Chapter 1: The earth's crust materials

Part 1 : The minerals

Introduction

The Earth's crust is the solid surface of the material from which the Earth is made. It is the upper part of the lithosphere (which forms the tectonic plates).The Earth's crust exists in two radically different "varieties" : continental crust and oceanic crust.

The earth's crust is made up of rocks and minerals.

The crust of Earth is of two distinct types:

1. Oceanic: 5 km to 10 km thick and composed primarily of denser, more mafic rocks, such as basalt, diabase, and gabbro.

2. Continental: 30 km to 65 km thick and mostly composed of less dense, such as granite. In a few places, such as the Tibetan Plateau (Asia), the continental crust is thicker 50 km to 80 km.

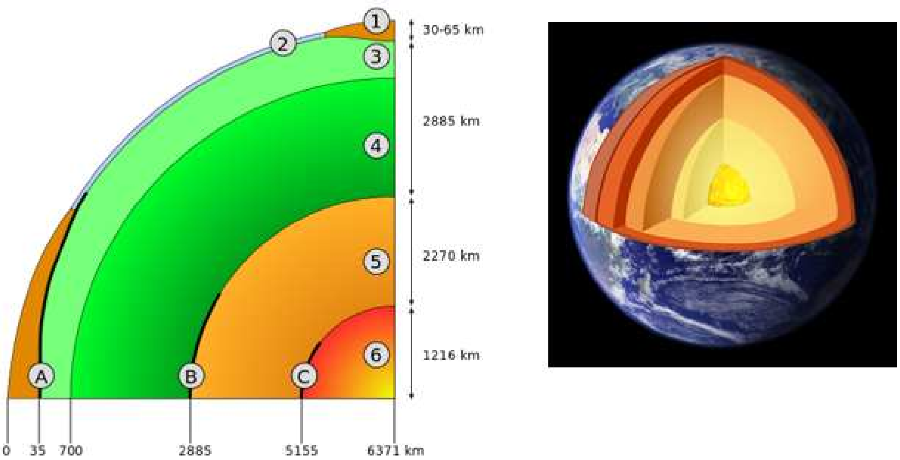


Fig.1. Earth's internal structure

Earth's internal structure :

1. Continental crust
2. Oceanic crust
3. Upper mantle
4. Lower mantle (or Mesosphere)
5. Outer core
6. Inner core (or terrestrial seed)

A. Mohorovičić discontinuity ; B. Gutenberg discontinuity ; C. Lehmann discontinuity

Table 1. Average chemical composition of the earth's crust according to Clark

Oxide	Percentage % weight
SiO_2	59,71
Al_2O_3	15,41
CaO	4,90
MgO	4,36
Na_2O	3,55
FeO	3,52
K_2O	2,80
Fe_2O_3	2,63
H_2O	1,52
TiO_2	0,60
P_2O_5	0,22
total =	*99,22*

All other constituents are present in very small quantities (total less than 1%).

SiO_2 : Silicium dioxide

Combined : silicates (Al : aluminium, Fe : iron, Mg: magnesium, Ca: calcium, Na: sodium, K: potassium, etc.).

1.1. The Minerals

1.1.1. Crystallography and crystal systems

- A **crystal** or **crystalline solid** is a solid material whose constituents (such as atoms, molecules) are arranged in a highly ordered microscopic structure, forming a crystal lattice that extends in all directions. In addition,

macroscopic single crystals are usually identifiable by their geometrical shape, consisting of flat faces with specific, characteristic orientations.

- **A Mineral**

in geology and mineralogy, a mineral or mineral species is, broadly speaking,

a solid substance with a fairly well-defined chemical composition and a

specific crystal structure that occurs naturally in pure form.

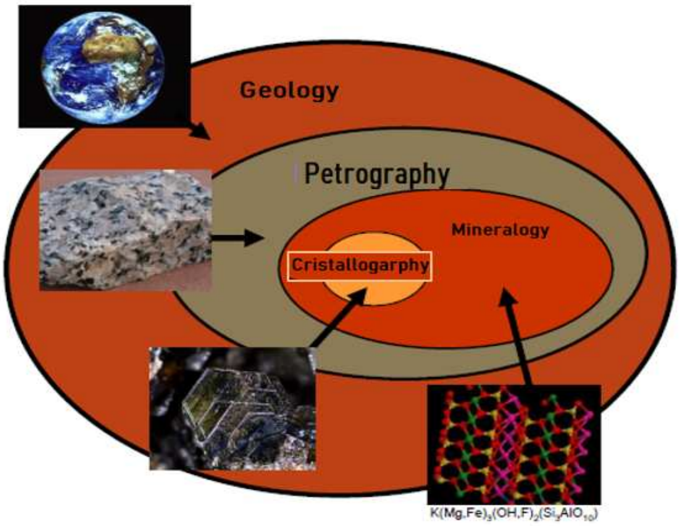
These two terms are not therefore synonymous

Comparison between a mineral and a crystal

Crystal = form, geometry

Mineral: chemical composition

A mineral is necessarily associated with a chemical composition ($CaCO_3$: Calcite)



Note/

While most minerals are crystallized, there are exceptions to this definition:

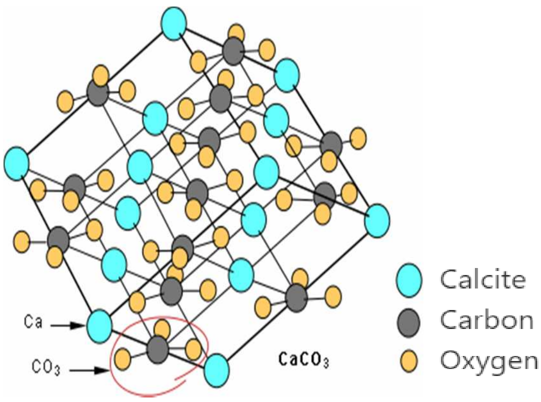
- Mercury is a liquid mineral
- Opal, flint and agate are solidified gels

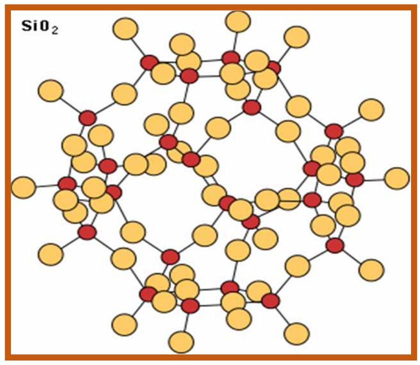
Opal, flint and agate are solidified gels with no ordered atomic structure. These minerals are said to be **amorphous.**

Fig. 2. Flint (SiO_2) Opal ($SiO_2 \cdot n\ H_2O$) Agate (SiO_2)

Crystallization systems

Crystalline lattice geometry





Calcite : $CaCO_3$ **Quartz : SiO_2**

Fig. 3 .The elementary crystal lattice

What is Crystal Lattice?

The crystal lattice is the symmetrical three-dimensional structural arrangements of atoms, ions or molecules (constituent particle) inside a crystalline solid as points. It can be defined as the geometrical arrangement of the atoms, ions or molecules of the crystalline solid as points in space

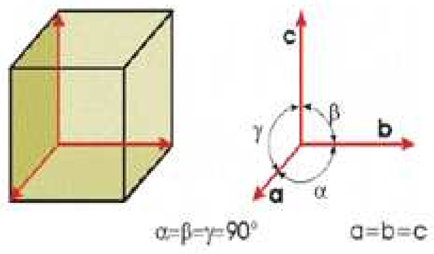
Characteristics of Crystal Lattice

- In a crystal lattice, each atom, molecule or ions (constituent particle) is represented by a single point.
- These points are called lattice site or lattice point.
- Lattice sites or points are together joined by a straight line in a crystal lattice.
- When we connect these straight lines we can get a three-dimensional view of the structure. This 3D arrangement is called: Crystal Lattice also known as Bravais Lattices.

Unit Cell

Unit Cell is the smallest part (portion) of a crystal lattice. It is the simplest repeating unit in a crystal structure. The entire lattice is generated by the repetition of the unit cell in different directions.

There are six parameters of a unit cell. These are the 3 edges which are a, b, c and the angles between the edges which are α, β, γ. The edges of a unit cell may be or may not be perpendicular to each other.



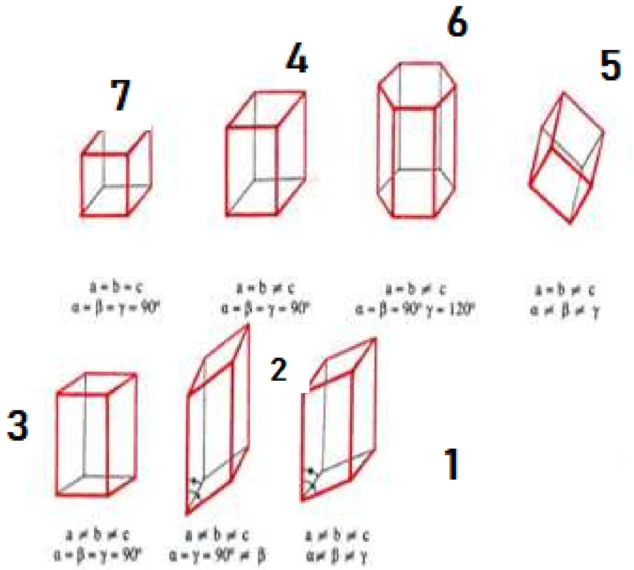


Fig. 4. The seven cristtaline systems

The seven cristtaline systems

1. **Triclinic,**
2. **Monoclinic,**
3. **Orthorhombic,**
4. **Tetragonal,**
5. **Rhombohedral,**
6. **Hexagonal,**
7. **Cubic**

Crystals formation

- Crystal-forming environments.
- Silicate crystal formation in magma.

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The forming of crystals, which are solid objects, necessarily involves a change of state: Example. H20

A change from liquid to solid state ⇒ solidification

Or from gaseous to solid state ⇒ condensation

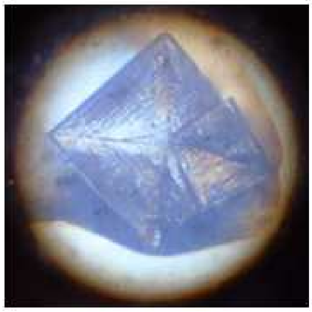
For us, the main environment for crystal formation will therefore be the liquid environment.

For crystals from sedimentary rock

For crystals from magmatic rock

Fig. 5. Crystals formation

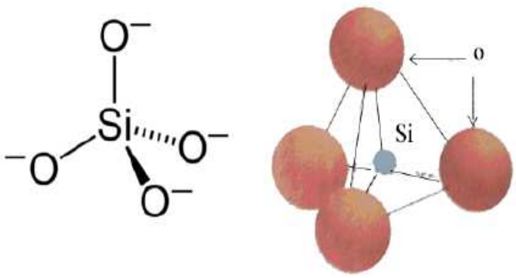
Example of a sedimentary rock: halite or sodium chloride (NaCl)



NaCl crystal observed under an optical microscope

- **The formation of silicate crystals in magmatic environments**

Oxygen (O) and silicon (Si) are the most abundant elements on Earth; they combine to form a tetrahedral SiO_4^{4-} molecule. The elemental tetrahedron therefore has the overall chemical formula: $(SiO_4)^{4-}$.



1.1.2 Mineralogy

Mineralogy is a multidisciplinary science concerned with minerals, their identification, characterization and description, analysis, varieties, classification and collection, deposits and distribution, origins and various modes of formation, and human uses.

Descriptive mineralogy studies the minerals found in natural environments, and the various constituents associated with rocks.

Mineral classification

The mineral classification used by the International Mineralogical Association is the Strunz classification. Introduced by German mineralogist Karl Hugo Strunz (1910-2006), it is based on their chemical composition. It divides the nearly 4,000 known minerals into 10 classes:

1. Native elements composed of a single, more or less pure chemical element ;
2. sulfides ;
3. halides ;
4. oxides and hydroxides ;
5. carbonates and nitrates ;
6. borates ; sulfates,
7. chromates,
8. molybdates and tungstates ; phosphates,
9. arsenates and vanadates ; silicates ;
10. organic minerals