Indian Institute of Technology, Kanpur
Department of Earth Sciences

ESO213A: Fundamentals of Earth Sciences

Lecture 12. Minerals and Their Classifications

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IITK Experimental Rock Deformation Laboratory

Aims of this lecture

- Minerals
- Classification
- Silicate Minerals

<u>Reference:</u>
Chapter 3, Grotzinger_Jordan's Book
Chapter 5, Marshak's Book

Most images used in this presentation are from different web sources and a few are own collection

Minerals

Minerals are beautiful, pleasing, elegant and charming..








Minerals

Gold
(Au)

Labradorite (Plagioclase)
$((Ca,Na)(Al,Si)_4O_8)$

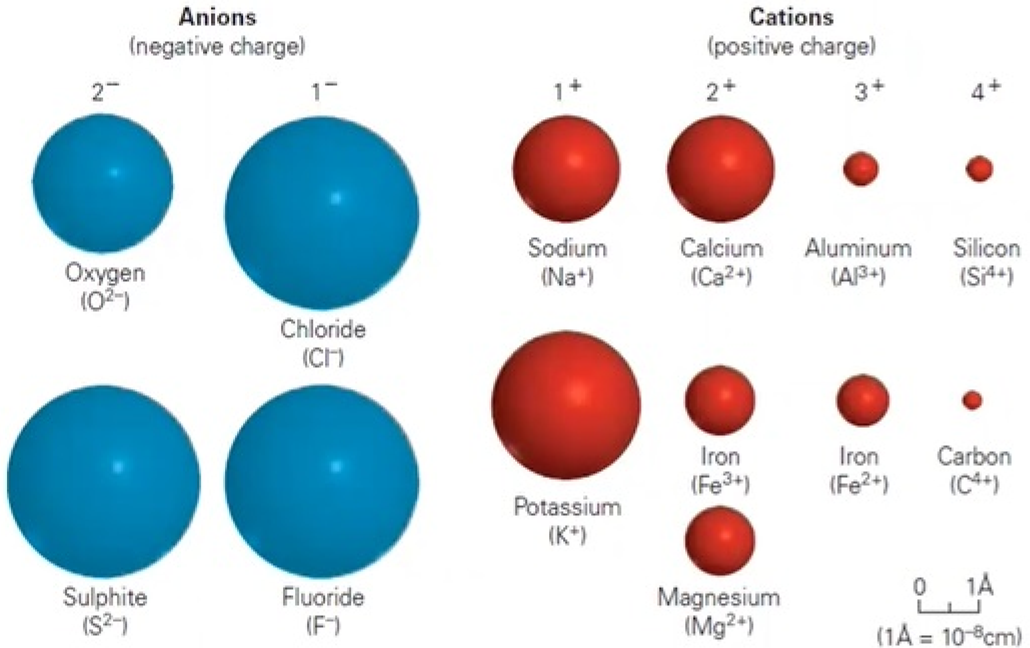
Muscovite (Mica)
$KAl_3Si_3O_{10}(OH)_2$

Hornblende
$((Ca,Na)_{2\text{-}3}(Mg,Fe,Al)_5(Si,Al)_8O_{22}(OH,F)_2$

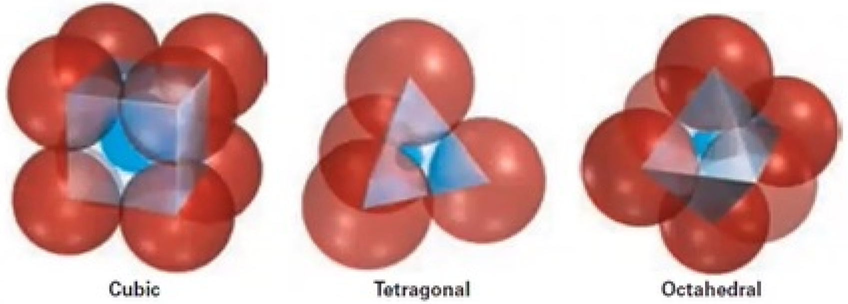
There are more than 3000-4000 known minerals !!

Minerals: Classification Scheme

- Like all objects in the world, we also classify Minerals based on their several physical properties. The most common of them is by specifying the principal anion or anionic group within the mineral (Baron Jöns Jacob Berzelius (1779–1848)).



Ions come in a wide range of sizes. The difference in size depends, in part, on the number of electrons they contain.



Ions can pack together in different ways. Each configuration can be described by a geometric shape.

Classification of Minerals

- **SILICATES**: The fundamental component of silicate minerals is the SiO_4^{4-} anionic group.

Quartz (SiO_2)

Feldspar ($KAlSi_3O_8$).

- **SULFIDES**: Sulfides consist of a metal cation bonded to a sulfide anion (S^{2-}).

Galena (PbS)

Pyrite (FeS_2)

- **OXIDES**: Oxides consist of metal cations bonded to oxygen anions. Typical oxide minerals include hematite (Fe_2O_3) and magnetite (Fe_3O_4).

Hematite (Fe_2O_3)

Magnetite (Fe_3O_4).

Classification of Minerals

- **HALIDES**: The anion in a halide is a halogen ion (such as chloride, Cl^-, or fluoride, F^-)

Halite ($NaCl$)

Fluorite (CaF_2)

- **CARBONATES**: In **carbonate minerals**, the molecule CO_3^{2-} serves as the anionic group.

Calcite ($CaCO_3$)

Dolomite ($CaMg[CO_3]^2$)

- **NATIVE METALS**: The metal atoms are bonded by metallic bonds.

Gold (Au)

Copper (Cu)

- **SULFATES**: Sulfates consist of metal cations bonded to SO_4^{2-} anionic groups.

Gypsum ($CaSO_4.2H_2O$)

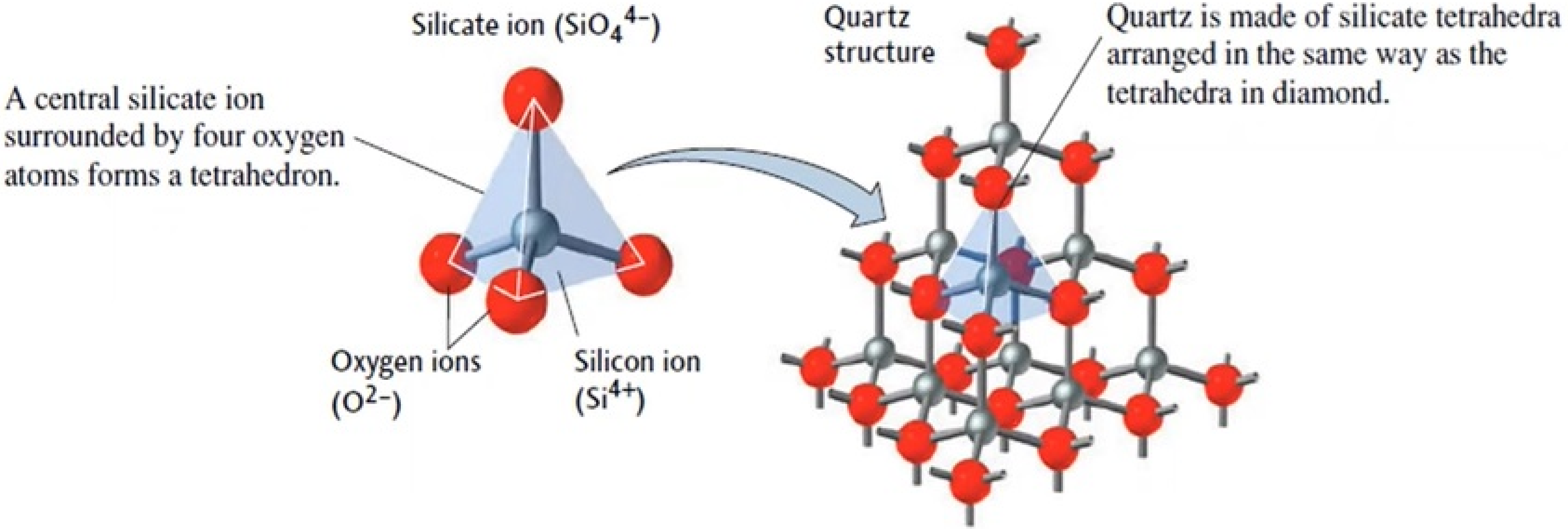
Anhydrite ($CaSO_4$)

Classification of Minerals

CLASS	DEFINING ANIONS	EXAMPLE
Silicates	Silicate ion (SiO_4^{4-})	Quartz (SiO_2)
Sulphides	Sulfide ion (S^{2-})	Pyrite (FeS_2)
Oxides	Oxygen ion (O^{2-})	Magnetite Fe_3O_4)
Halides	Chloride (Cl^-), fluoride (F^-),	Halite (NaCl)
Carbonates	Carbonate ion (CO_3^{2-})	Calcite ($CaCO_3$)
Native Metals	no charged ions	Gold (Au)
Sulphates	Sulfate ion (SO_4^{2-})	Gypsum $CaSO_4.2H_2O$)

Silicate Group of Minerals

- 95% of the earth's crust and almost entire mantle are made of silicate minerals
- In this group, four oxygen atoms surround a single silicon atom, thereby defining the corners of a tetrahedron, a pyramid-like shape with four triangular faces → Silica-Oxygen Tetrahedron

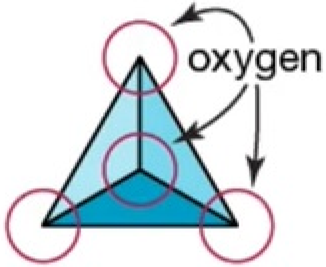


- The Silica-Oxygen Tetrahedron can be arranged in many different ways. The arrangement also determines the degree to which tetrahedra share oxygen atoms.

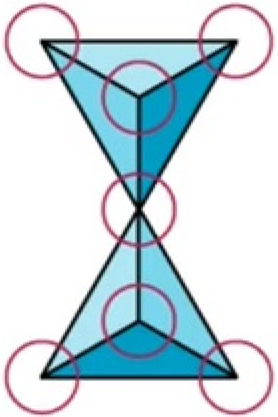
Silicate Group of Minerals

- ***Independent (Single/Double) tetrahedra:*** In this group, tetrahedra are independent and do not share any oxygen atoms. The attraction between the tetrahedra and positive ions holds crystals together. This group is also known as Nesosilicates (single) and Sarosilicates; also as Olivine Group.

Nesosilicates
Unit composition: $(SiO_4)^{4-}$
Example: olivine,
$(Mg, Fe)_2SiO_4$

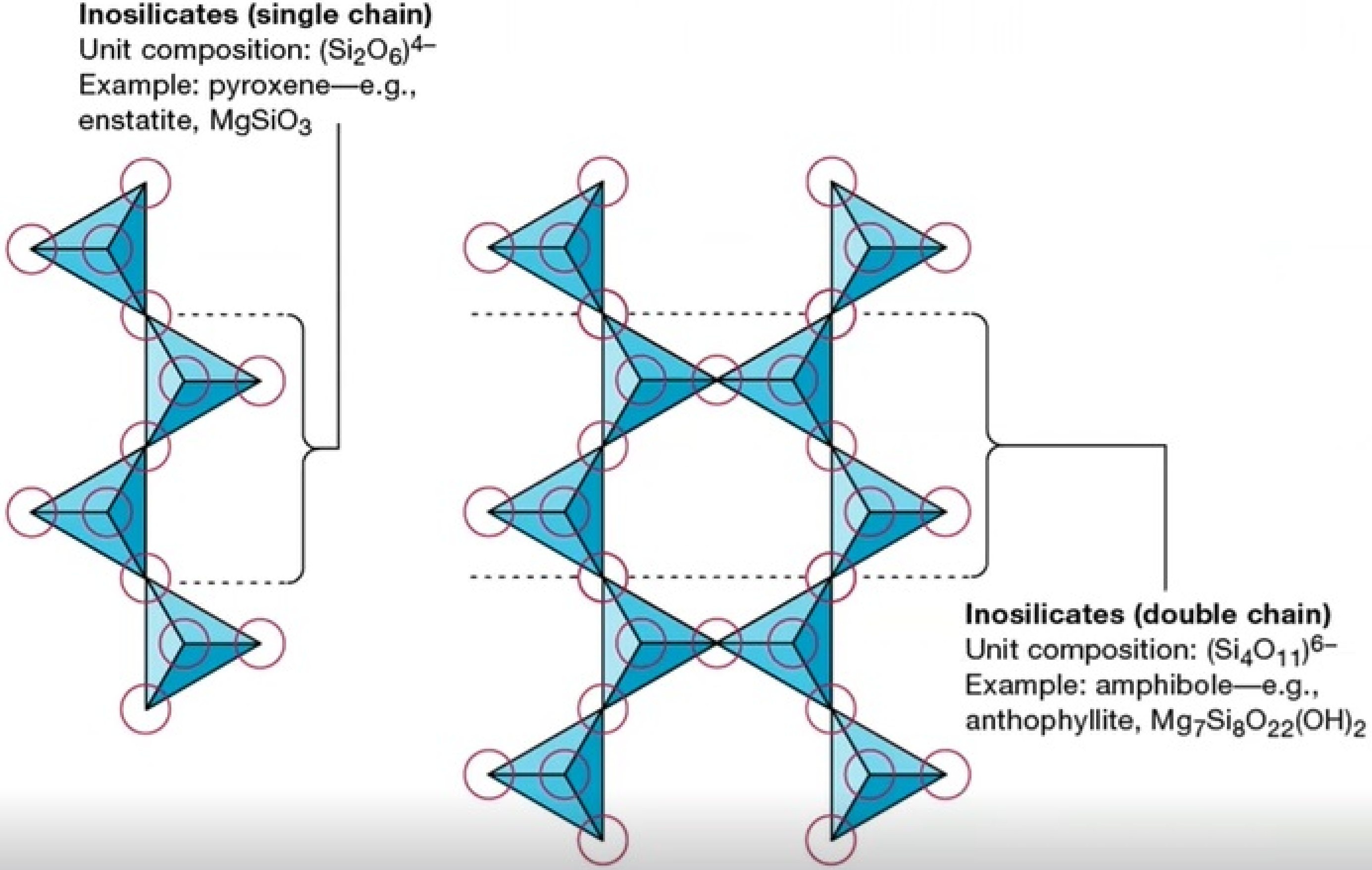


Sorosilicates
Unit composition: $(Si_2O_7)^{6-}$
Example: hemimorphite,
$Zn_4Si_2O_7(OH)_2 \cdot H_2O$



Silicate Group of Minerals

- ***Chain Silicates:*** In a single-chain silicate, tetrahedra link to form a chain by sharing two oxygen atoms; in a double-chain silicate, tetrahedra link to form a double chain by sharing two or three oxygen atoms. Also known as Inosilicates.

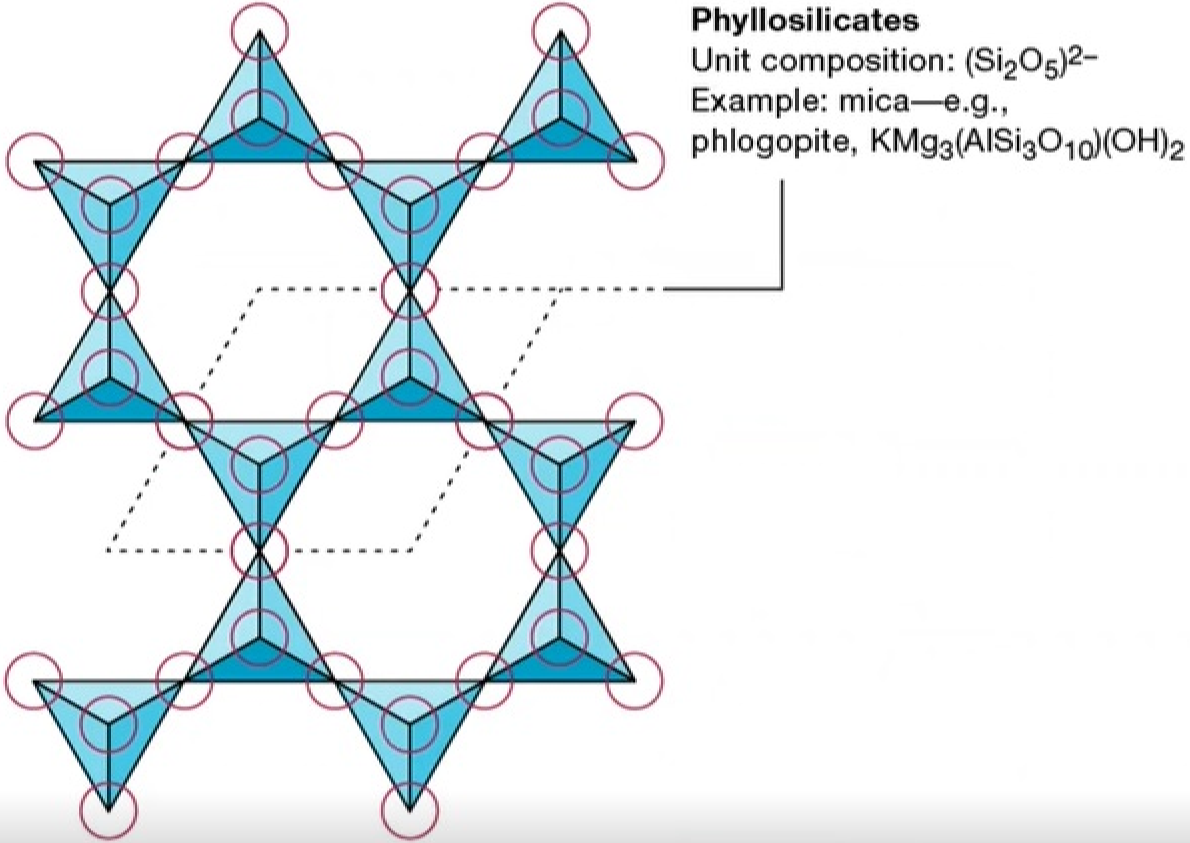


Single Chain:
PYROXENE

Double Chain:
Amphibole

Silicate Group of Minerals

- ***Sheet Silicates:*** Tetrahedra in this group share three oxygen atoms and therefore link to form two-dimensional sheets. Other ions fit between the sheets in sheet silicates. Also known as Phyllosilicates or Mica Group of minerals.

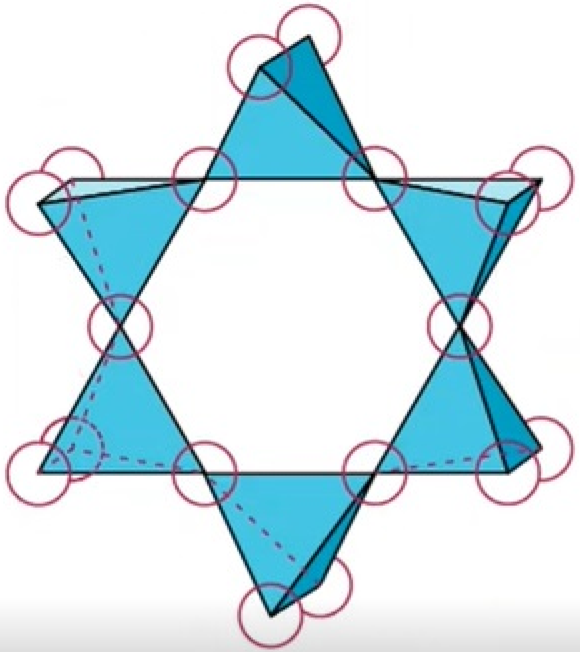


<u>Examples:</u>
Muscovite, Biotite, Clay minerals

Silicate Group of Minerals

- ***Ring silicates:*** This group of minerals have three or more tetrahedra linked in a ring. Also known as Cyclosilicates.

Cyclosilicates
Unit composition: $(Si_6O_{18})^{12-}$
Example: beryl,
$Be_3Al_2Si_6O_{18}$

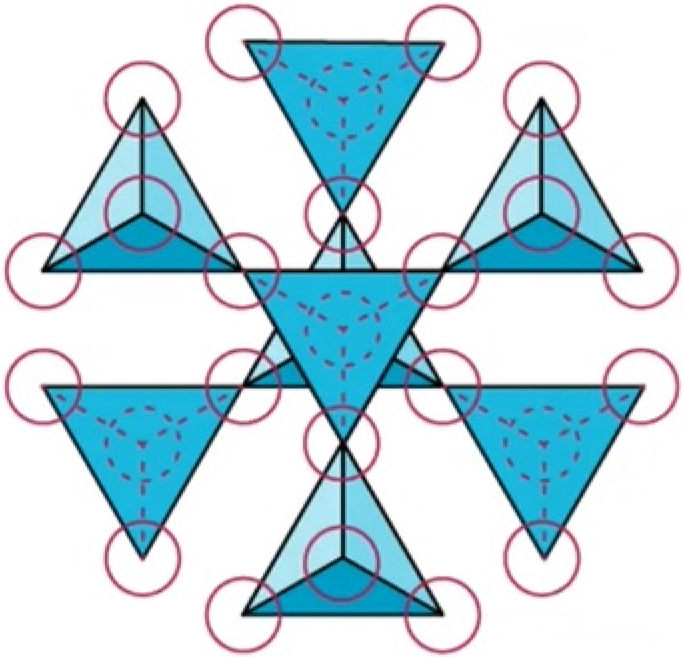


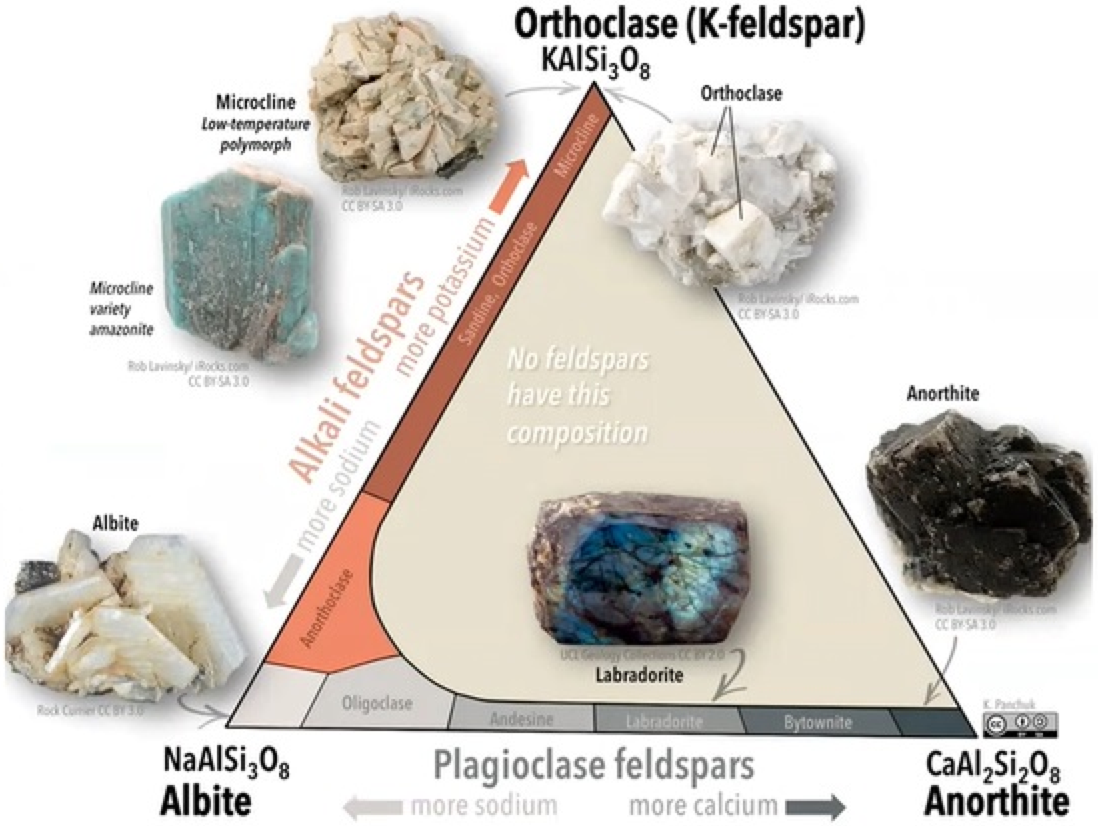
Examples:
Beryl

Silicate Group of Minerals

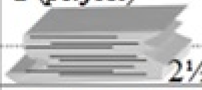
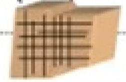
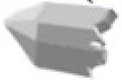
- ***Framework silicates:*** In a framework silicate, each tetrahedron shares all four oxygen atoms with its neighbours, forming a three-dimensional structure. Also known as Tectosilicates.

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





Silicate Group of Minerals: Summary

Silicate Structure	Example Mineral	Silica Content (%SiO_2)	Fe/Mg‡ Content	Al† content	Cleavage, Hardness	Density, Color	‡Ferromagnesians †Alluminosilicates
Isolated Silicates	Olivine	~16%	~50% ‡	0%	none  6½	~4 g/cm³ green	Comprises most of the ***Mantle***
Single Chain Silicates	***Pyroxene***# Group (e.g., Augite)	25-50%	18-26% ‡	0-16% (†)	2 (90°)  5½	~3.3 black	Found in basalt ***Oceanic Curst*** with ***Ca-Plag.***#
Double Chain Silicates	***Amphibole***◊ Group (e.g., Hornblende)	50-60%	15-22% ‡	0-9% †	2 (120°-60°)  5½	~3.3 black	Found in ***Continental Crust***◊
Sheet Silicates	***Mica*** Group (e.g., ***Biotite***◊)	39%	18-33% ‡	6% †	***1*** (*perfect*) 	~3.0 black	Found in ***Continental Crust***◊
	(e.g., ***Muscovite***◊)	39%	0%	20%	2½	2.8 slvr	
	Clay Group (e.g., Kaolinite)	46%	0%	21% †	***Microscopic platelets*** 	2.6 green or gray	From ***chemical weathering of silicates****
Frame-work Silicates	***Feldspar*** Group, Plagioclase(***Na***◊-***Ca***#)	43-69%	0%	10-19% †	2 (90°)  6	2.6 wht-blk	***Ca Plag.***# in ***Oceanic Crust***
	Orthoclase (***K***◊)	76%	0%	10% †		2.7 pink	***Others Contin***◊.
	Quartz (*pure* SiO_2◊)	100%	0%	0%	***none*** (fracture)  7	2.6 white to gray	Concentrated in ***Continental*** Environments

General trends toward bottom: ***Increasing*** SiO_2, ***Decreasing Fe/Mg, Lighter in density, Lighter in Color***

\# Oceanic Crust is mostly Pyroxene and Ca-Feldspar → more dense and dark in colour.

◇ Continental Crust is mostly rich in silica and low Fe → less dense and lighter in colour.

Melting points and crystallization temperature decreases towards the bottom.

Melting points and crystallization temperature decreases towards the bottom.

Resistance to chemical weathering increases towards the bottom.

All silicate minerals are concerted to clay minerals by chemical weathering.

Use of Silicate Minerals

- Silicate minerals are a natural resource we can't live without on our planet, and not just because of our increasing reliance on computers.
- Without quartz, there would be no glass.
- Without the clay minerals, we would have no ceramics or pottery. We use silicate minerals in the manufacture of many building materials, including bricks and concrete.
- The weathering of silicate minerals on the surface of Earth produces the soils in which we grow our foods and the sand on our beaches.

Gemstones

See a brief list (Table 5.2) in the Marshak's book

- Gemstones are particularly rare and beautiful minerals. The gems or jewels found in jewelry have been faceted using a lap. The facets are not natural crystal faces or cleavage surfaces. The fire of a jewel comes from the way it reflects light internally.

- Not all gemstones ate minerals (Amber, pearl etc.)

Gemstones cannot change and/or alter your luck, mood, health, relationship status, job, promotion etc. and have no relationship with planetary system (there is also no Rahu and Ketu).

Next Lecture

Identification of Minerals
(and Intro to Rocks)