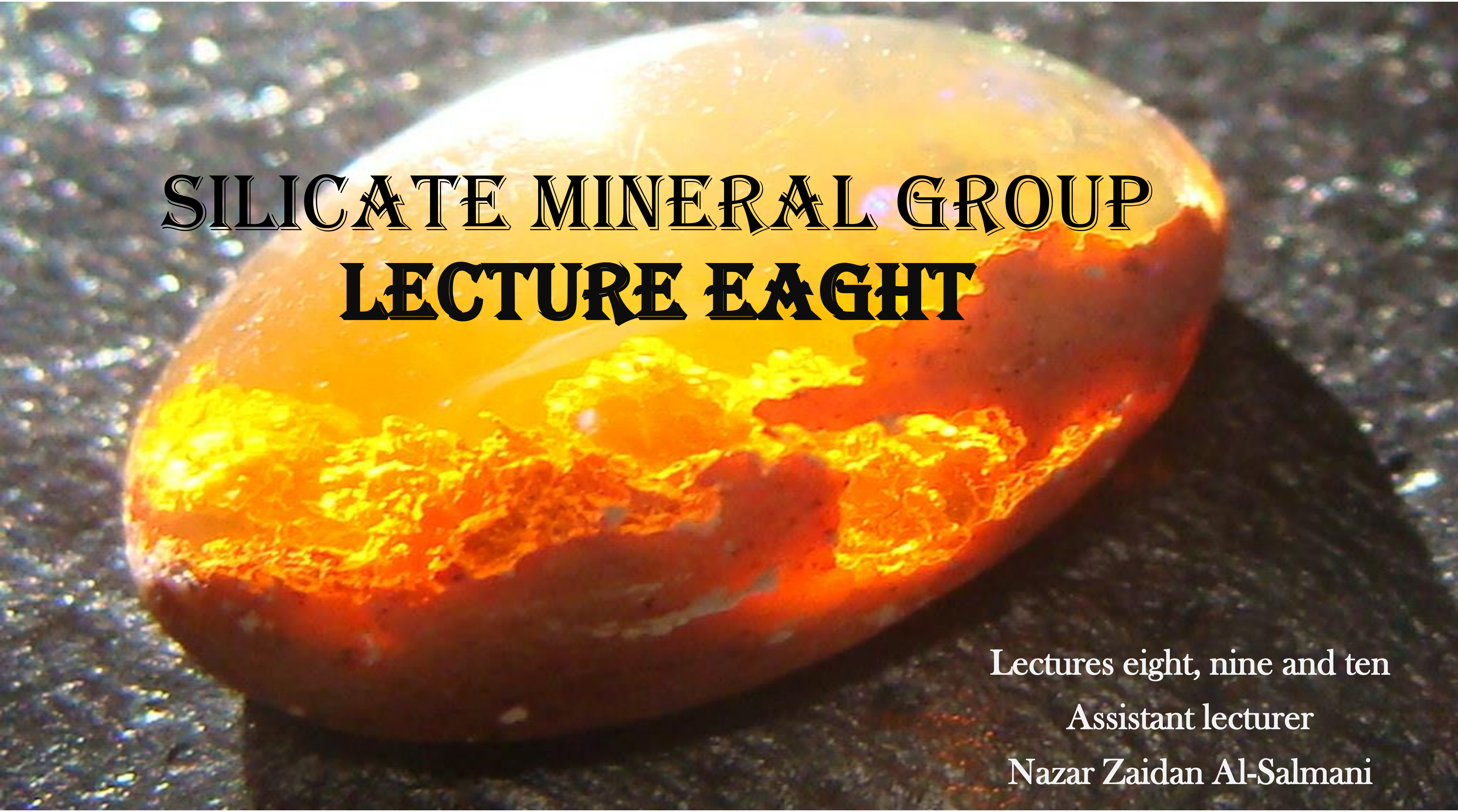
University of Anbar
Collage of Science
Department of Geology
Minerals / 1st stage.

SILICATE MINERAL GROUP

Assistant lecturer
Nazar Zaidan Khalaf



SILICATE MINERAL GROUP
LECTURE EAGHT

Lectures eight, nine and ten

Assistant lecturer
Nazar Zaidan Al-Salmani

- **Silicates mineral group**

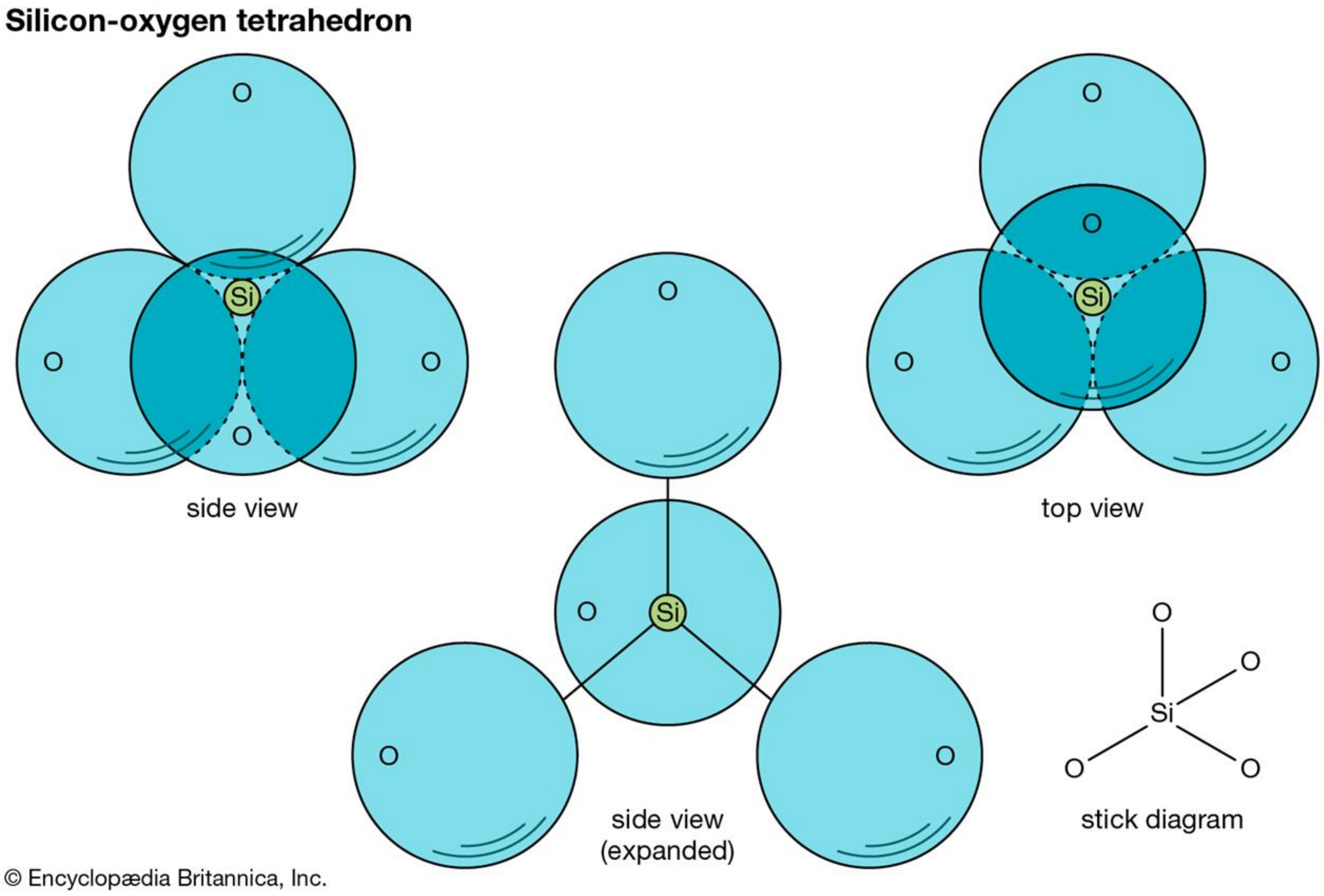
- Silicates are the most common and most important petrogenic minerals, particularly feldspars, amphiboles, pyroxenes, olivine, micas and clay minerals.

-Their main characteristics are:

- difficult to melt and often have very complex chemical composition because of isomorphic replacement. Most silicate minerals are formed by crystallization of magma at high temperatures, and in metamorphic processes at high temperature and high pressure.
- Silicate minerals are classified according to the structure with main feature of strong relationship between major oxygen ions, and minor silicon ions.

Silicates mineral group

- Four oxygen ions are arranged in close form of the tetrahedron with a small silicon ion in the center. Therefore, the basic structural unit of silicate minerals is SiO4 tetrahedra.



Silicates miner

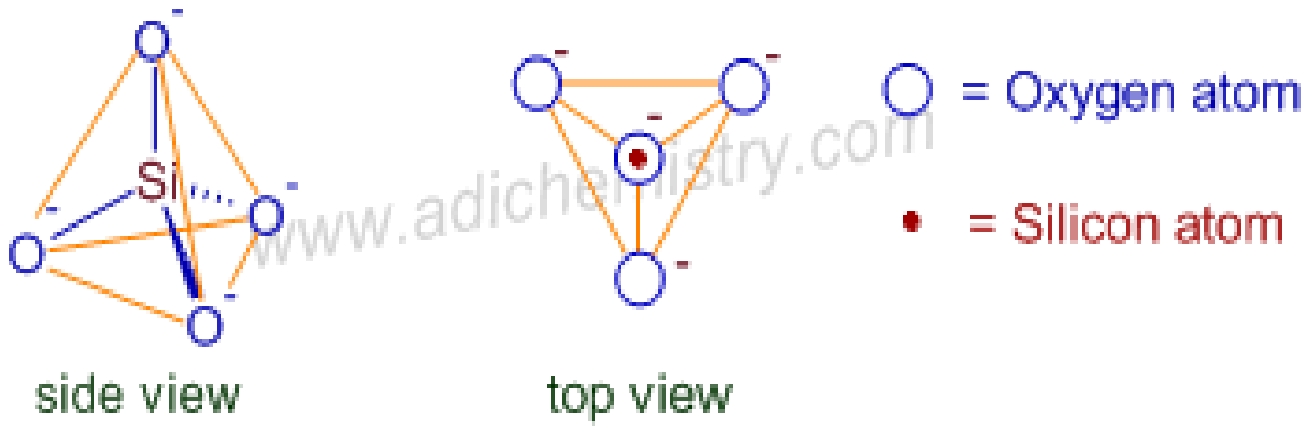
- **Structure**
- The basic structural unit of all silicate minerals is the silicon tetrahedron in which one silicon atom is surrounded by and bonded to (i.e., coordinated with) four oxygen atoms, each at the corner of a regular tetrahedron. These SiO_4 tetrahedral units can share oxygen atoms and be linked in a variety of ways, which results in different structures
- The topology of these structures forms the basis for silicate classification. For example,
- nesosilicates are minerals whose structure are made up of independent silicate tetrahedrons.
- Sorosilicates are silicate minerals consisting of double tetrahedral groups in which one oxygen atom is shared by two tetrahedrons.
- Cyclosilicates, in contrast, are arranged in rings made up of three, four, or six tetrahedral units.
- Inosilicates show a single-chain structure wherein each tetrahedron shares two oxygen atoms.
- Phyllosilicates have a sheet structure in which each tetrahedron shares one oxygen atom with each of three other tetrahedrons.
- Tectosilicates show a three-dimensional network of tetrahedrons, with each tetrahedral unit sharing all of its oxygen atoms.

Silicates mineral group

- Silicate minerals are put together by binding siliconeoxygen tetrahedra to each other and to other ions in a fairly small number of ways. Even this number represents only variations on the theme of combining ionic and covalent bonds. The ionic bonding of tetrahedra involves another atom, a cation which usually carries a +2charge. This ion is situated between the corners of two tetrahedra where it can receive one electron from the nearest oxygen in each. The covalent bonding of tetrahedra involves actually sharing one oxygen atom between two adjacent tetrahedra. One of the extra electrons of the shared oxygen is used by one silicon, and the other electron is used by the other. Between these two extreme cases, there are a number of different cases of bonding two, three, four, six or more of the SiO4 tetrahedra,
- so that there are seven different major structural types of silicate minerals. These are the following:

NESOSILICATES $[SiO_4]^{4-}$

- In the structure of nesosilicates, SiO_4 tetrahedra are not directly connected with mutual oxygen ion, only by interstitial cations. The simplest structure in nesosilicates have mineral forsterite $Mg_2[SiO_4]$. The most important minerals from the nesosilicates are shown in Table below. Olivine with little iron is closer to forsterite with greenish color. The same with more iron is closer to fayalite with dark green color. Olivine crystallizes in orthorhombic system and hardness of 7-6.5 (depending on the isomorphous replacement of Mg with Fe). It forms by crystallization of magma at high temperatures (pyrogen minerals). In normal atmospheric conditions, it has low resistance to weathering and easily subjected to metamorphism in the mineral serpentine (olivine serpentinization), talc or actinolite.

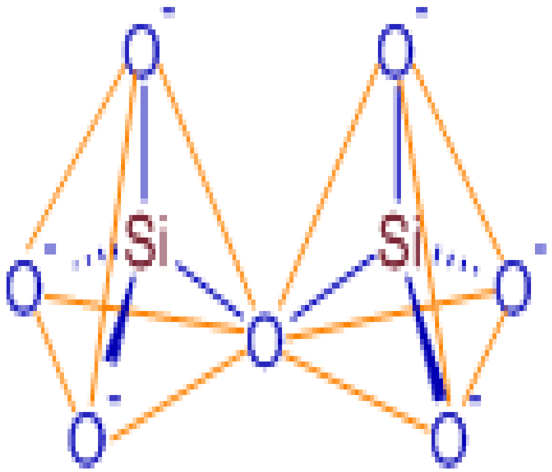


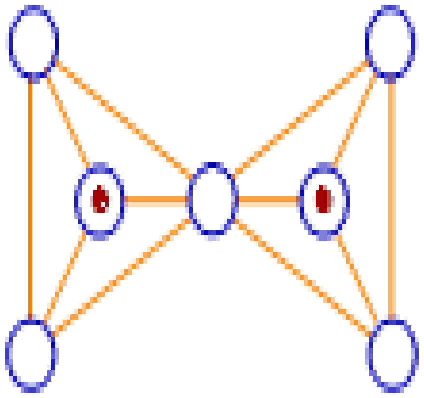
The Most Important Petrogenic Minerals from Nesosilicates Group

Olivines Group	Al_2SiO_5 Group
Forsterite – Mg_2SiO_4	Andalusite – Al_2SiO_5
Fayalite – Fe_2SiO_4	Kyanite – Al_2SiO_5
	Sillimanite – Al_2SiO_5
Garnet Group	**Zircon Group**
Pyrope – $Mg_3Al_2(SiO_4)_3$	Zircon – $ZrSiO_4$
Almandine – $Fe_3Al_2(SiO_4)_3$	Titanite – $CaTiSiO_{52}$
Spessartine – $Mn_3Al_2(SiO_4)_3$	
Grossular – $Ca_3Al_2(SiO_4)_3$	
Andradite – $Ca_3Fe_2(SiO_4)_3$	
Uvarovite – $Ca_3Cr_2(SiO_4)_3$	

Sorosilicates $[Si_2O_7]^{6-}$

- Sorosilicates have isolated double tetrahedra groups with $(Si_2O_7)^{6-}$ or a ratio of 2:7. There are no significant petrogenic minerals among sorosilicates, except epidote, zoisite and vesuvianite

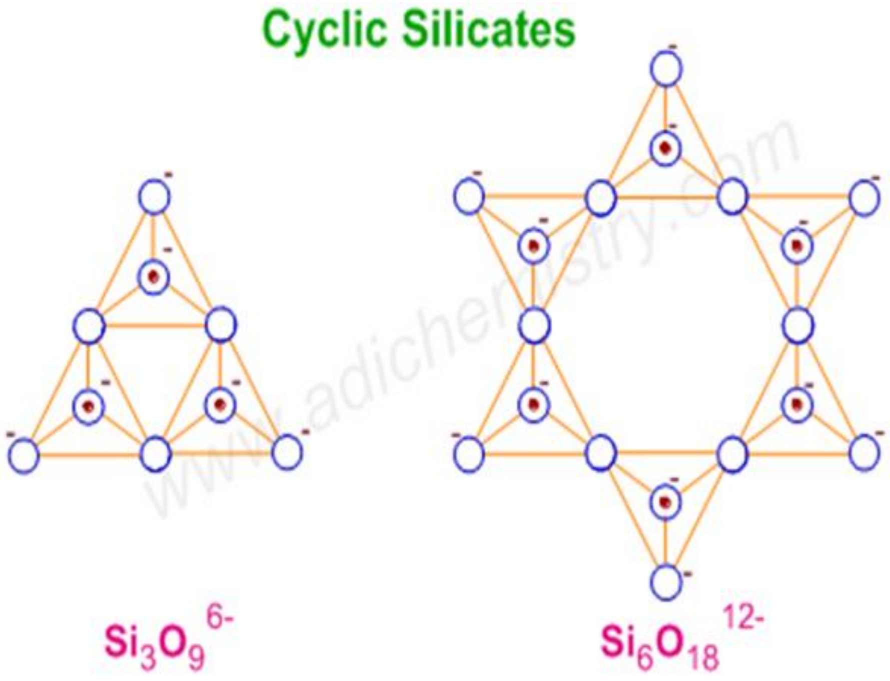




Cyclosilicates: $[Si_nO_{3n}]^{2n-}$

- Cyclosilicates, or ring silicates, have linked tetrahedra with $(Si_xO_{3x})_{2x}$ or a ratio of 1:3. These groups of minerals exist as three-member $[Si_3O_9)^{6-}]$. four-member $(Si_4O_{12})_{8-}$ and six member $[Si_6O_{18})^{12-}]$. rings.
- 1. Three-member ring Benitoite - $BaTi(SiO_3)_3$
- 2. Four-member ring Axinite {(Ca,Fe,Mn)3Al2(BO3)(Si4O12)(OH)}
- 3. Six-member ring Beryl/Emerald {$Be_3Al_2(SiO_3)_6$ Cordierite {$(Mg,Fe)_2Al_3(Si_5AlO_{18})$}

- Cyclosilicates



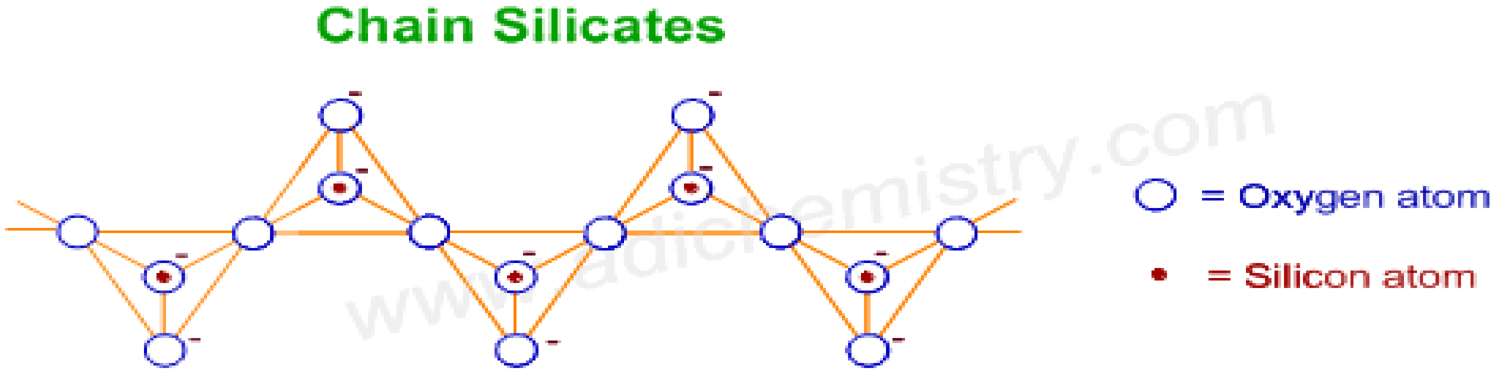
• The Most Important Petrogenic Cyclosilicates

6-Member Ring	
Tourmaline group	Beryl
MgeAl:	$Be_3Al_2Si_6O_{18}$
$Al_5Mg_3CaMg\ (OH,F)_4\ Si_6O_{27}B_3$	
NaeAl:	
$Al_7Na_2Mg\ (OH,F)_4\ Si_6O_{27}B_3$	Cordierite
FeeAl:	$(Mg,Fe)_2Al_3(Al,Si)_5O_{18}$
$(Al,Fe)_5FeCaFe\ (OH,F)_4\ Si_6O_{27}B_3$	

INOSILICATES

- Inosilicates, or chain silicates, have interlocking chains of silicate tetrahedra with either SiO_3, 1:3 ratio, for single chains or Si_4O_{11}, 4:11 ratio, for double chains.
- **SINGLE CHAIN- INOSILICATES,PYROXENE GROUP**
- The pyroxenes are important rock-forming inosilicate minerals and often exist in many igneous and metamorphic rocks. They share a common structure of single chains of silica tetrahedra . The group of minerals crystallizes in the monoclinic and orthorhombic systems. Inosilicates with a single-chain SiO4 tetrahedron of the pyroxene group are very important and widespread petrogenic minerals . Pyroxenes constitute a related group of silicate minerals with similar crystallographic, physical and chemical properties. The most important of them are given in Table below.

- **SINGLE CHAIN-**



- **THE MOST IMPORTANT PETROGENIC MINERALS FROM PYROXENE GROUP**

Petrogenic Important Pyroxenes		
Orthopyroxenes	Clinopyroxenes	Alkaline Pyroxenes
Enstatite	Pigeonite	Jadeite
$Mg_2Si_2O_6$	$(Mg,Fe^{2+},Ca)(Mg,Fe^{3+})Si_2O_6$	$NaAlSi_2O_6$
Bronzite	Diopside	Aegirine
$(Mg,Fe)_2SiO_6$	$CaMgSi_2O_6$	$NaFeSi_2O_6$
Hypersthene	Hedenbergite	AegirineeAugite = isomorphic member
$(Mg,Fe)_2Si_2O_6$	$CaFeSi_2O_6$	of aegirine and augite
	Dialage = rich in iron diopside turned into	Spodumene
	Aleaugite	$LiAlSi_2O_6$
	Augite	Omphacite
	$Ca(Mg,Fe^{2+},Al)\ (SiAl)_2O_6$	$(Ca,Na)(Mg,Fe^{2+},Al)Si_2O_6$
	Fassaite = augite with $Al_2O_3 > Fe_2O_3$	
Wollastonite $Ca_3Si_3O_9$		

- The most petrogenic important minerals among the group are the following:

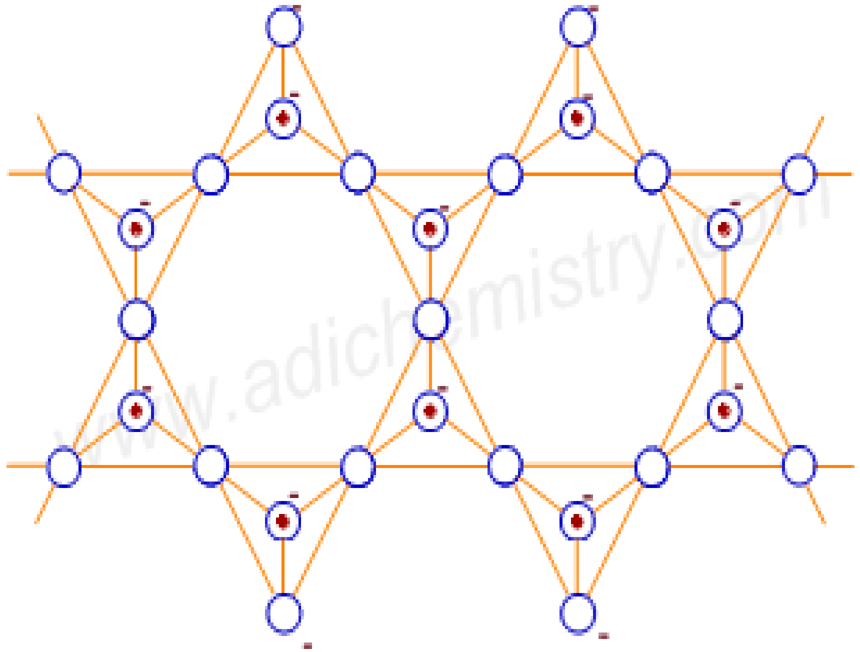
- 1. Diopside-hedenbergite series
- 2. Augite group
- 3. Pyroxenes (aegirine-augite and jadeite-augite)
- 4. Pigeonite

DOUBLE-CHAIN INOSILICATE/ AMPHIBOLE GROUP

- Amphibole is an important group of generally dark-colored inosilicate minerals. It is composed of double-chain SiO4 tetrahedra, linked at the vertices and generally containing ions of iron and/or magnesium in their structures. Amphiboles crystallize in monoclinic and orthorhombic system. In chemical composition, amphiboles are similar to the pyroxenes. The differences from pyroxenes are that amphiboles contain essential hydroxyl (OH) or halogen (F, Cl) and the basic structure is a double chain of tetrahedra. Amphiboles are the primary constituent of amphibolites. Amphiboles along with pyroxenes and feldspars are the most abundant rock-forming minerals (Table below).

DOUBLE-CHAIN INOSILICATE/

Amphibole silicates



The Most Important Petrogenic Minerals of Amphibole Group

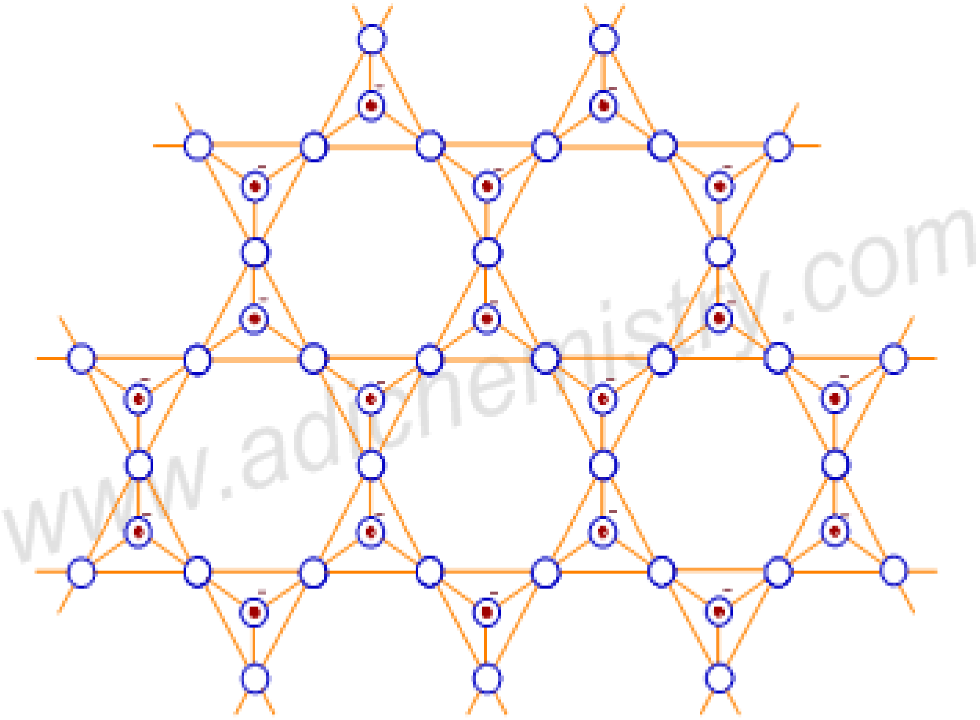
Petrogenic Important Amphiboles		
Orthorhombic	Monoclinic	Alkaline
Anthophyllite $(Mg,Fe)_7(OH)_2Si_8O_{22}$	Tremolite $Ca_2(Mg)_5(OH)_2Si_8O_{22}$	Glaucophane $Na_2Mg_3Al_2(OH)_2Si_8O_{22}$
	Actinolite $Ca_2(Mg,Fe)_5(OH)_2Si_8O_{22}$	Riebeckite Na e Fe amphibole with 15 e 30% Fe_2O_3
	Ferrohornblende $Ca_2Fe_4^{2+}(Al,Fe^{3+})(OH)_2Si_7AlO_{22}$	Arfvedsonite Na-amphibole with 5 e 10% Na_2O
	Magnesiohornblende $Ca_2Mg_4(Al,Fe^{3+})(OH)_2Si_7AlO_{22}$	

Phyllosilicates ⊲ $[Si_{2n}O_{5n}]^{2n-}$

The basic structure of the phyllosilicates is based on interconnected six-member rings of SiO_4^{-4} tetrahedra that extend outward in infinite

sheets. Three out of the four oxygens from each tetrahedron are shared with other tetrahedral as shown. The most important petrogenic minerals among phyllosilicates are group talc-pyrophyllite, mica, chlorite, vermiculite, smectite and kaolinitee serpentine (Table below).

Sheet (phyllo) Silicates



The Most Important Petrogenic Minerals from the Group Phyllosilicates

KaolineSerpentine Group	
Kaolin Minerals Belongs to Clay Minerals	**Serpentine Minerals**
Kaolinite $Al_2(OH)_4Si_2O_5$	Lizardite $Mg_3(OH)_4Si_2O_5$
Dickite $Al_2(OH)_4Si_2O_5$	Chrysotile $Mg_3(OH)_4Si_2O_5$
Nacrite $Al_2(OH)_4Si_2O_5$	Antigorite $(Mg,Fe)_3(OH)_4Si_2O_5$
TalcePyrophyllite Group	Vermiculite Group Belongs to Clay Minerals
Talc $Mg_3(OH)_2Si_4O_{10}$ Pyrophyllite $Al_2(OH)_2Si_4O_{10}$	$(Mg,Al,Fe^{2+})_3(Si,Al)_4O_{10}(OH)_2\$4H_20$
Chlorite Group	Smectite Group Belongs to Clay Minerals
Includes hydrosilicates which make mixed crystals of complex chemical composition whose general formula is:	Includes dioctaedric aluminum mica series montmorillonitee beidellite and iron mica nontronite
M_{4e6} T_4 $O_{10}(OH,O)_8$	Montmorillonitee beidellite $Na_{0.5}Al_2(Si_{3.5},Al_{0.5})O_{10}(OH)_2\$nH_2O$
M = Al, Fe^{3+}, Fe^{2+}, Li, Mg, Mn^{2+}, Cr, Ni and Zn T = Si, Al, Fe^{3+}, Be and B	Nontronite = Feesmectite $Na_{0.5}Fe_2(Al,Si)_4(OH)_2\$nH_2O$

MICA GROUP	
Muscovite $KAl_2(OH)_2AlSi_3O_{10}$	Celadonite $KFE^{3+}(Mg,Fe^{2+})(OH)_2Si_4O_{10}$
Celadonite $KFe^{3+}(Mg,Fe^{2+})(OH)_2Si_4O_{10}$	Paragonite $NaAl_2(OH)_2AlSi_3O_{10}$
BIOTITE PHOLOPITE GROUP	
Biotite $K(Mg,Fe)_3(OH)_2AlSi_3O_{10}$	Phologopite $KMg_3(OH)_2AlSi_3O_{10}$
Illite $K_{0.65}Al_2(OH)_2Al_{0.65}Si_{3.35}O_{10}$	Glauconite is the name of series with mixed layer rich in iron mica

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