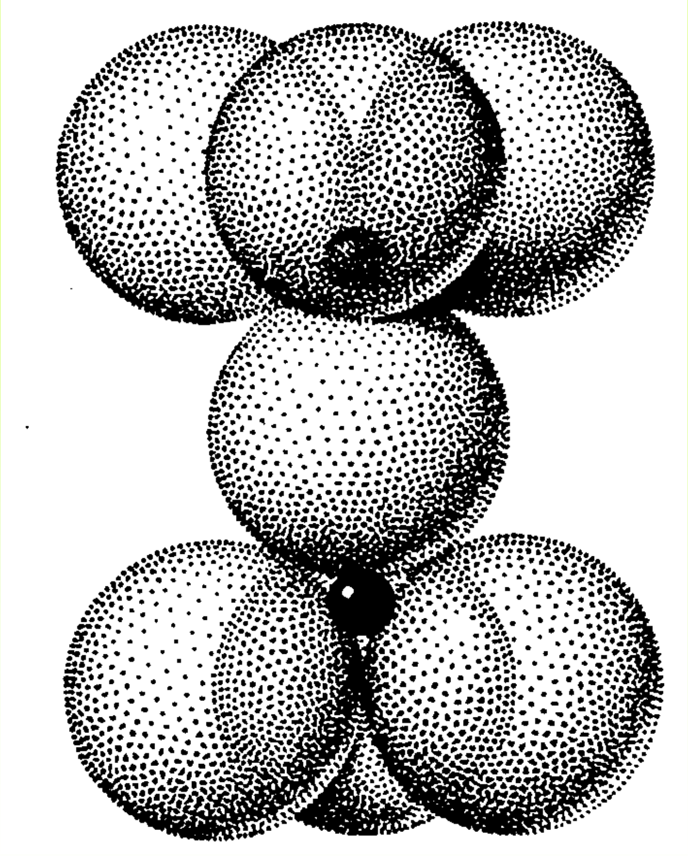
Zircon: $Zr\ SiO_4$

Topaz: $Al_2\ SiO_4(F, OH)_2$

Spehene : $CaTiO(SiO_4)$

SORO-SILICATES (Group; 2 SiO_4 groups are linked $(Si_2O_7)^{-6}$ Si/O = 1/3.5,

Epidote: $Ca(Fe^{3+}, Al)\ Al_2O(SiO_4)$ $(Si_2O_7)\ (OH)$

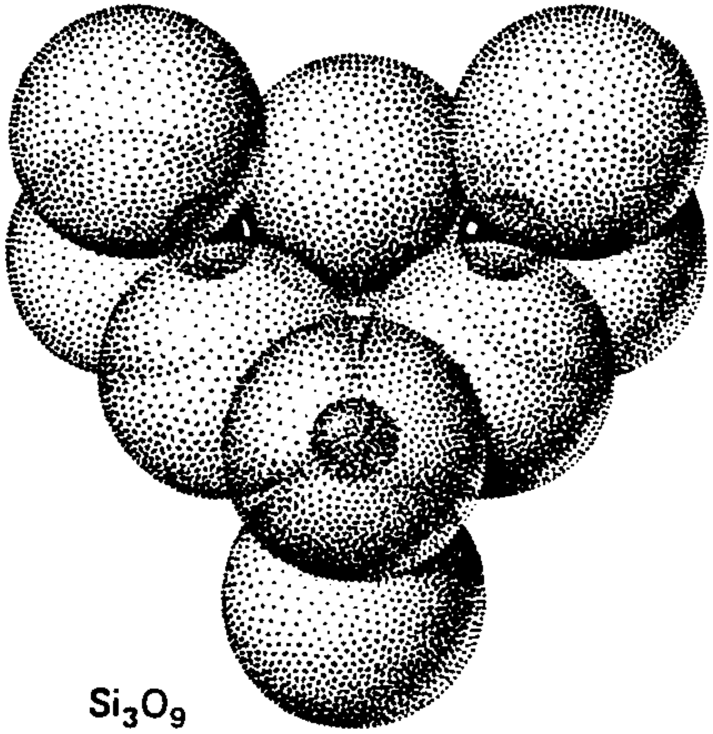


Close packing representation of Si_2O_7 group

3. CYCLO-SILICATES (ring) more than two SiO_4 groups are linked $(Si_6O_{18})^{-12}(Si_xO_{3x})$, Si/O=1/3, Si_4O_{15}, Si_6O_{18}

Beryl: $Be_6Al_2Si_6O_{18}$

Tourmaline (Turamali, Sri Lanka):



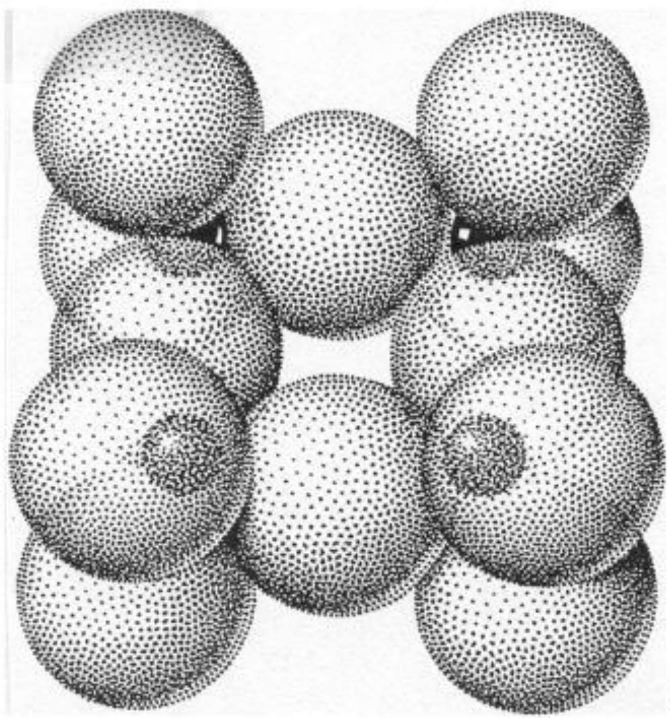
(a)

$(Na,Ca)(Li, Mg, Al)(Al,Fe,Mn)^{-6}$

$(BO_3)_3(Si_6O_{18})(OH)_4$

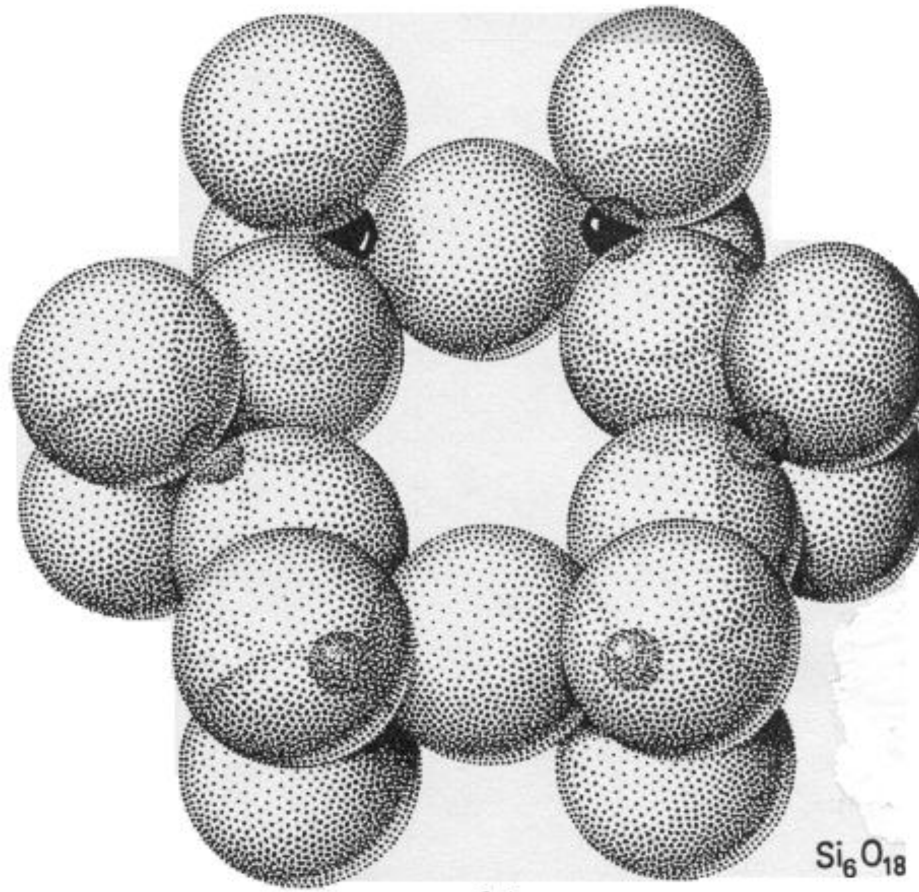
Cyclosilicates (cont.)

Close packing representation of ring structures in the cyclosilicates.



Si_4O_{12}

(b)



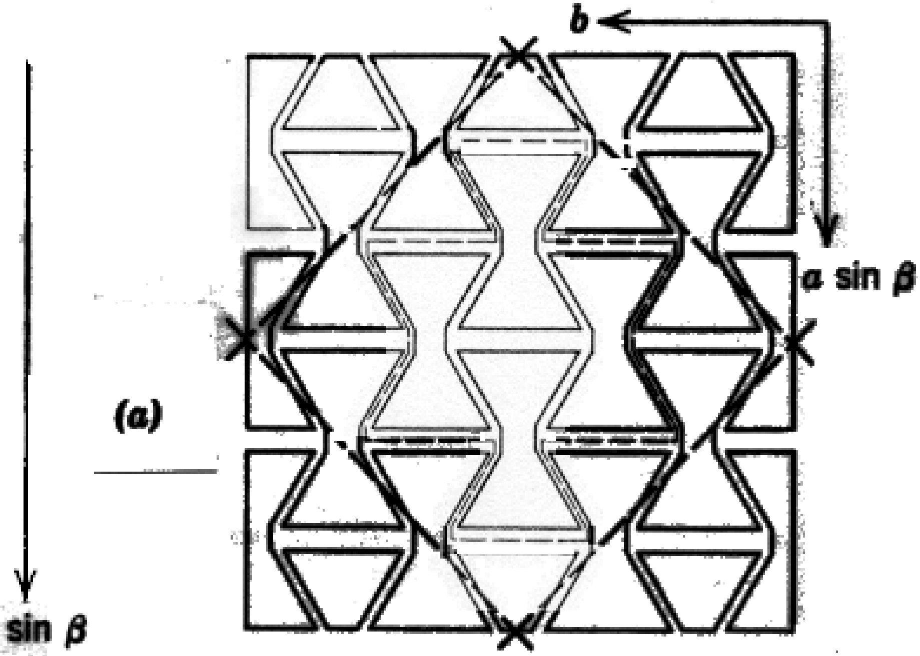
(c)

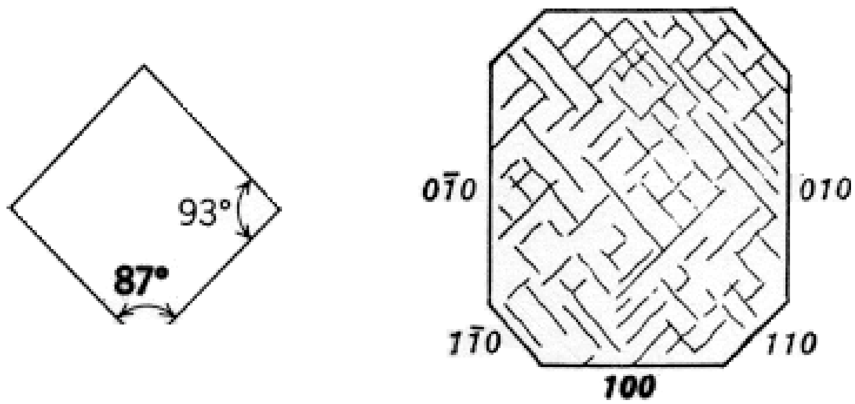
4. INO-SILICATES (thread), they are like CYCLO but open: a- one thread; b- two threads $(SiO_3)^{-2}$ or $(Si_4O_{11})^{-6}$ Si/O=1/3 or 1/2.75,

Pyroxenes = single thread

Amphiboles = double threads

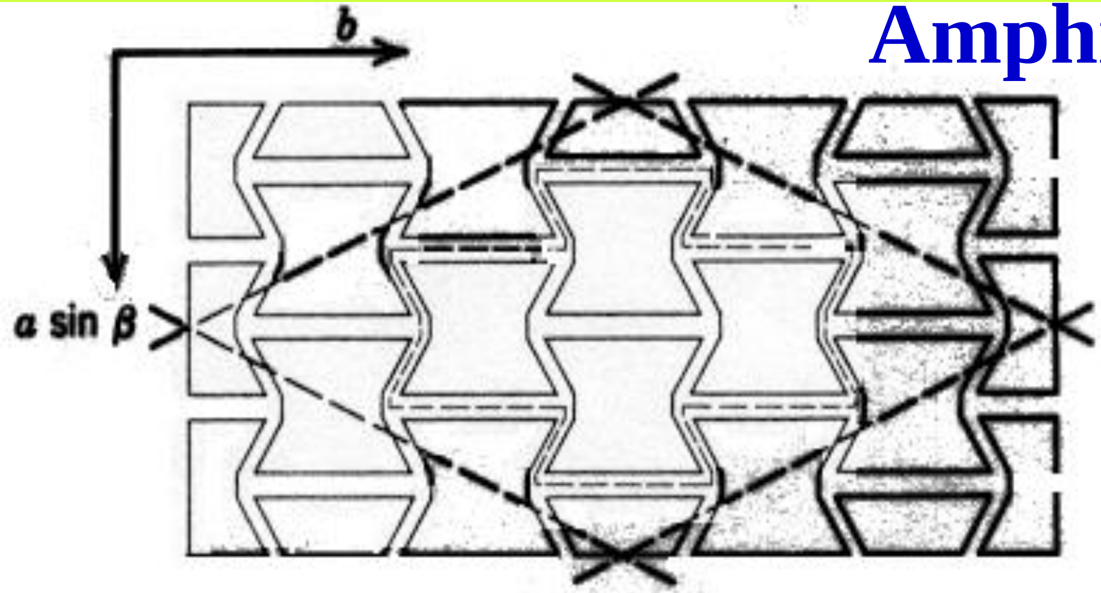
Pyroxenes



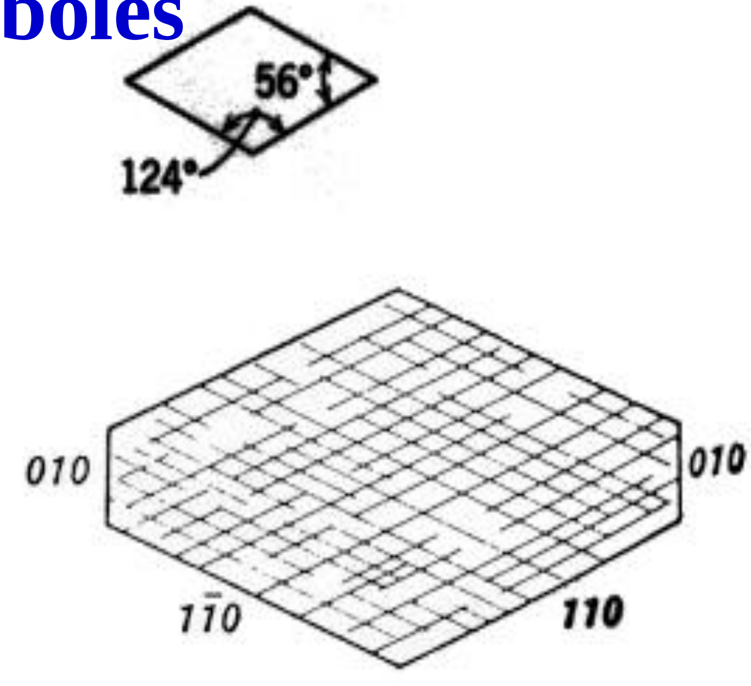


(b)

Amphiboles



(b)



- **Many properties are similar.**
- **"c" dimension is similar (approx. 5.2 Å), because of the double thread "b" dimension of amphiboles is roughly two times than pyroxenes.**
- **OH group only present in amphiboles, therefore, their specific density and refractive index is slightly lower than pyroxenes.**
- **Amphiboles are generally acicular.**
- **Pyroxenes form magma at early stage, they may be converted to amphiboles. Amphiboles are easy to weather.**

Pyroxene general formula: XYZ_2O_6.

Example: Augite XYZ_2O_6 (Ca,Na) (Mg, Fe, Al) $(Si,Al)_2O_6$

Amphiboles: $W_{0-1}X_2Y_5Z_8O_{22}(OH,F)_2$

Example: Hornblende $(CaNa)_{2-3}(MgFeAl)_5Si_6(SiAl)_2O_{22}(OH)_2$

5. PHYLLO-SILICATES (leaf, sheet) three O is shared Si_2O_5, Si/O=2.5,

- Low specific density,

- One prominent cleavage,

- Contains OH group,

- Important part of soil clays.

6. TECTO-SILICATES (framework) SiO_2, Si/O=1/2.

- Nearly three quarter of the earth's crust made of these minerals (three dimensional framework),
- Each Oxygen in tetrahedron is shared with neighboring tetrahedra.

Examples:

Quartz (quartz, tridymite, cristobalite, opal) Opal $SiO_2\ nH_2O$

Feldspars: K-feldspars: Microcline $KAlSi_3O_8$

Orthoclase

Sanidine

Plagioclase:

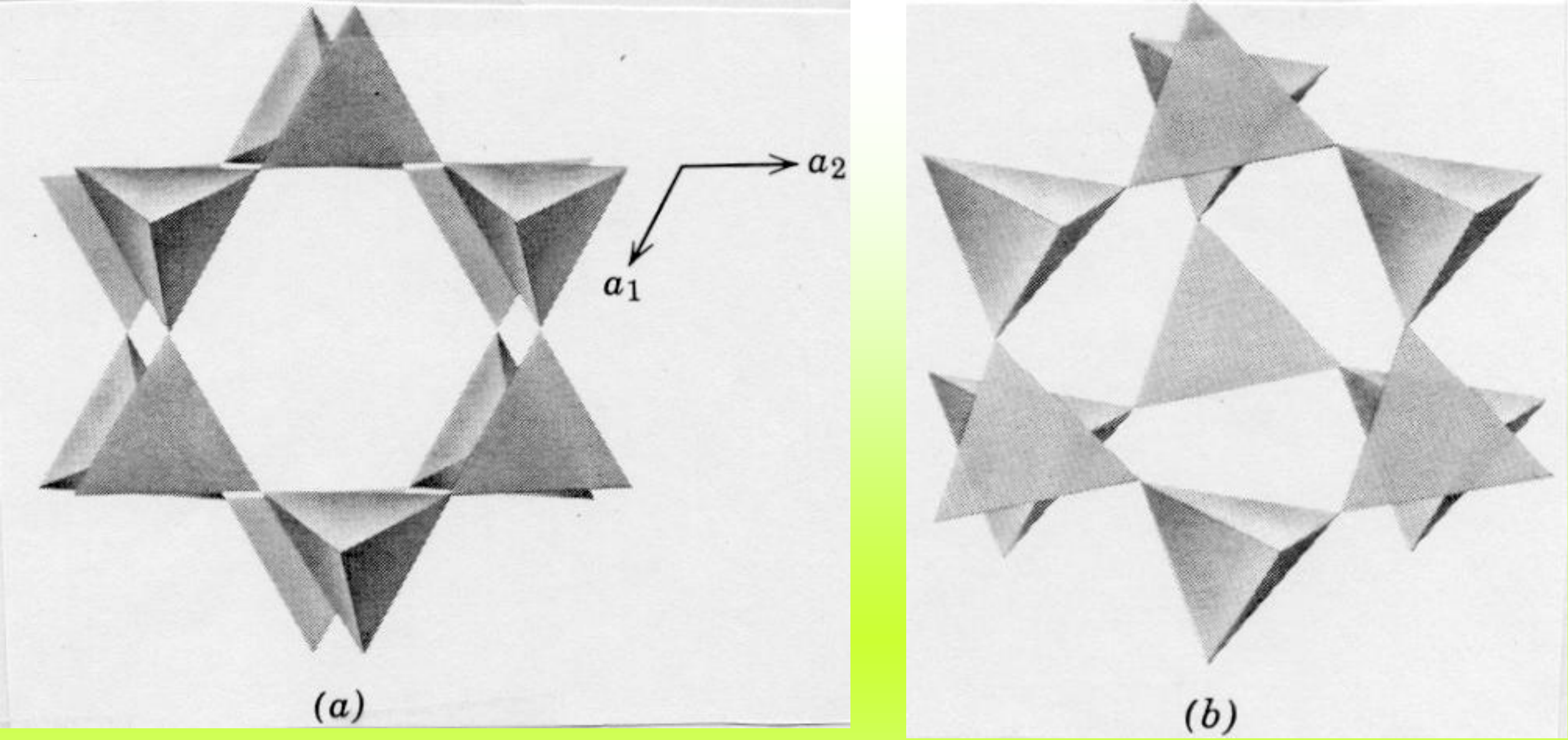
Albite: Na $AlSi_3O_8$

Anorthite: $CaAl_2Si_2O_6$

Feldspatoids

Scapolite Series

Zeolites



Structures of some polymorphs of SiO_2,

(a) Tetrahedron layers in high tridymite projected onto (0001).

(b) portion of the high cristobalite structure projected onto (111).