II-2-6 INO-SILICATES (Silicates with chain tetrahedrons

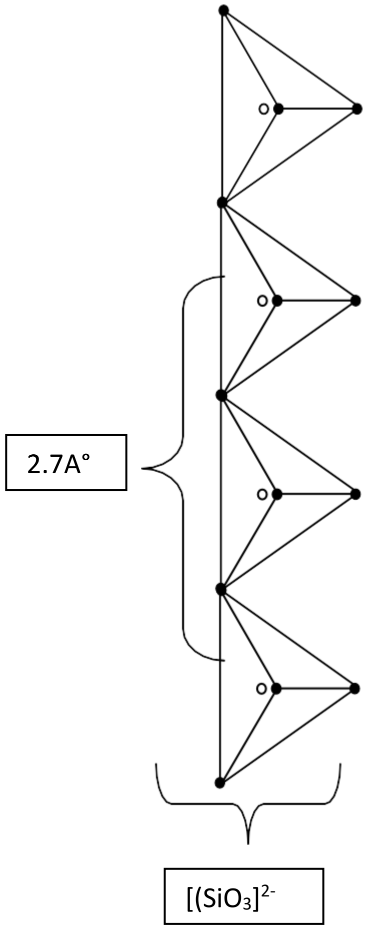
When each tetrahedron shares an oxygen we obtain a **simple chain** of tetrahedra. The result is that for each tetrahedron 2 negative charges have been neutralized. The formula is **$[Si_2O_6]^{4-}$** (pyroxenes).

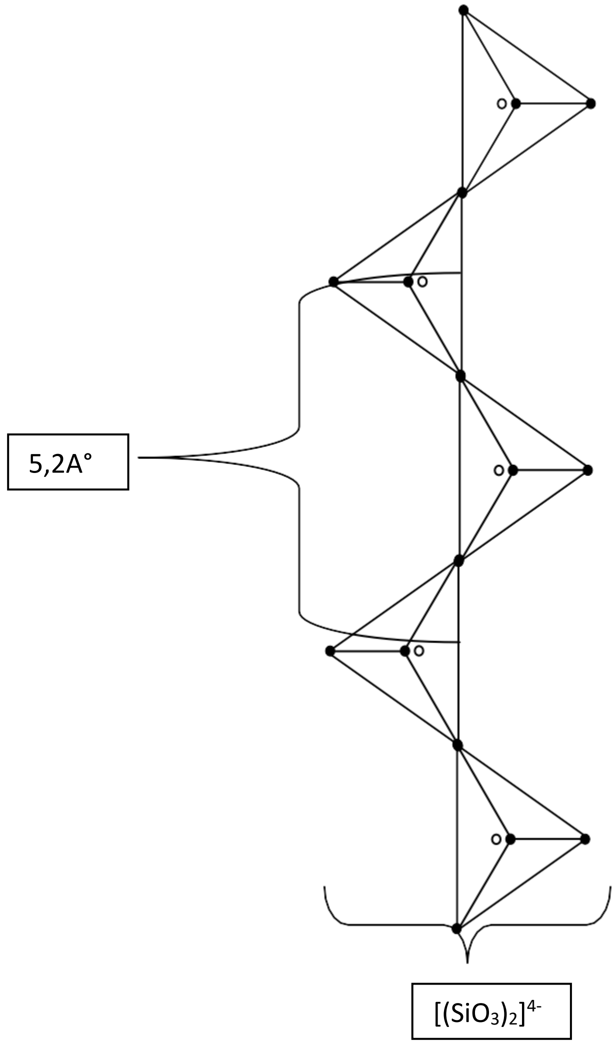
When **two single chains** unite through their oxygens to form double chains, we obtain a structure with the general formula: **$[Si_4O_{11}]^{6-}$** with the presence of OH (amphiboles)

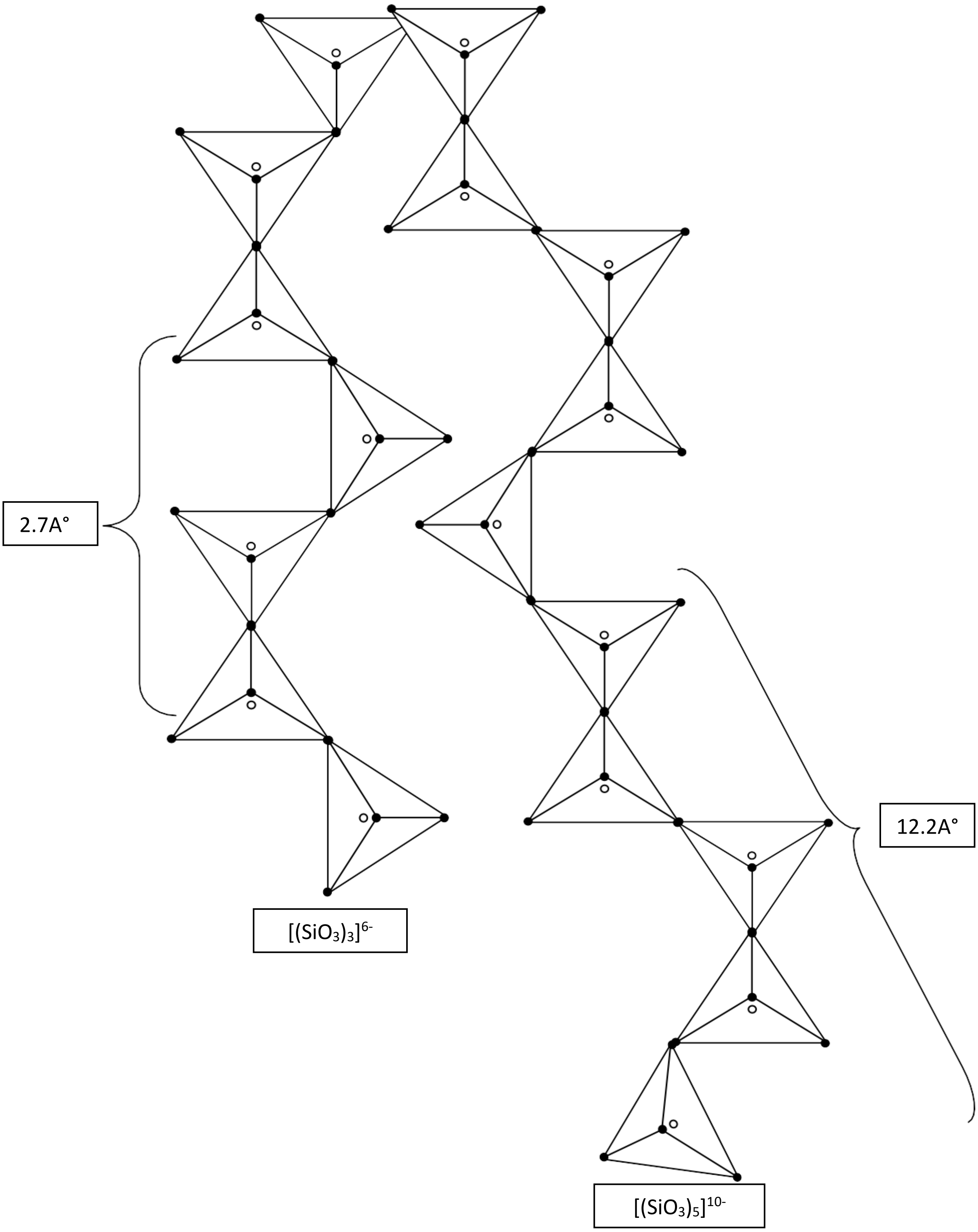
Ino-silicates Are silicates characterized by structures in which

anions consist of infinite single chains or double chains.

- This category of silicates is made up of open chains of tetrahedra. These chains can be single (proxenes) or double (amphiboles)







Reminder: Ino-silicates are silicates with tetrahedra associated in a chain which can be simple, such is the case of Pyroxenes of general formula $(Si_2O_6)^{4-}$, or double chain in the case of amphiboles of general formula $(Si_4O_{11})^{6-}$ **OH .**

II-2-6-1 Pyroxenes

In pyroxenes, the chains are elongated along the c axis and their period is 2 tetrahedra, hence their formula $(Si_2O_6)^{4-}$.

The general formula for pyroxenes is written as follows:

$W_{(1-p)}$ $(X,Y)_{1+p}$ $(Si,Al)_2$ O_6 $0 < p < 1$

In which:

W= Ca or Na cations of large size

X = Fe^{2+}, Mg, Mn, Li, Ni cations of medium size

Y = Fe^{3+}, Al, Ti cations of small size

The chains of tetrahedrons are linked together laterally by the cations Ca, Na, Mg, Fe, Al etc. These cations occupy 2 different kinds of sites: M_1 and M_2. The M_1 sites, located between the small bases of 2 trapezoids, are octahedral. While the M2 sites are located between the large bases and have a coordination between VI and VIII

And therefore less regular than the previous one.

The symmetry of the pyroxenes will in fact depend on the size of the cations which occupy this M_2 site.

If the cations present in this M_2 site are of medium size (Fe, Mg..) the symmetry will generally be orthorhombic, and they will be ortho-pyroxenes.

If, on the contrary, the cations present in the M_2 site are bulky (Ca, Na) the symmetry will be monoclinic and they will be clino-pyroxenes.

The substitution of Si by Al in tetrahedra is generally very weak.

II-2-6-2 General characteristics of pyroxenes

Pyroxenes are distinguished mainly by their shape and cleavage.

Shape: pyroxenes are generally stocky, however elongated, often acicular facies are all the more common as the Na content is higher.

Cleavages: they are characteristic along 110. The traces of these cleavages form an angle close to 90° between them. Furthermore, these divisions are gross and discontinuous.

II-2-6-2-1 Ortho-pyroxenes (OPX)

The OPX form a solid solution from a magnesium term the formula **Enstatite Si_2O_6 Mg_2** up to the iron term **Ortho-ferrosillite** of formula **Si_2O_6 Fe_2.**

The most common intermediate term is: **Hypersthene** Crisp OPX crystals are rare. Most often these pyroxenes appear in fibrous, lamellar or compact masses.

Color: Magnesian terms are light colored, gray, pale green, yellowish white, sometimes light brown. Under the microscope, they are virtually colorless in LN.

The extreme iron terms are greenish black or brownish. These are the intermediate terms that are most often encountered in rocks.

Hardness is between 5 and 6 and density ranges from 3.1 to 3.5

Alteration: OPX weathers into serpentine or talc for magnesium terms.

Deposit: OPX are common in basic and ultrabasic rocks (Gabbros, Norites, Pyroxenolites, Peridotites). They are rarer in metamorphic rocks. They are associated with olivine, serpentine and magnetite.

II-2-6-2-2 Clino-pyroxenes (CPX)

In the CPX the W site will be occupied by Ca or Na (large cations). The pyroxenes are then calcic or sodium and they crystallize in the monoclinic system.

II-2-6-2-2-1 Monoclinic calcium pyroxenes

These pyroxenes always contain a little Fe and Mg and are therefore classified according to the relative values of Ca, Mg, and Fe in the triangular diagram of POLDERVAART and HESS (1951). We thus distinguish:

- Diopside **Si_2O_6 CaMg,**
- Hedenbergite **Si_2O_6 CaFe**
- Augite **Si_2O_6 Ca (Fe, Mg, Al, Ti)**

II-2-6-2-2-1-1 The augite

Augite is the most widespread mineral, it can be ferric, titaniferous and even contain a little sodium (Na), we then say that it is aegyrinic augite. Generally well crystallized in stocky prisms of octagonal sections.

Its color varies from green-brown to black.

Conchoidal breakage. Clear divisions. Translucent to opaque. Vitreous shine.

Augites of volcanic origin often show an hourglass-shaped twin in LM. The Diallage is a variety of augite with additional cleavage 110.

Hardness = 5 to 6 and Density = 3 to 3.6

Deposit: augite is the most common mineral in basic plutonic rocks (Gabbros) and volcanic rocks (dolerites and basalts), but also in ultrabasic rocks (peridotites)

Alteration: augite weathers into uralite. **Uralitization** is the transformation of pyroxenes into green hornblende in association with Pistachite and chlorite when the degree of alteration is high.

II-2-6-2-2-2 Monoclinic sodium pyroxenes

We distinguish: Jadeite **Si_2O_6** Na Al and Aegyrine **Si_2O_6 Na Fe**.

However, the most widespread is aegyrine.

II-2-6-2-2-2-1 Aegyrin

It appears in elongated crystals, in acicular shape, sometimes striated or grooved.

Color: greenish black Transparent to opaque, glassy shine, Hardness varies from 5 to 6 and Density between 3.2 and 3.4

Deposit: aegyrine is a mineral present in alkaline granites and in Nepheline Syenites.

II-2-6-2-3- Amphiboles

Amphiboles exhibit double chain structures (ribbons) of SiO_4 tetrahedra. The structural unit is therefore the **(Si_4O_{11}) (OH)** ribbon directed along the c axis.

The general formula for amphiboles is as follows:

$A_{0-1}(X, Y)_{7-8} (Z_4O_{11})_2 (OH)_2$

With :

A= Ca, Na, K
X =Mg, Fe, Mn,
Y=Al, Fe^{3+} Ti, Cr, Li
Z= Si, Al

In **amphiboles** the tetrahedral substitution Si ↔Al is more pronounced than in pyroxenes.

Between the layers of formula: **$[(SiAl)_4O_{11}OH,F]$,** we distinguish 5 types of cation sites.

Site A: located in the middle of the large trapeze bases. This site can be occupied by the large cations Ca, Na, K with coordination 8 to 10, or unoccupied, that is to say vacant.

Site M4: located on the edge of the large trapeze bases. This site contains cations in 6-8 coordination.

Sites M1, M2, M3: these are small sites which house cations in octahedral coordination.

These sites accommodate the X and Y cations which will determine the orthorhombic or monoclinic symmetry of the amphiboles. So :

- If in X there is Fe and Mg the amphiboles are ferromagnesian and crystallize in the orthorhombic system.
- If X=Ca, the amphiboles are monoclinic calcic.

II-2-6-2-3-1 General characteristics of amphiboles

Amphiboles have great similarities with pyroxenes both in terms of their shape and their chemical composition. They are distinguished from pyroxenes by the structure, the prismatic habit generally more elongated and with a hexagonal section, the angle of cleavages close to 120°, the lower density (2.5 to 3.6) and a hydroxyl radical which does not exist in pyroxenes.

II-2-6-2-3-1-1 ferromagnesian amphiboles

They crystallize in the orthorhombic system because site X contains Fe, Mg. Among them we can distinguish **Anthophyllite** with the formula: **$[(Si_4O_{11})\ OH]_2\ (FeMg)_7$** Crystals with prismatic facies are rare. It often presents as a compact, fibroradiated, fibrous mass.

Color: gray, brownish, brownish green, to reddish brown.

Cleavage following the prism (110) with a cleavage of 120°. Vitreous luster Hardness=5.5 to 6 and density=2.8 to 3.2

Deposit: it is an essential mineral of crystalline shales.

II-2-6-2-3-1-2 Calcium monoclinic amphiboles

In this case site X contains Ca, the amphiboles belonging to this class are:

The actinolite-tremolite group and hornblende.

II-2-6-2-3-1-2-1 Actinote-tremolite

It forms a solid solution since:

a magnesium term, **Tremolite**: **$[(Si_4O_{11})\ OH]_2Ca_2\ Mg_5$** towards a ferrous term, ferroactinote: **$[(Si_4O_{11})\ OH]_2\ Ca_2\ Fe$**, the intermediate term being Actinolite of formula

[(Si4O11) OH] 2 Ca2 (Mg, Fe)5,

Crystals are rare in **Tremolite**, however they are more common in Actinolite; prisms more or less elongated, sometimes lamellar. Usually in acicular to fibrous aggregates.

White to dark gray color. Vitreous to silky shine; uneven breakage Hardness = 5 to 6 and density = 2.9 to 3.2

Long-fiber asbestos is a fibrous variety of **Tremolite**.

Deposit: tremolite is found mainly in crystalline limestones and dolomites.

Actinolite in crystalline, chloritic or talcose shales.

II-2-6-2-3-1-2-2 Hornblende

Its formula is: **$[(Si_3AlO_{11})\ OH]_2\ (Ca, Na, K)_{2\text{-}3}(Mg, Fe^{2+}, Fe^{3+}, Al)_5$**We distinguish between green hornblende and brown hornblende or basaltic hornblende which is richer in iron.

Basaltic hornblende is generally well crystallized: elongated prismatic crystals with a hexagonal section. Green hornblende in loose, unclear crystals, in elongated flattened, fibrous, sometimes massive aggregates.

Green Hb color: green, bluish green, light brown, blackish green. Hb brown: brown to shiny black.

Translucent. Subconchoidal breakage. Hardness = 5 to 6 and density = 3 to 3.4 Alteration into epidote, serpentine, chlorite.

Deposit: brown Hb or basaltic Hb is more common in volcanic rocks (basalts, trachytes). Green Hb is found in granites, syenites, diorites but also in rocks of contact metamorphism and in crystalline schists (amphibolites).

II-2-6-2-3-1-3 Monoclinic sodium amphiboles

Site X contains Na.

Among the most important we will cite **Riebeckite** of formula: **$[Si_4O_{11}(OH)]_2 Na_2 Fe^{3+}$**

It occurs in irregular or fibrous prismatic crystals and in lamellar or asbestiform aggregates.

Color: blue black to black

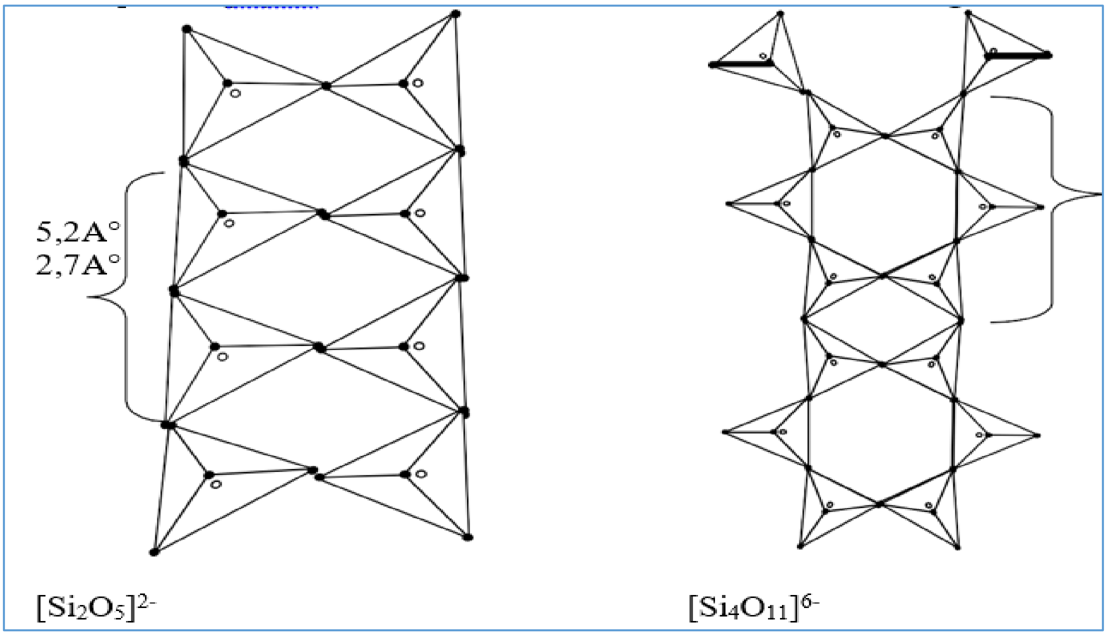
Glassy shine but sometimes silky to shimmering Perfect cleavage according to the vertical prism Hardness = 5.5 to 6 and density = 3.02 to 3.42.

Deposit: **Riebeckite** is found in rocks of low temperature and low and medium pressure metamorphism, but also in alkaline magmatic rocks: in granites and syenites.

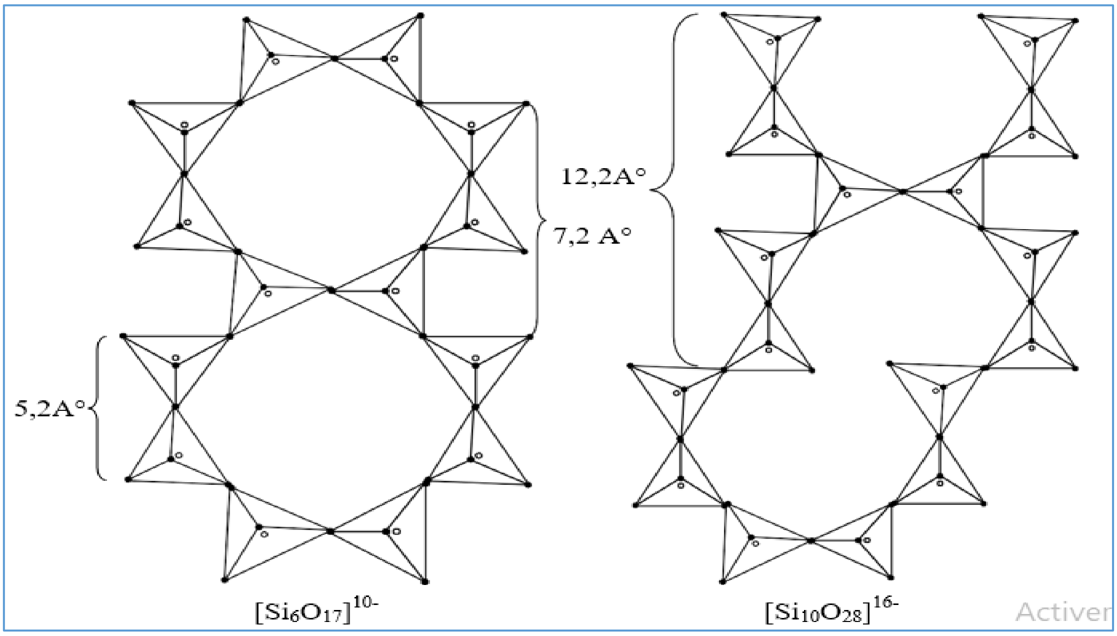
II-2-7 PHYLLOSILICATES (Sheet tetrahedron)

If we extend ribbons of tetrahedra indefinitely in 2 directions we obtain structural sheets where all the tetrahedra are linked by 3 of their vertices. The framework will have pseudo-hexagonal symmetry and excellent basal cleavage. The anionic group will be $[Si_4O_{10}]^{4-}$. In this group, tetra coordinated Al can replace up to 2 of the 4 Si atoms.

Examples of phyllo-silicates: micas, talc, clay minerals.



Container of single period channels Pairing of two (02) double period channels



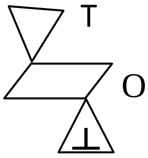
Pairing of two triple period chains Pairing of two quintuple period chains

Jumelage de deux chaines à périodes triple (Fr) Jumelage de deux chaines à périodes quintuple

Phyllo-silicates belong to them the following minerals:

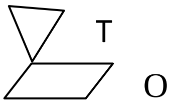
Muscovite, Biotite, that is to say micas, chlorites and clay minerals. a- General formula of phyllo-silicates of the type.

a- General formula of phyllo-silicates of the type (TOT)



Example : A2-3[(Si, Al)4 O10 (OH)2]

b- General formula of phyllo-silicates of the type (TO)



Example: $A_{2-3}[(Si, Al)_2\ O_5\ (OH)_2]$

There are several groups of phyllosilicates:

1- Talc-type phyllo-silicates

2- Group of micas: Biotite, Muscovite, Glauconium, Phlogopite, Lepidolite etc,….

3- Chlorite group: clino-chlorine

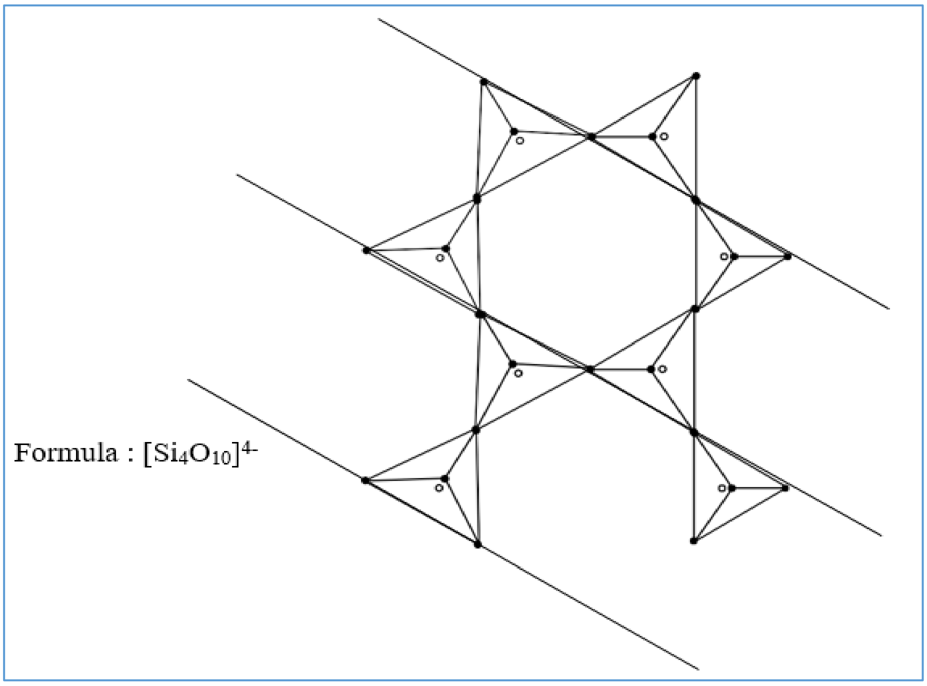
4- Clay group: Kaolin, Montmorillonite

5- Serpentine group: serpentine, chrysolite.

If we consider the smallest possible unit which accounts for the architect of the mineral, we see that, in the building, each tetrahedron has only one unsaturated oxygen.

II-2-8 TECTO-SILICATES (SHEET TETRAHEDRON)

The tetrahedra have all their oxygens in common, they are linked by all their vertices. The tetrahedra form a three-dimensional framework. The structural formula is **SiO_2**. The oxygens of the framework do not form a compact stack, cations of variable size occupy the gaps. Within the tectosilicates we distinguish the families of silica, feldspars and feldspathoids.



Rappel

Les tecto-silicates sont des silicates à tétraèdres en édifices à 3 dimensions ou tecto-silicates, c'est à dire tétraèdres disposés en charpente ou toit.

Les tétraèdres SiO4 sont soudés les uns aux autres par leur 4 sommets. De ce fait chaque atome d'O2 appartient à 2 tétraèdres voisins.

Lorsque les tétraèdres sont dépourvus d'Al la charpente atteint la neutralitéélectrique et la formule structurale de l'édifice est SiO4/2 ce qui donne **SiO_2**, c'est le groupe de la silice.

Lorsque les tétraèdres contiennent de l'Al les charges négatives excédentaires de la charpente sont compensées par de gros cations alcalins ou alcalino-terreux qui viennent se loger dans les cavités, la formule structurale devient alors **$[(Si\ Al)O_2]_n$** , c'est le groupe des feldspaths , des feldspathoïdes et des zéolites.

Tecto-silicates are subdivided into 5 groups or families:

- silica group
- feldspar group
- feldspathoid group
- zeolite group
- scapolite group

II-2-8-1 Silica family or group

II-2-8-1-1 silica polymorphism

Silica occurs in the form of numerous polymorphic varieties, varieties whose stability field is given in the P-T equilibrium diagram (see drawing)
There are several varieties of silica:
- crystallized with quartz as an example
- with a fibrous structure, for example chalcedony
- amorphous example opal

II-2-8-1-2 Quartz (SiO2)

It crystallizes in the pseudo-hexagonal rhombohedral system, it often has a bi-pyramid shape.
Color: although normally colorless (rock crystal or hyaline quartz), quartz can present numerous colors (allochromatism phenomenon). We thus distinguish:

1. Rose quartz, color due to traces of Mn or hematite inclusions.
2. Yellow quartz or citrine color due to traces of colloidal ferric hydroxides.
3. Purple quartz or amethyst color due to traces of Re3+. Black or smoky quartz
4. Milky white quartz

In these last 2 cases the coloring would be linked to a particular electronic distribution.
Tiger's Eye**:** variety of silica with shimmering reflections.

- Hardness: 7
- Conchoidal breakage, greasy to vitreous shine.
- No cleavage, but presence of twins through penetration or adjoining.

Deposit: It can be present in all types of rocks, whether magmatic, metamorphic or sedimentary.
In igneous rocks, it is involved in the classification of rocks as a cardinal mineral in the same way as feldspars and feldspathoids. It characterizes supersaturated rocks. It is found in granites, granodiorites, quartz diorites and their effusive equivalents.
In metamorphic rocks, it is present both in rocks of contact metamorphism and those of general metamorphism.
In sedimentary rocks, it characterizes sandstones.

II-2-8-1-3 chalcedony and opal $(SiO_2)_n\ H_2O$

These are products of silica concretion in a sedimentary (flint, chert) or igneous (agate nodules, filling of vacuoles) context.
Chalcedony can be subdivided into chalcedony in the strict sense with uniform coloring, and agate variously colored in parallel or concentric bands. They can be white, red, brown or green.
Opals are called hyalite when they are colorless and transparent with a bold sheen, and noble opal when they are translucent but reflective of light.

II-2-8-1-4 Tridymite and cristobalite

Tridymitis is found in 2 forms:
-high temperature, crystallizing in the hexagonal system

-low temperature crystallizing in the orthorhombic system
It generally comes in thin twinned hexagonal plates 2 by 2 or 3 by 3.
It also comes in rosettes of white crystals.
Deposit: tridymite is a mineral from acidic volcanic rocks: trachytes, andesites and rhyolitic tuffs.
Cristobalite is also found in 2 forms:
- high temperature, crystallizing in the cubic system
- low temperature crystallizing in the quadratic system
It appears in the form of octahedral crystals, sometimes twinned on (111), or in spherolitic masses.
Deposit: it is associated with tridymite.

II-2-8-2 Family or group of feldspars

Feldspars are by far the most important minerals in the earth's crust. The composition of usual feldspars is described as a ternary solid solution between 3 stoichiometric poles:

- ✓ Orthose : $\mathbf{Si_3Al\ O_8\ K}$ (3/1)
- ✓ Albite $\mathbf{Si_3Al\ O_8\ Na}$ (3/1)
- ✓ Anorthite $\mathbf{Si_2Al_2\ O_8\ Ca}$ (1/1)

There are 2 fundamental groups of feldspars: Alkaline feldspars: orthoclase-albite
Calco-sodium feldspars: plagioclase

II-2-8-2-1 Alkaline feldspars

We distinguish between potassium feldspars and sodium feldspars.
- potassium feldspars
They are polymorphic with formulas $\mathbf{Si_3Al\ O_8\ K}$, we have:

- **Orthoclase** crystallizing in the monoclinic system
- **Microcline** crystallizing in the triclinic system
- **Sanidine** crystallizing in the monoclinic system

We can consider that the microcline phase has a fully ordered structure from the point of view of the positions of the Si tetrahedra and the Al cations. While the orthoclase phase admits partial disorder between Si and Al. The disorder becomes total in the monoclinic sanidine.
The ordered phases produced during slow cooling are called low temperature, while the disordered phases crystallizing quickly are called high temperature.

II-2-8-2-2 Sodium feldspars

They are represented by the albite with the formula $Si_3Al\ O_8Na$.
In alkali feldspars, there can be a perfect solid solution from sodium feldspars to potassium feldspars but only at high temperatures, as in lavas (see diagram).
On the other hand, at low temperature, there is immiscibility between the extreme terms (the K and Na ions have ionic radii which differ by more than 15%), and the medium which has, for example, a composition of 60% Orthoclase. and 40% of albite consolidates into a heterogeneous crystal: Perthite.
The dominant feldspar constitutes the matrix of the building in which the other is dispersed in the form of facules having the appearance of veins, spindles, laces, spots, etc.

visible to the naked eye and under a microscope.

The appearance of the continuous series of high temperatures or that of low temperatures depends on 2 factors:

- the initial consolidation temperature
- the cooling speed which must be rapid so that the series of high temperatures can persist. (diagram)

II-2-8-2-3 Calco-sodium feldspars: Plagioclase

It is the perfect type of a complete isomorphic series from albite to anorthite. (diagram see plate). We distinguish:

- ✓ Albite 0 to 10% of An Oligoclase 10 to 30% of An
- ✓ Andesine 30 to 50% of An
- ✓ Labrador 50 to 70%
- ✓ Bytownite 70 to 90%
- ✓ Anorthitis 90 to 100%

Plagioclase crystallizes in the triclinic system.

II-2-8-2-4 General characteristics of feldspars

Feldspars have a large number of common characteristics, whatever the species to which they belong. When they are not altered, they are porcelain white or more rarely colorless.

They crystallize in monoclinic or triclinic systems.

Perfect (001) and imperfect (010) cleavages are common to all feldspars.

Feldspars are very often twinned:

Carlsbad twin: simple, adjoining of 2 individuals is characteristic of potassium feldspars (orthoclase and sanidine).

Albite twin: polysynthetic by the joining of several individuals characteristic of plagioclase.

Pericline twin: this is a polysynthetic twin of albite and microcline.

The grid observed in LM of the microcline corresponds to the combination of albite and pericline twins.

Feldspars are often automorphic.

Feldspars are rarely transparent, they are generally translucent. Color: Feldspars are milky white, grayish or pinkish (orthoclase) or light green, notably microcline which is called amazonite.

The luster of feldspars is glassy and sometimes pearly to iridescent.

Their hardness is 6 and their density is between 2.5 and 2.7.

Deposit: Feldspars are the cardinal minerals of igneous, supersaturated, saturated and even undersaturated silica, grained, micrograined or microlitic rocks.

II-2-8-3 Feldspathoids

These are minerals deficient in silicon, they are symptomatic (indicate) of undersaturated rocks in the classification of magmatic rocks.

According to their structure, we distinguish 3 groups of feldspathoids:

- nepheline group characterized by the tridymite skeleton
- leucite group " " " " " cristobalite
- sodalite group characterized by a caged skeleton.

II-2-8-3-1 Nepheline group

In this group we distinguish nepheline and cancrinite.

Nepheline (Ne) of formula: $(SiAlO_4)4\ Na_3\ K$, crystallizes in the hexagonal system. It is stable up to 900°C and at 1250°C it becomes charged with cubic carnegieite.

Ne is rarely well crystallized in a squat prism, it is often grainy or massive.

Its break is subconchoidal, it is colorless, yellowish white, sometimes greenish, or reddish.

The sheen of nepheline is glassy to oily. It weathers into sodalite, pinite or zeolites.

Deposit: Ne is the most common feldspathoid, it is found in all undersaturated, plutonic or volcanic rocks (nepheline syenites, phonolites, basanites).

The mineral also arises metasomatically in metamorphic rocks such as nepheline limestones.

Cancrinite of formula $(SiAlO_4)_3\ (Na,Ca)_4\ CO_3\ (H_2O)_{0\text{-}3}$

1 cancrinite is equivalent to 3 Ne + $CaCO_3$

It rarely occurs in prismatic crystals but rather in compact masses in nepheline syenites.

II-2-8-3-2 leucite group

In this group we distinguish leucite and analcime.

Leucite of formula: $(Si_2\ Al\ O_6)\ K$ crystallizes, in the quadratic system, in included pseudocubic crystals, sometimes reaching 5 cm, showing trapezohedral faces, often striated faces. It is sometimes grainy or massive, with a conchoidal break, milky white to gray in color, opaque sometimes translucent, with a glassy sheen.

Deposit: Leucite is found mainly in lavas: leucite basalts, phonolites, and leucitites.

The analcime with the formula $(Si_2\ Al\ O_6)\ Na\ H_2O$ is sometimes classified as a zeolite because it contains H_2O. It crystallizes in the cubic system with free crystals sometimes reaching up to 15 cm in geodes. It very rarely appears in cubes, rather in compact earthy masses of yellow-white or pinkish color with a vitreous sheen.

Deposit: Analcime is found in basalts, basaltic tuffs, trachytes and phonolites, in sedimentary rocks where it results from the alteration of leucite.

II-2-8-3-3 Sodalite Group

In this group we distinguish:

- Sodalite of formula: $(Si\ AlO_4)_6\ (Na_8\ Cl_2)$
- Noséane of formula: $(Si\ AlO_4)_6\ (Na_2\ SO_4)$
- Haüyne of formula: $(Si\ AlO_4)_6\ (Na, Ca)_{4-8}\ (SO4)_{1-2}$

Sodalite crystallizes in the cubic system, it rarely occurs in crystals but often in compact masses and grains. It can be colorless,

white, gray, greenish, sometimes even lavender blue. It is transparent to translucent and its luster is vitreous.

Haüyne most often appears in rounded grains of white to sky blue color with clear transparent to translucent cleavage.

Deposit: In undersaturated plutonic and volcanic rocks where these minerals coexist with leucite and nepheline, in nepheline syenites and in phonolites.

II-2-8-3-4 Zeolite group

They are tecto-silicates characterized by large channels that contain loosely bound water molecules (zeolite water). This water can be absorbed or resorbed reversibly, in response to variations in partial pressure of water vapor or heating (

At moderate temperatures, the silicate skeleton remains rigid.

The expelled zeolite water can be reversibly replaced by different gaseous atoms or molecules (H_2S, NH_3, CCl_4, Ar, Xe, Ne, etc.) or metals (Hg), hence their use as a molecular trap in vacuum pumps, and as selective traps of small molecules in a mixture (molecular sieve).

These are hydrated alumino-silicates whose negative charges of the framework are compensated by Ca, Na, and K and more rarely by Ba, Sr, and Mg.

The chemical formulas of zeolites correspond to the relationship: $(CaO + Na_2O + K_2O + BaO + SiO + MgO) / Al_2O_3 = 1$

These cations which are also housed in the channels are poorly bonded, they are easily exchangeable between them 2Na Ca hence their use in the softening of hard water.

According to their structure and their facies, we distinguish 3 families:

II-2-8-3-4-1 Fibrous zeolites: elongated facies, acicular to fibrous, they form fibroradiated groups.

- Natrolite: **$Na_2\ (Al_2Si_3O_{10})2H_2O$**,, which crystallizes in the orthorhombic system.
- Thomsonite
- Mesolite: **$Na_2\ Ca_2\ (Al_2Si_3O_{10})\ 8H_2O$** which crystallizes in the monoclinic system.

II-2-8-3-4-2 Lamellar zeolites: flattened facies, easy cleavage according to 010.

- Heulandite: **$(Ca,Na_2)(Al_2Si_7O_{18})6H_2$**O, crystallizes in the monoclinic system.

- stilbite: **$(Ca, Na_2, K_2)(Al_2Si_7O_{18})\ 7H_2O$**, crystallizes in the monoclinic system.

II-2-8-3-4-3 Isometric zeolites: they are excellent molecular sieves, their symmetry is pseudo cubic or cubic.

- Chabazite: $(Ca, Na_2)(Al_2Si_4O_{12})\ 6\ H_2O$ crystallizes in the rhombohedral system.

- Pargasite: $(Ca, Na_2)(Al_2Si_4O_{12})\ 16\ H_2O$ crystallizes in the cubic system.

Zeolites are colorless or white with yellowish, greenish or reddish reflections.

Vitreous to silky shine.

Hardness between 4 and 5.5, density 2 to 2.5

Zeolites can be distinguished from each other by an X-ray study

Deposit: They are generally present in association with calcite in the vacuoles of effusive rocks (basalts) and in pegmatites.

II-2-8-3-5 Group of scapolites or wernerites

These minerals have the same silicate framework as feldspars, but large cations are inserted into the large gaps in the framework. The symmetry is quadratic.

The scapolites form an isomorphic series between:

Marialite **$(Si_3AlO_8)_6\ (Cl_2, SO_4, Ca_3)\ Na_8$** and

Meionite **$(Si_3AlO_8)_6\ (Cl_2, SO_4, Ca_3)\ Ca_8$**

The dipyrus being the middle term of the series.

We can say that: Marialite is equivalent to 3 albites + 2 NaCl and Meionite is equivalent to 3 anorthites + $CaCO_3$.

This led us to think that the wernerites were a type of plagioclase with a pneumatolitic tendency.

Deposit: Wernerites are found in metamorphic rocks enriched locally or regionally in Cl2, CO3, SO3. They alter into mica, epidote, albite or kaolin.

https://www.studocu.com/row/document/universite-ibn-zohr/m3-geologie-generale/cours-mineralogie-cours/47577524

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