GGY3051 – GEOLOGY FOR ENGINEERS

Matter and Minerals

Lecturer: Eng. Derrick Zilifi

GEOLOGY DEPARTMENT

Learning Goals

In this lecture, participants will lean how to identify:

- common minerals using different Properties.

1. Matter

- Is a substance of which any physical object is composed.
- Occurs in three states:
  - Solid
  - Liquid
  - Gas
- Each of the states is controlled by:
  - Temperature
  - Pressure
  - Exemples:
    - ✓ Gold – SOLID
    - ✓ Water – LIQUID
    - ✓ Oxygen - GAS

1. Matter…..contd.

The make-up of **solid** matter on Earth comprises:

Atoms → **Elements** → **Compounds** → **Minerals** → **Rocks**

(smallest) *(largest)*

2. Minerals

- Are building blocks of rocks
- Are defined as naturally occurring:
  - ✓ Inorganic
  - ✓ Solid
  - ✓ With characteristic crystalline structure and
  - ✓ Definite chemical composition

2. Minerals…..contd.

- A mineral has DEFINITIVE properties:
  - ✓ is made of an element or a chemical compound
  - ✓ has a definitive chemical composition
  - ✓ has an orderly, regular repeating internal atomic arrangement and crystalline structure
  - ✓ is made of inorganic solids
  - ✓ is formed by geologic processes.

2. Minerals…..contd.

- **Naturally formed**
  - Means that any substance that is created artificially is NOT a mineral – *plastic, steel, sugar, paper*

- **Inorganic**
  - Means that anything formed by/from a living organism, and containing organic materials, is not a mineral – *wood, plants, shells, coal*

- **Solid**
  - Means liquids and gases – *water, petroleum, lava, oxygen* – are not minerals.

2. Minerals…..contd.

- **Characteristic crystalline structure,** means it must:
  - have an ordered arrangement of atoms
  - display repetitive geometric patterns in 3-D, implying that glass *(which has no internal crystalline structure)* is ***not*** a mineral.
- **Definite chemical composition**, means it must have:
  - consistent chemical formula – e.g. quartz (SiO_2)

2. Minerals – Exercise

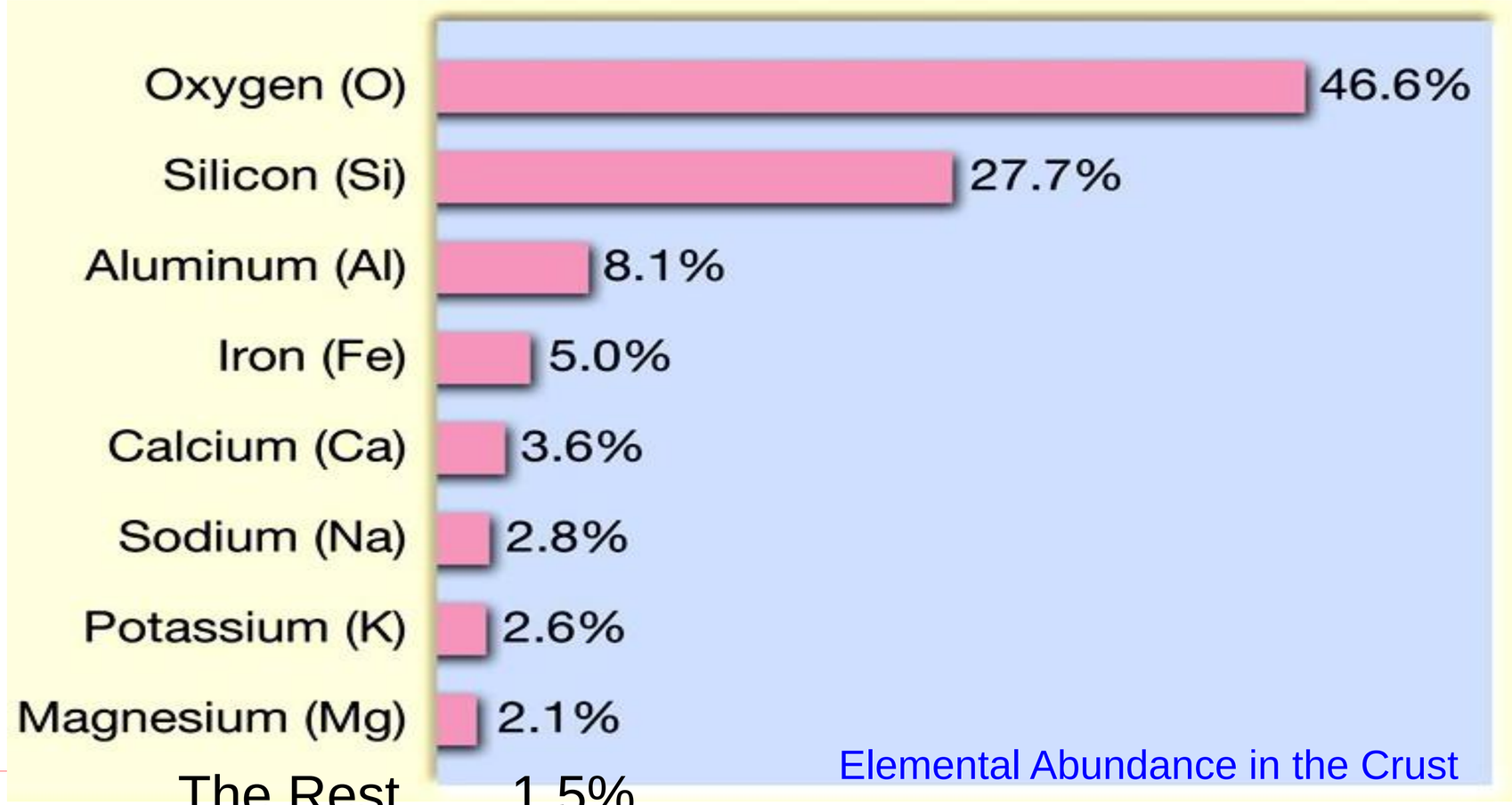
Minerals are:

1. naturally occurring
2. inorganic
3. solid
4. With characteristic crystalline structure and
5. definite chemical composition

Steel	Plastic	Sugar	Table salt	Mercury
No, #1	No, #1	No, #1,2	YES	No, #3
Gold	**Paper**	**Chalk**	**Ice**	**Coal**
YES	No, #1,2	No, #2	YES	No, #2

2.1 Rock-Forming Mineral Groups

- 30 common minerals make up most rocks in Earth's crust
- Composed mainly of EIGHT elements that make up over 98% of crust



Elemental Abundance in the Crust

2.1 Rock-Forming Mineral Groups…..contd.

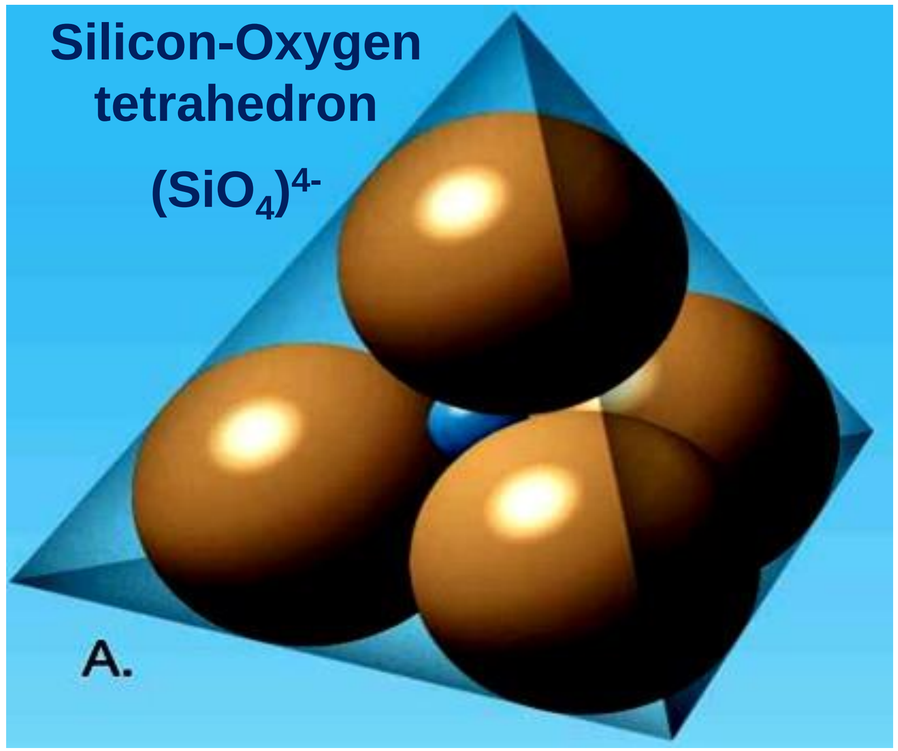
Comprise:

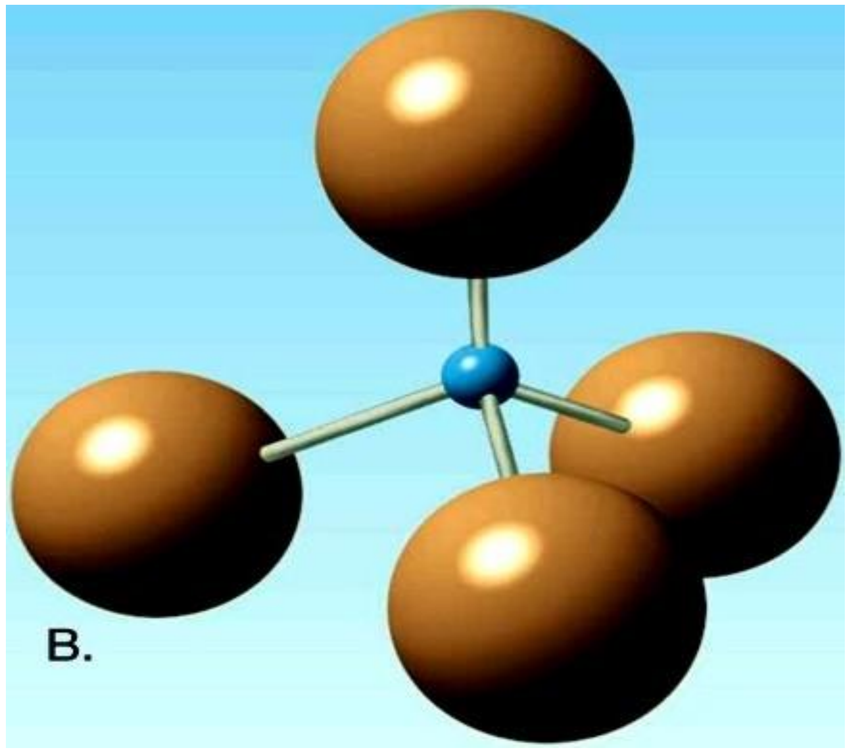
- **Silicates** (most abundant minerals – ca. 92% – in Earth's Crust)
- **Non-silicates** (~8% of Earth's crust):
  - ✓ Oxides - O^{2-}
  - ✓ Carbonates - CO_3^{2-}
  - ✓ Sulfides - S^{2-}
  - ✓ Sulphates - SO_4^{2-}
  - ✓ Halides - Cl^-, F^-, Br^-
  - ✓ Native elements - single elements; e.g., Au)

2.1.1 Silicate Minerals

Formed from SiO_4-tetrahedron

- Where Four (4) oxygen ions surround a silicon ion.
- Is a fundamental building block for silicates





2.1.1 Silicate Minerals…..contd.

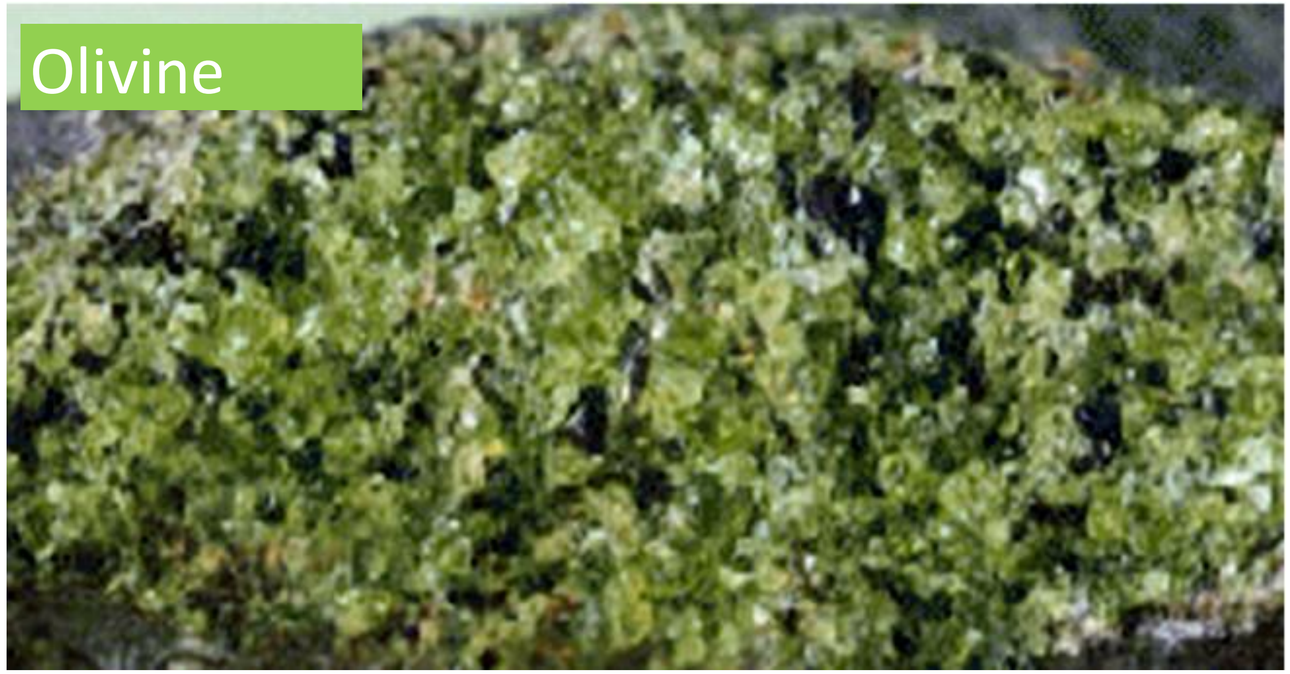
Silicate Structures occur as:

- independent tetrahedra
- single chains
- double chains
- sheets
- 3-D framework

2.1.1.1 Independent Tetrahedra Silicates…..contd.

Olivine Group

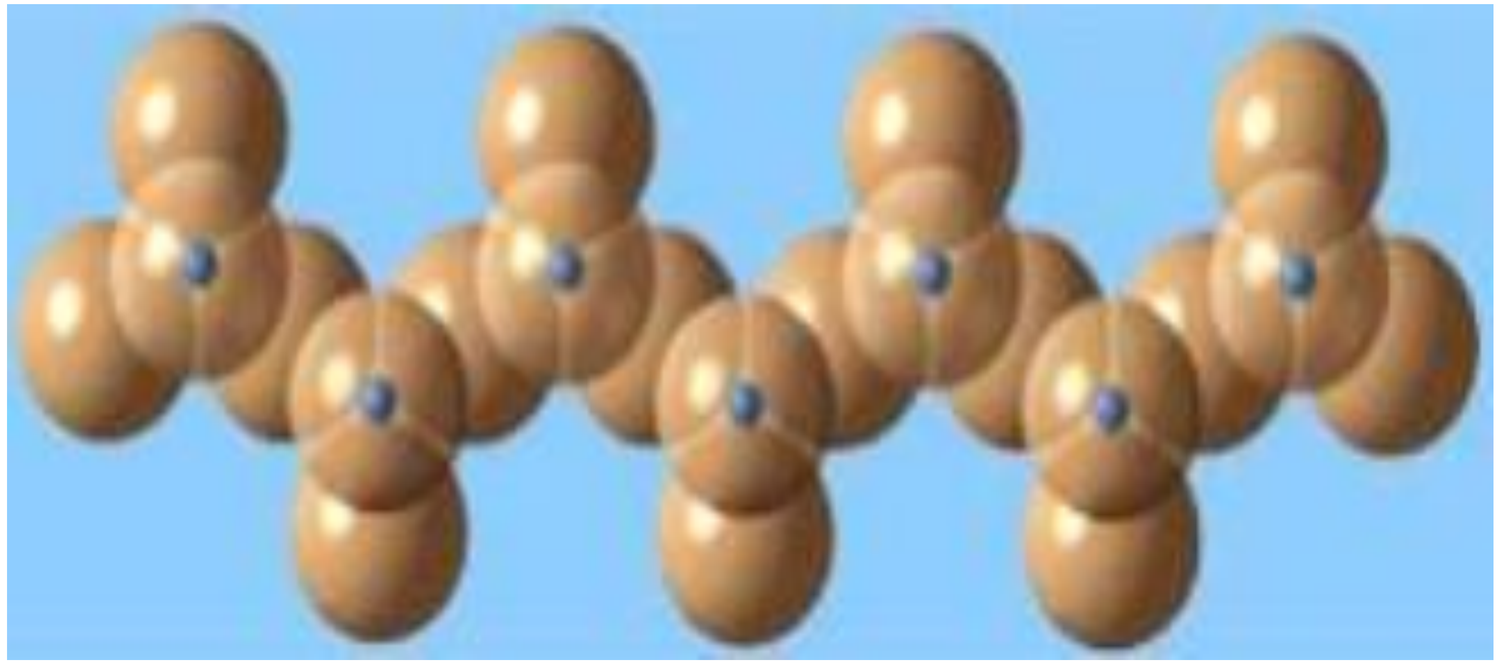
- Dark silicates, rich in Fe & Mg
  - Are thus, called *Ferromagnesian minerals*
- Formed from Independent Tetrahedra

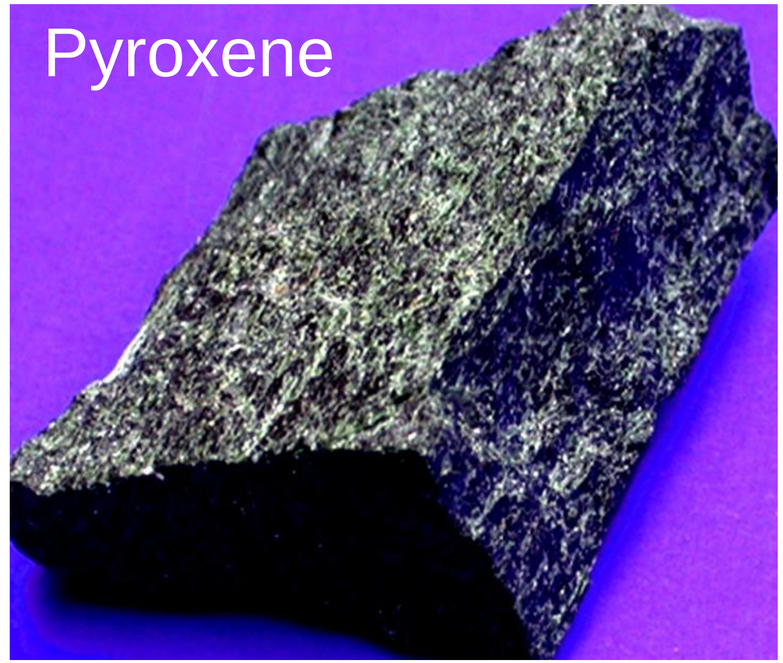


2.1.1.2 Single Chain Silicates

Pyroxene Group

- Ferromagnesian / dark silicates (Fe-Mg)
- Form from Single Chains

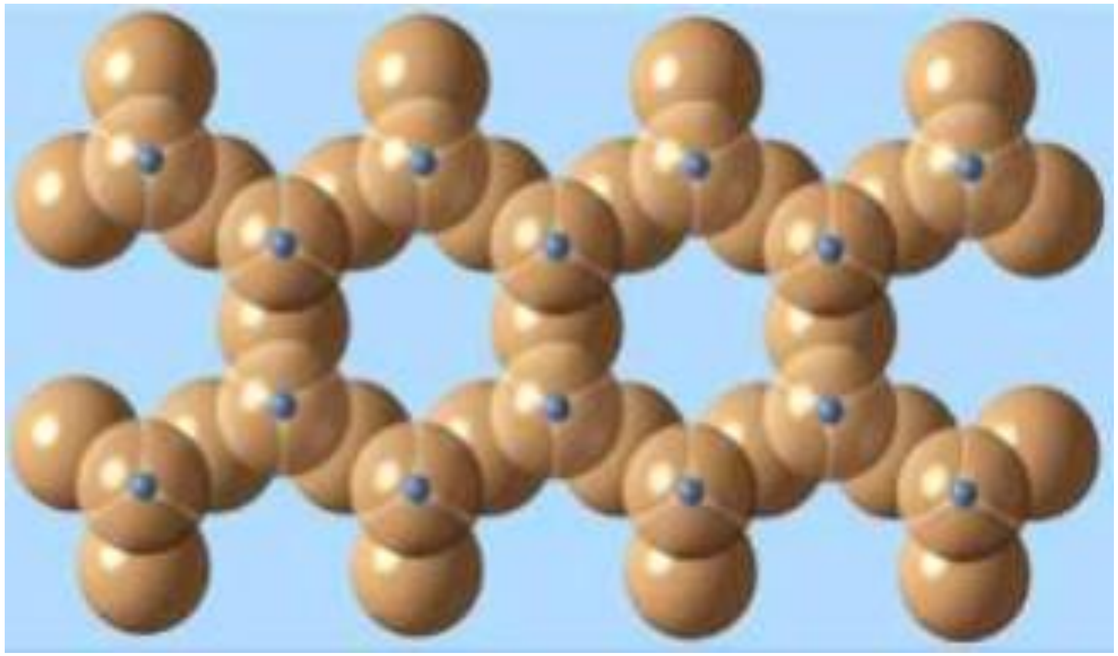




2.1.1.3 Double Chain Silicates

Amphibole Group

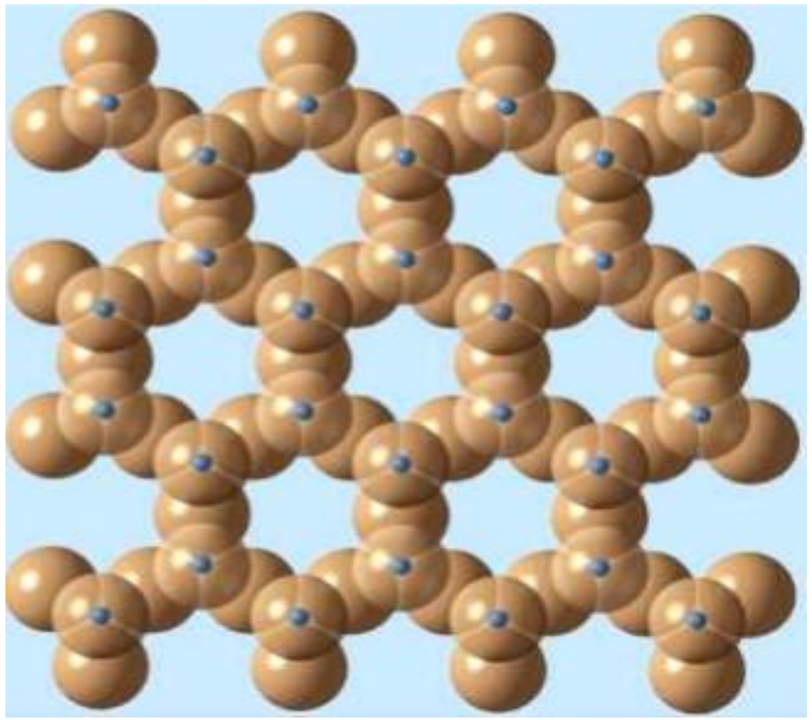
- Ferromagnesian / dark silicates (Ca, Fe-Mg)
- Form from Double Chains



2.1.1.4 Sheet Silicates

Mica Group & Clay Minerals

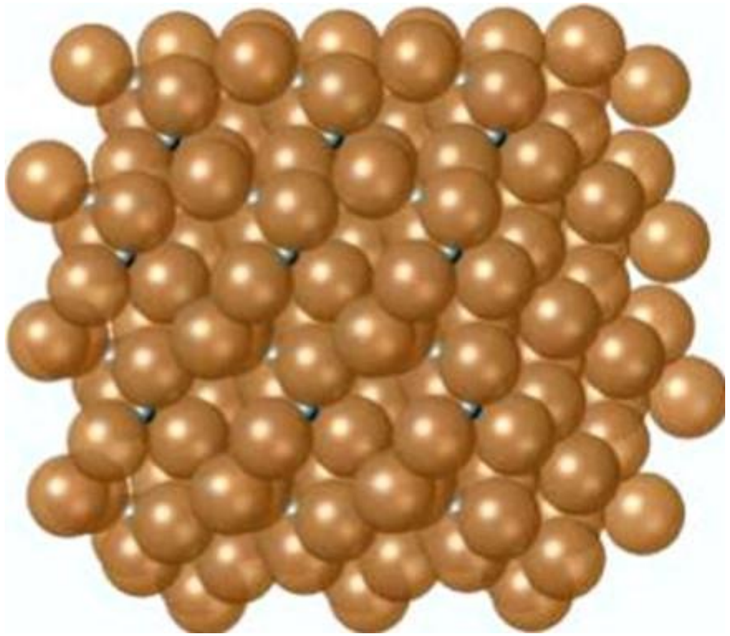
- Light-coloured silicates, with K & Al Cations
- Are non-ferromagnesian
- Form from Sheets / Layers



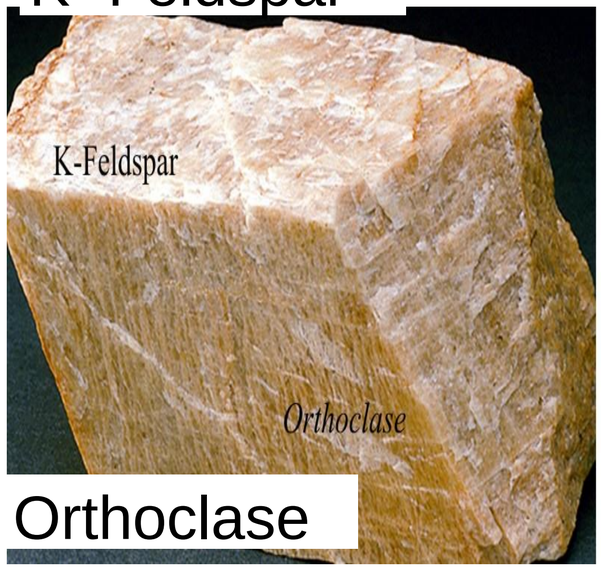
2.1.1.5 Framework Silicates

a) Feldspar Group

- Light-coloured silicates with K-Na-Ca, Al
- Most common mineral group
- Made from 3-dimensional networks



K- Feldspar



Orthoclase

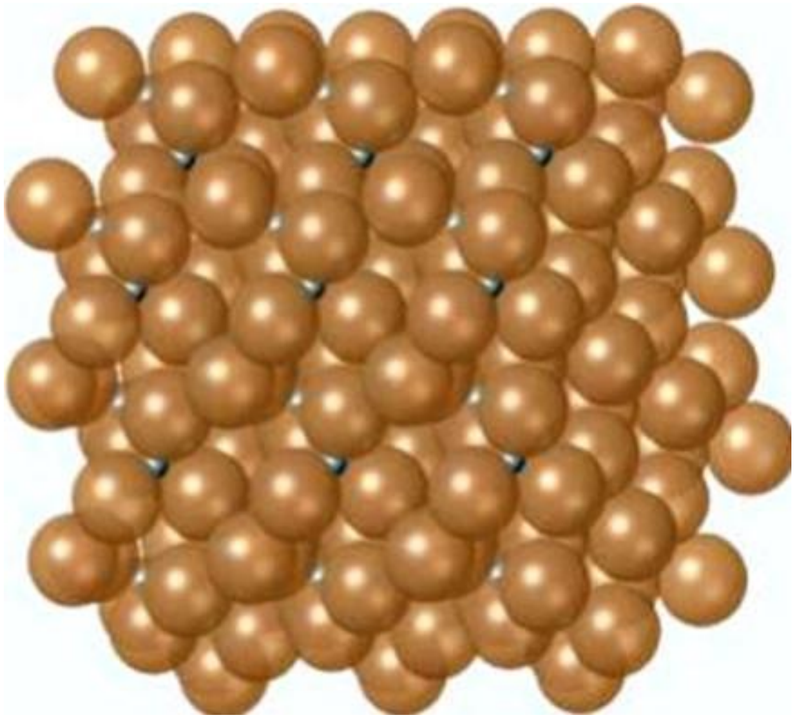
Ca/Na - Feldspar

Plagioclase

2.1.1.5 Framework Silicates…..contd.

b) Quartz

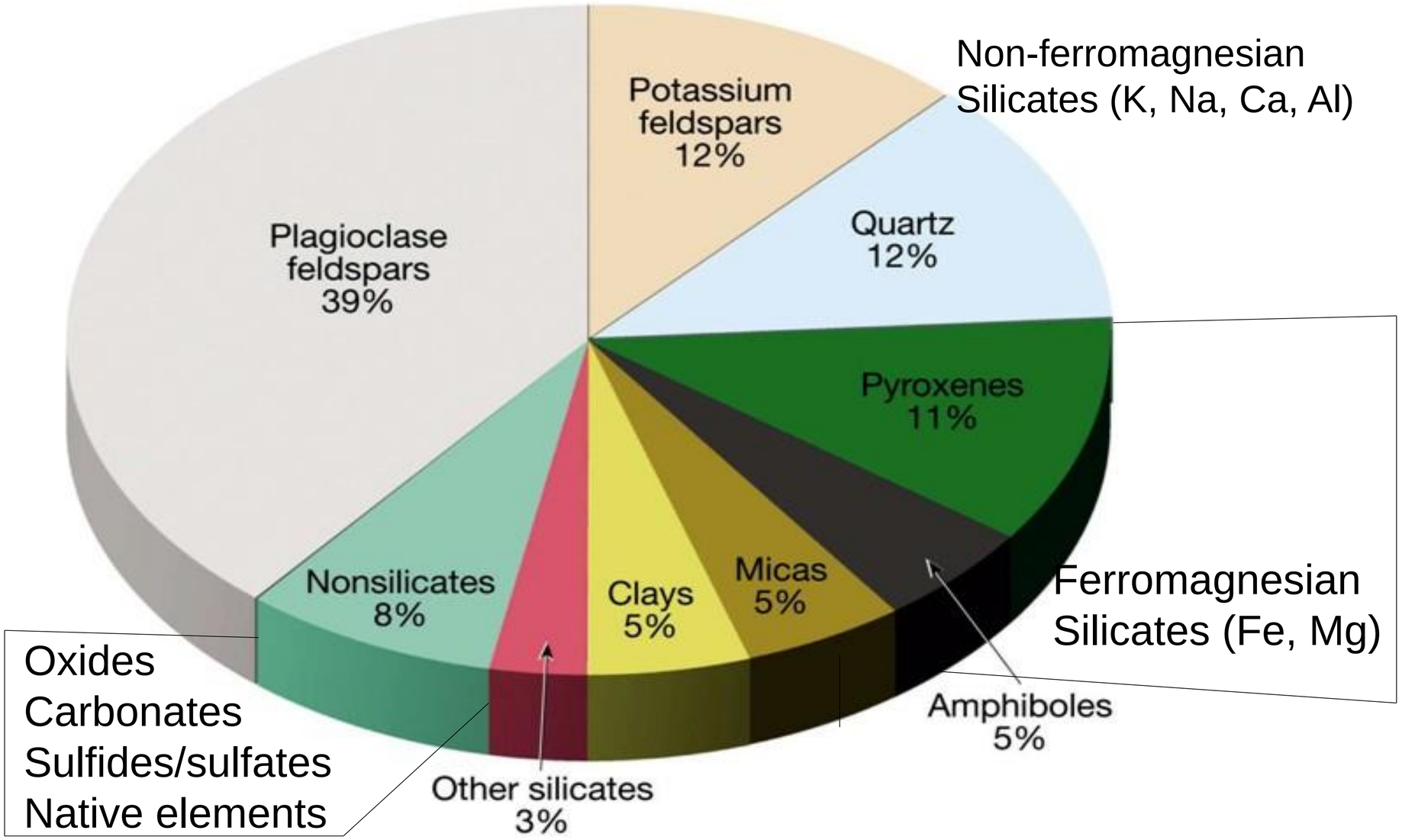
- Light-coloured silicates
- Is pure SiO_2
- Made from 3 dimensional networks



2.2 Summary of Rock-Forming Mineral Groups

Mineral Group	Examples	Chemical Formula	Comments
Silicates	Quartz	SiO_2	Common
	Plagioclase feldspars	$(Na, Ca)Al(Si, Al)_2O_8$	Very common
	Pyroxene	$(Ca, Mg, Fe)_2Si_2O_6$	Ferromagnesian mineral
Carbonates	Calcite	$CaCO_3$	Main minerals in limestone and marbles
	Dolomite	$(Ca, Mg)CO_3$	
Oxides	Hematite	Fe_2O_3	Primary ore of iron
	Bauxite	Hydrous aluminum oxides	Primary ore of aluminum
Sulfides	Pyrite	FeS_2	Major constituent of acid mine drainage
	Galena	PbS	Primary ore of lead
Native elements	Gold	Au	Precious metal, industrial uses
	Diamond	C	Jewelry, industrial uses
	Sulfur	S	Used to produce sulfuric acid

2.2 Summary of Rock-Forming Mineral Groups…..contd.



2.3 Mineral Diagnostic Properties

- Based mainly on Physical properties:
  - Color
  - Streak
  - Luster
  - Crystal form/shape
  - Cleavage
  - Hardness
  - Special properties – *taste, smell, feel, reaction to acid, magnetism, etc.*

2.3.1 Colour

- Most obvious, but often misleading

because:

- Different colors may result from

impurities, example, **QUARTZ**

2.3.2 Streak

- Color of a mineral in powdered form(used for metallic minerals).
- Obtained by scratching a mineral on a piece of unglazed porcelain.

Example: Hematite

2.3.3 Luster

- How a mineral surface reflects light
- Two major types:
  - Metallic luster
  - Non-metallic luster

Example:
Galena

Example:
Orthoclase

2.3.4 Crystal Form / Shape

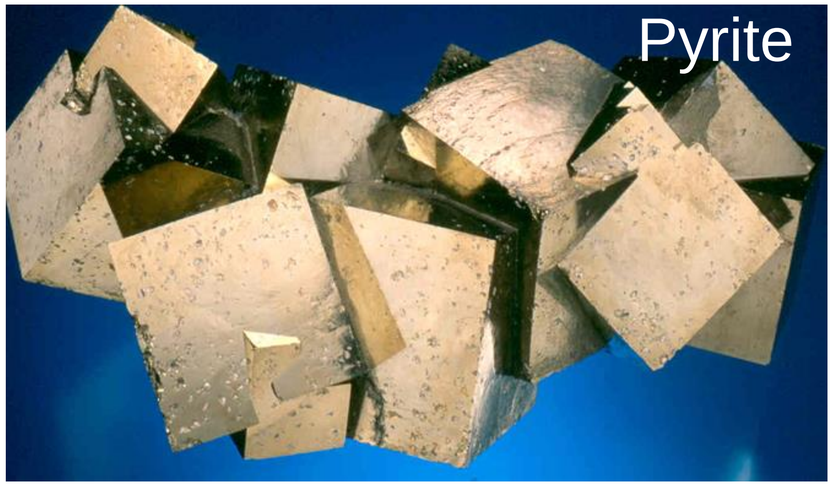
- external expression of mineral's

  internal atomic structure

- planar surfaces are called crystal faces

- angles between crystal faces are

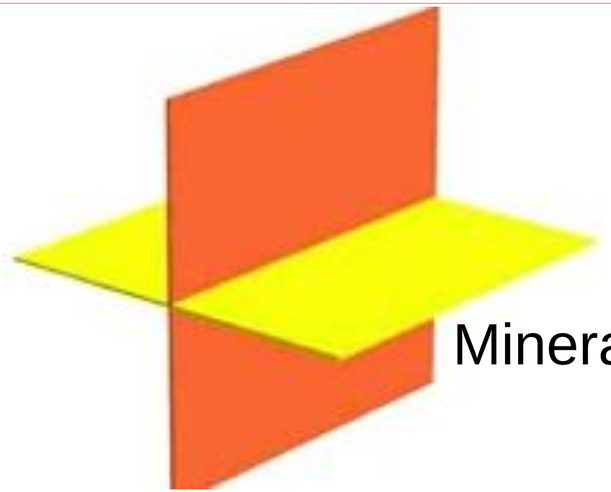
  constant for any particular mineral



2.3.5 Cleavage

Reflects the way a mineral breaks

- Cleavage is a mineral's tendency to break along planes of weakness
- Minerals that do not exhibit cleavage are said to fracture



Mineral Cleavage

Conchoidal fracture – when mineral breaks in glass-like manner

2.3.5 Cleavage…..contd.

- **is described by:**
  - Number of planes
  - Angles between adjacent planes
    - These are constant for a particular mineral

2.3.5 Cleavage…..contd.

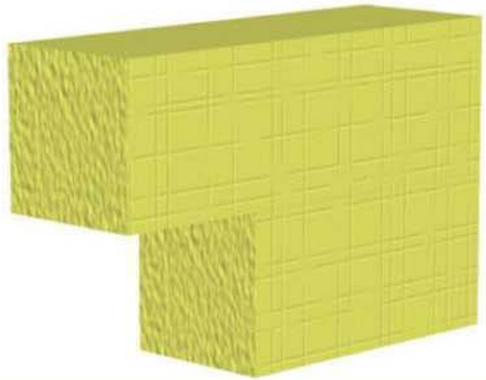
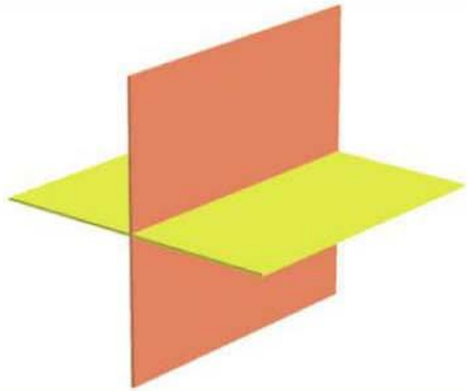
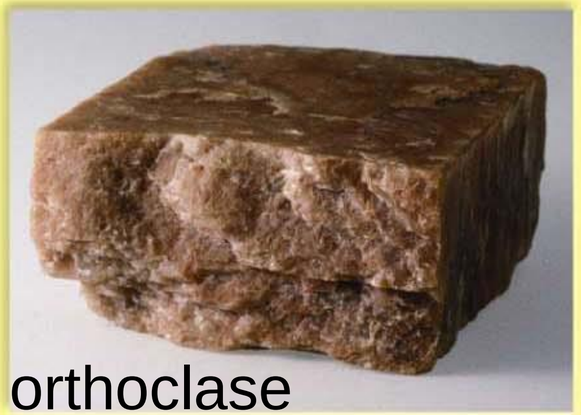
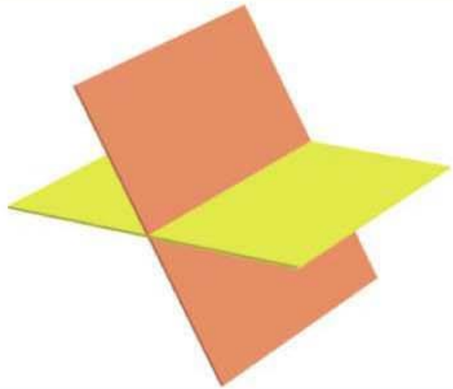
Cleavage in One-direction

Number of Cleavage Directions	Sketch	Illustration of cleavage directions	Example
1			

Example: Mica

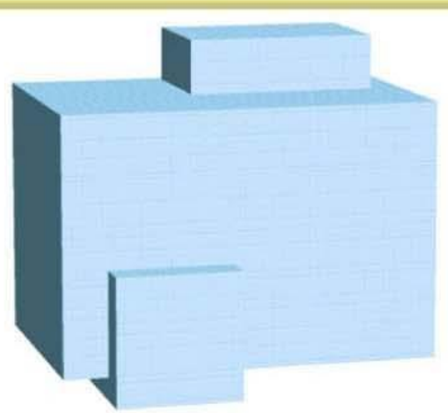
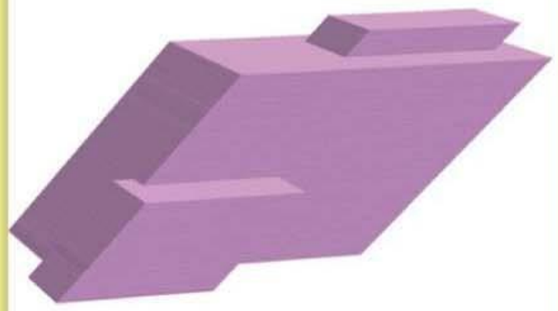
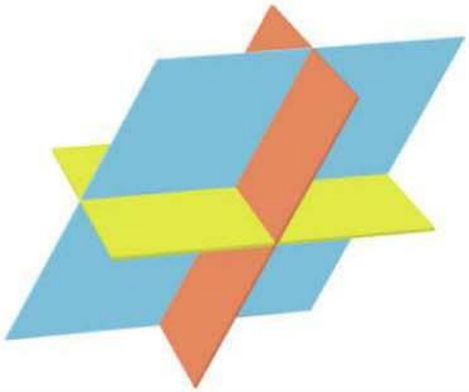
2.3.5 Cleavage…..contd.

Cleavage in Two-directions

Number of Cleavage Directions	Sketch	Illustration of cleavage directions	Example
2 at 90°			 orthoclase
2 not at 90°			 amphibole

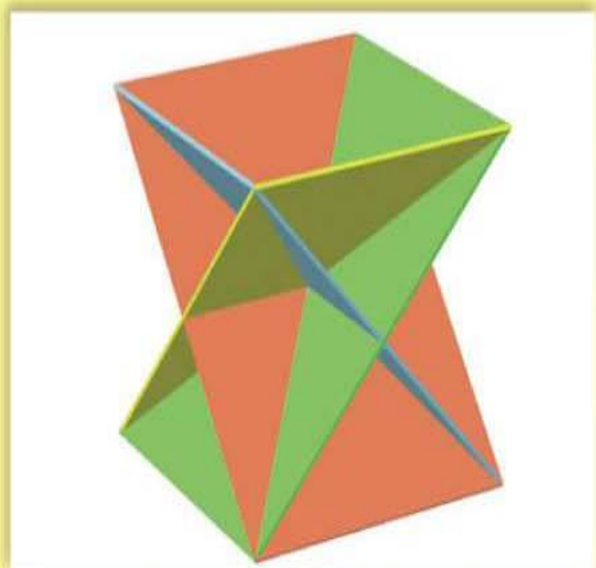
2.3.5 Cleavage…..contd.

Cleavage in Three-directions

Number of Cleavage Directions	Sketch	Illustration of cleavage directions	Example
3 at 90°			 halite
3 not at 90°			 calcite

2.3.5 Cleavage…..contd.

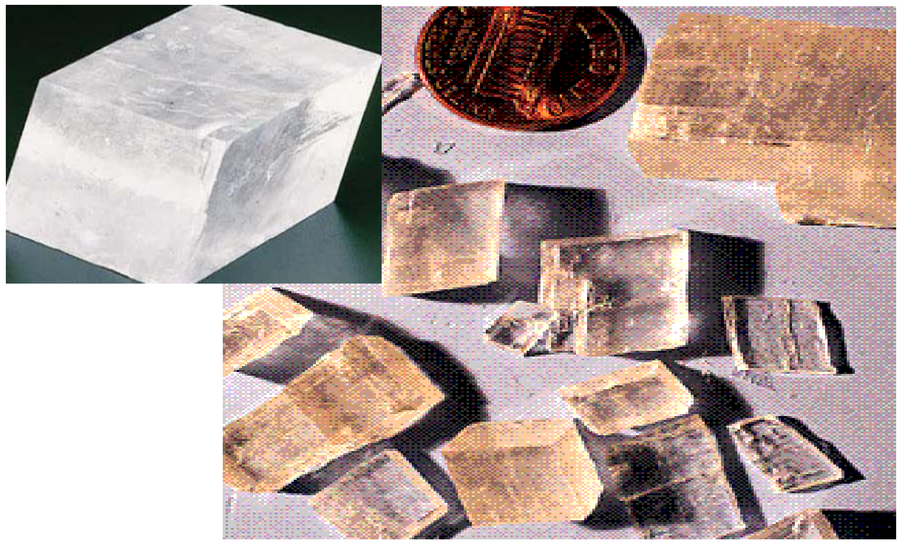
Cleavage in Four-directions

Number of Cleavage Directions	Sketch	Illustration of cleavage directions	Example
4			

2.3.5 Cleavage…..contd.

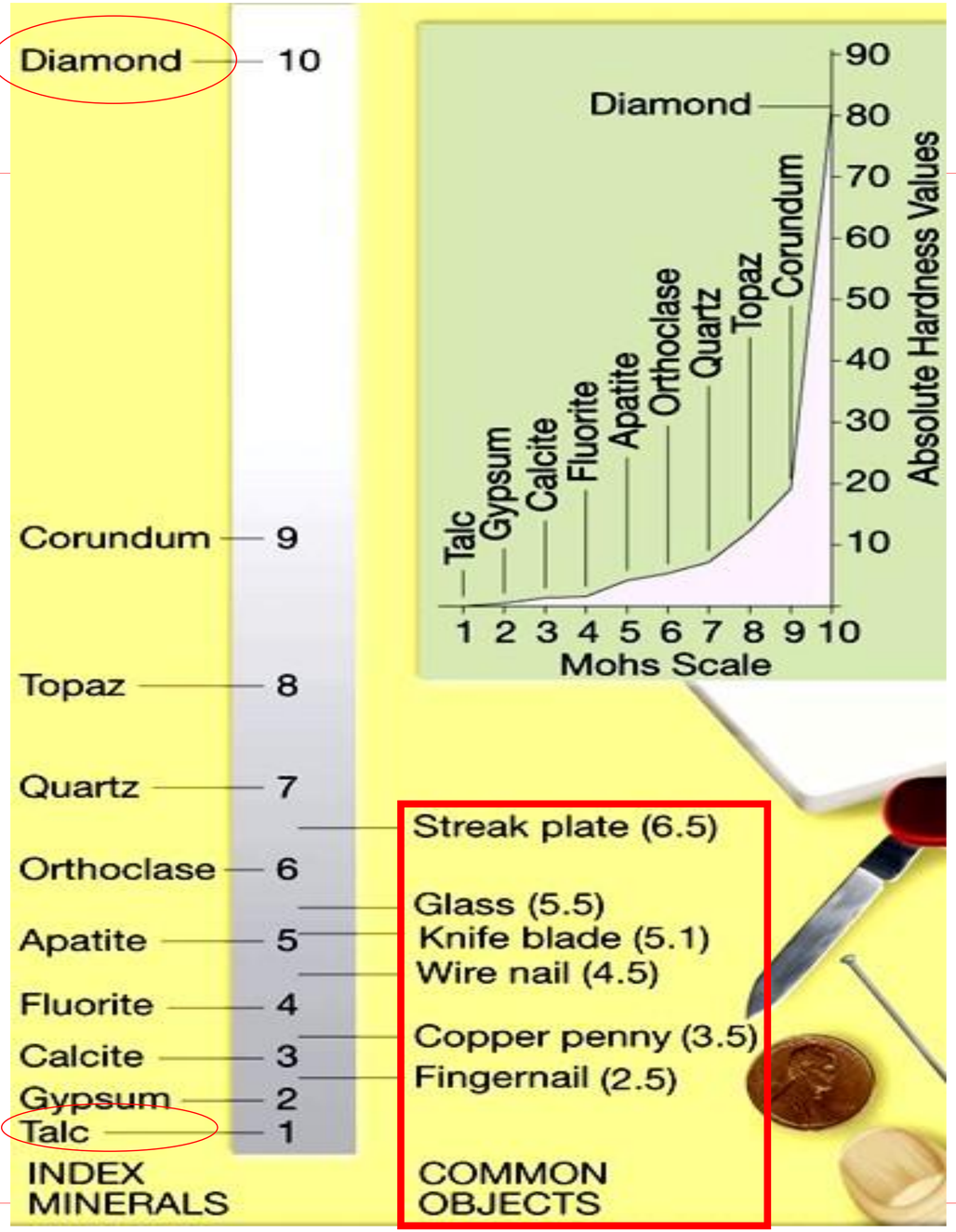
Note:

- **Cleavage planes** repeat, when a mineral is broken.
- cleavage planes must NOT be confused with crystal faces!
  - Crystal faces are just on surface and may NOT repeat, when mineral is broken.



2.3.6 Hardness

- How easy it is to scratch a mineral
- Measured on Mohs Scale of Hardness
  - relative scale
  - consists of 10 minerals, ranked from 1 (softest) to 10 (hardest).



2.3.7 Specific Gravity

- Is density of a mineral divided by density of water:

$$Specific\ Gravity = \frac{density\ of\ the\ object}{density\ of\ water} = \frac{\rho_{object}}{\rho_{H_2O}}$$

- metallic minerals tend to have higher specific gravity than non-metallic minerals

2.3.8 Other Properties

These include:

- reaction with hydrochloric acid (calcite fizzes)
- taste (halite tastes salty)
- feel (talc feels soapy, graphite feels greasy)
- magnetism (magnetite attracts a magnet)

Summary

- **Minerals** are the substances that make up rocks.
- A mineral is a **naturally occurring inorganic solid with a definite chemical composition and a crystalline structure**.
- Each mineral consists of chemical elements bonded together in definite proportions, and its chemical composition can be given as a chemical formula – SiO_2.
- A mineral's **crystalline structure** is an orderly, periodically repeated arrangement of its atoms.

Summary…..contd.

- Every mineral is distinguished from others by its **chemical composition** & **crystal structure**.
- Minerals are identified by observing a few of their physical properties – **crystal habit**, c**leavage**, **fracture**, **hardness**, **specific gravity**, **colour**, **streak**, & **lustre**.
- Although ca. 3500 minerals are known in Earth's crust, only nine **rock-forming mineral groups** are abundant in most rocks – **feldspar**, **quartz**, **pyroxene**, **amphibole**, **mica**, **clay minerals**, **olivine**, **calcite**, and **dolomite**.

Summary…..contd.

- The first seven – ***feldspar***, ***quartz***, ***pyroxene***, ***amphibole***, ***mica***, ***clay minerals***, ***olivine*** **–** are **silicates**, whose structures and compositions are based on **silicate tetrahedra**.
- Silicate tetrahedra link together by sharing oxygens to form basic structures of silicate minerals.
- Silicates are most abundant minerals because silicon & oxygen are two most abundant elements in Earth's crust & bond together readily to form silicate tetrahedron.
- Two carbonate minerals – **calcite** & **dolomite** – are also sufficiently abundant to be called rock-forming minerals.

End of Lecture