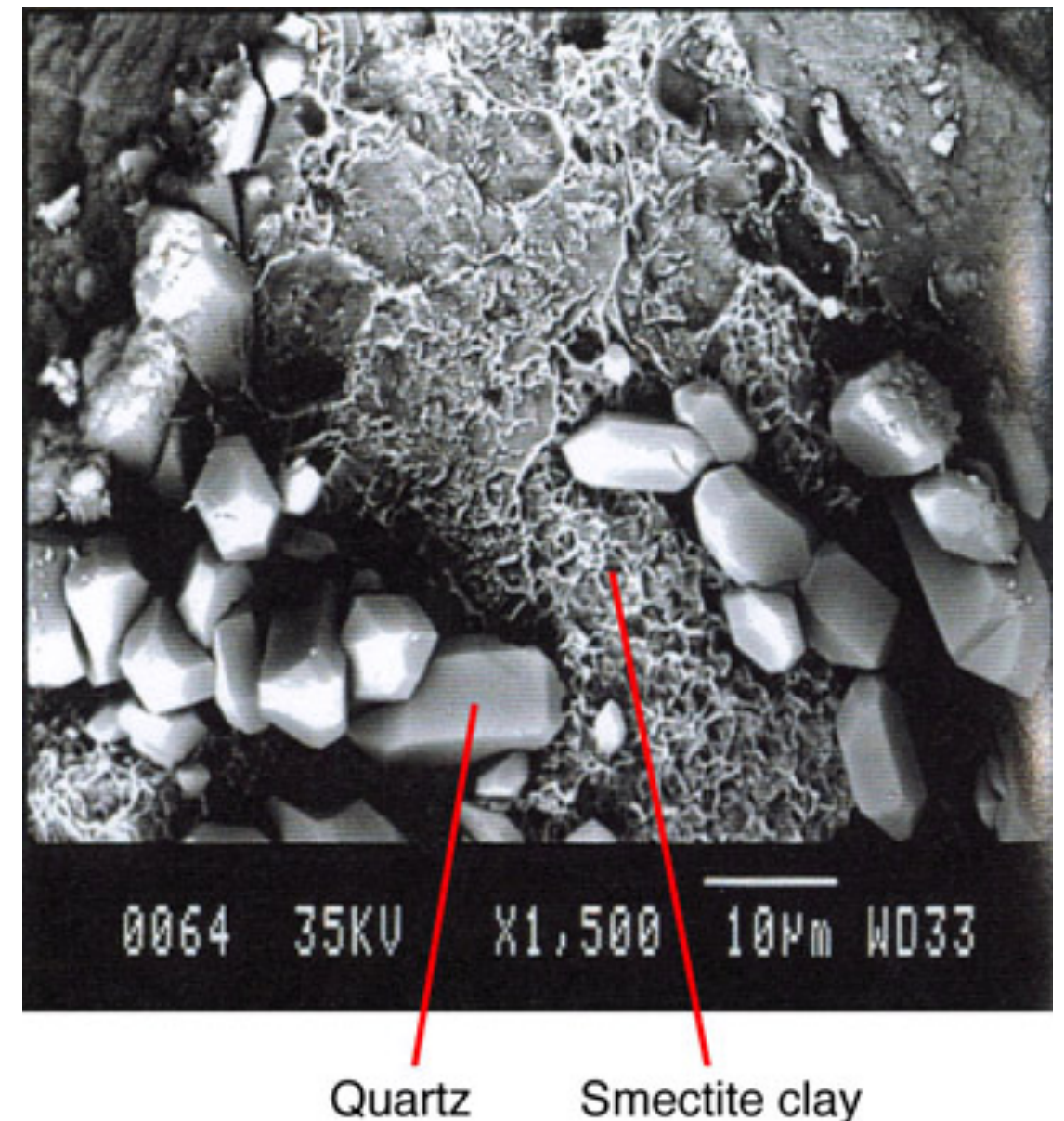


Soil Science: Introduction

Soils are formed by the weathering of rocks and decomposition of organic matter. The physical properties of soil are dictated by the minerals that constitute the soil particles and their structural arrangement.

The size of individual soil grains varies over a wide range. Many of the physical properties of soil are dictated by the size, shape and chemical composition of the soil grains.



Rock Cycle and Weathering

Figure 2.1 shows a diagram of the formation cycle of different types of rock and the processes associated with them. This is called the rock cycle:

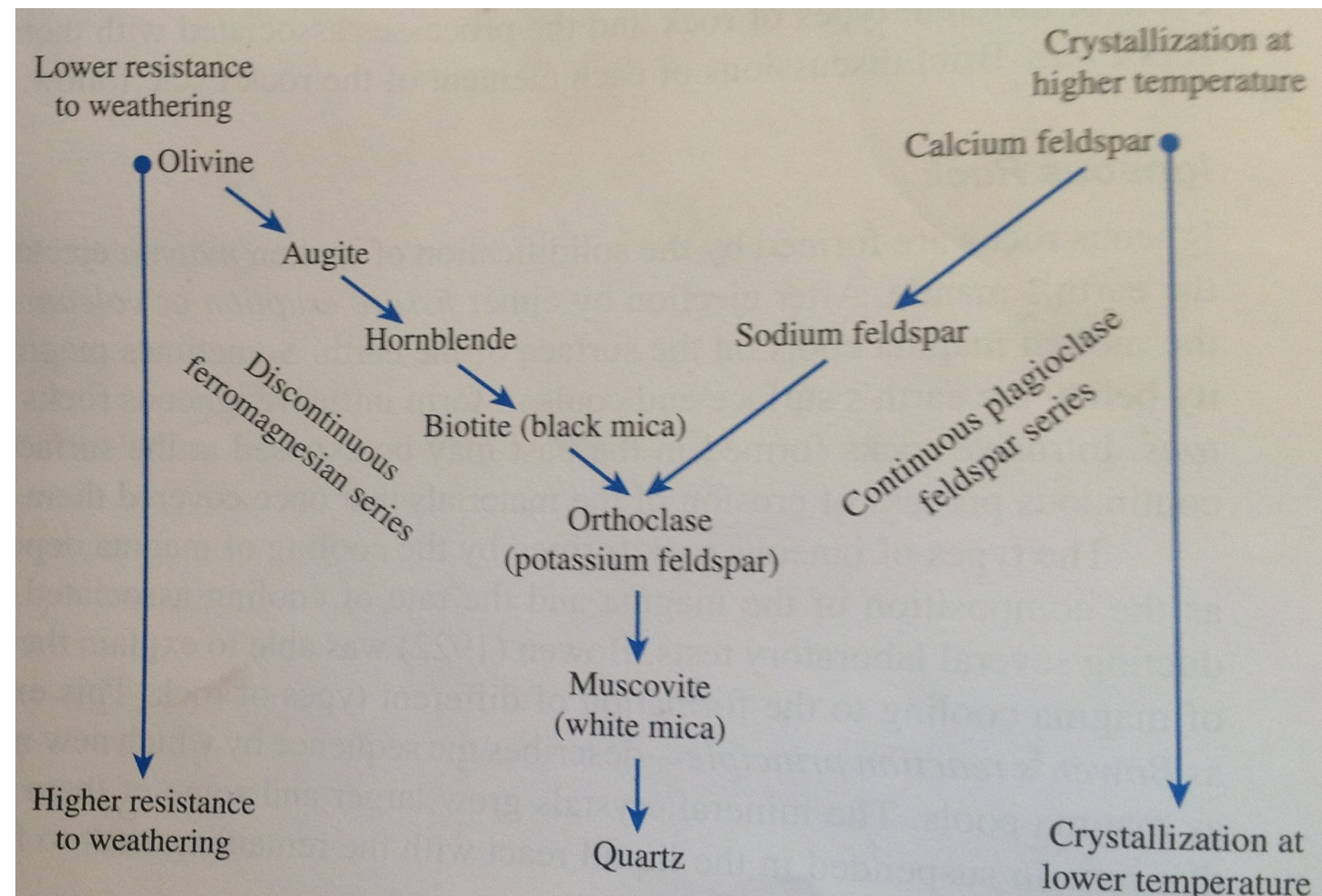
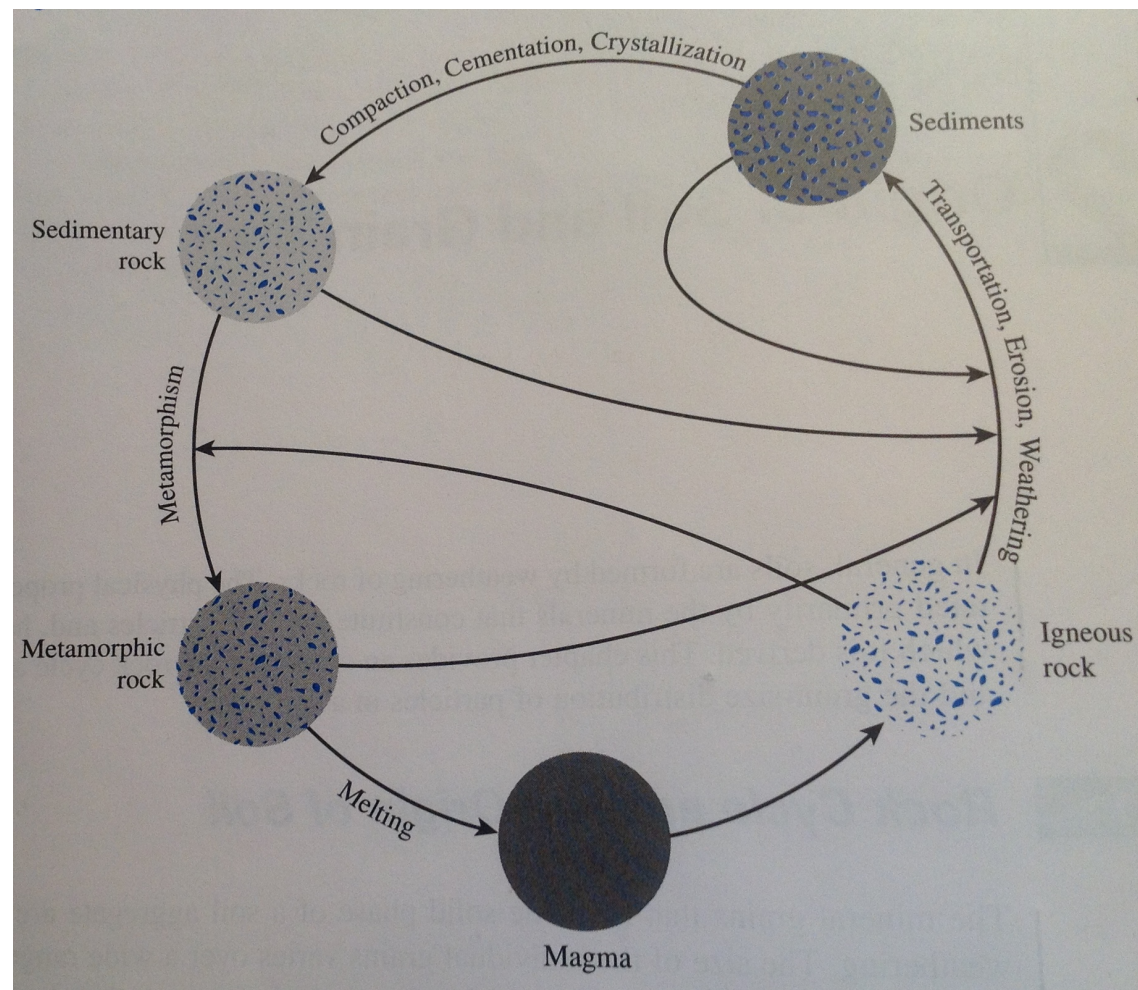
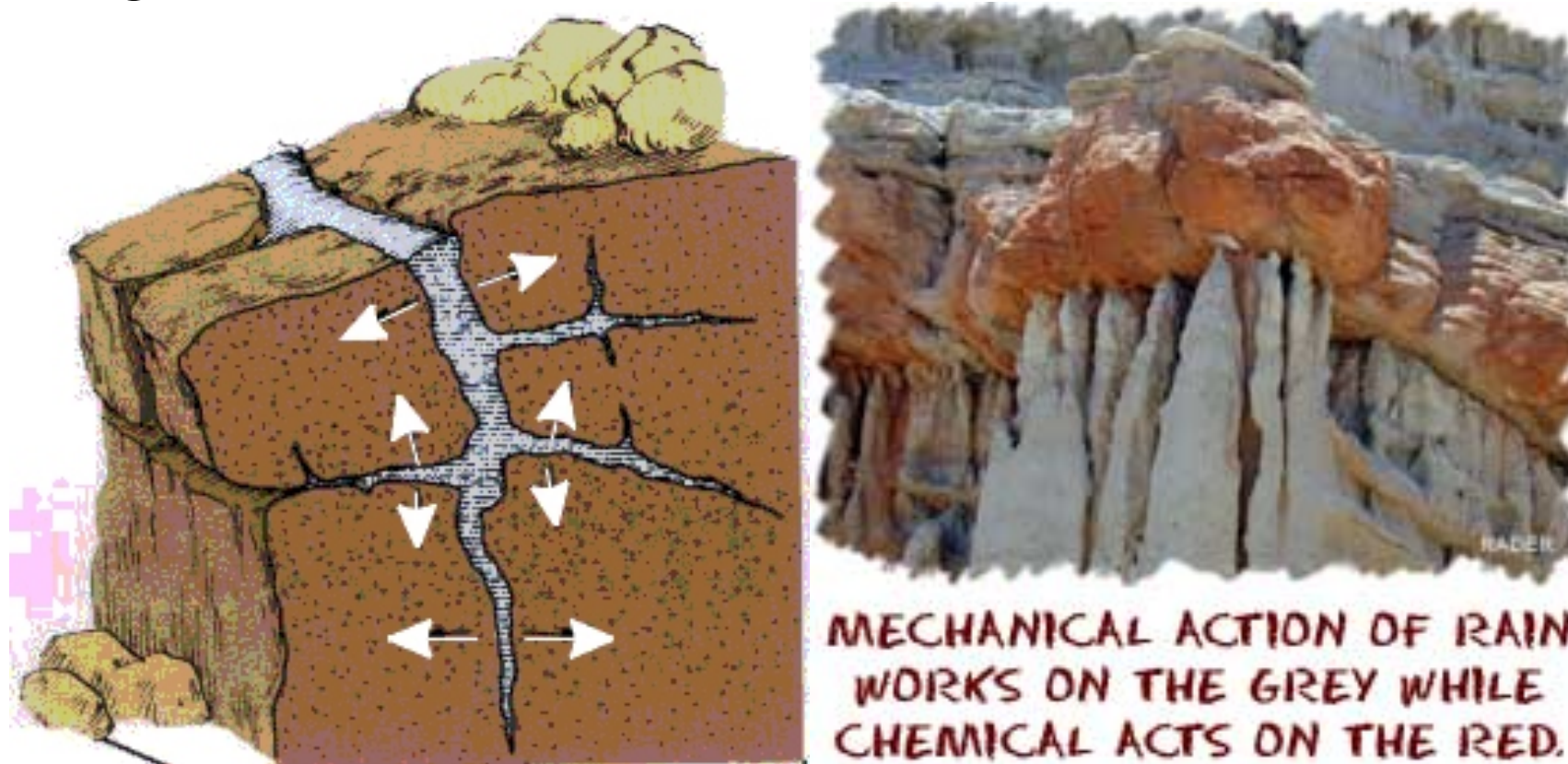


Figure 2.2 is the Bowen reaction series, which depicts the relative resistance to weathering of different minerals, partly in relation to their igneous crystalline formation.

Weathering

Weathering is the process of breaking down rocks by mechanical and chemical processes into smaller pieces. Mechanical weathering may be caused by the expansion and contraction of rocks from the continuous gain and loss of heat, which results in disintegration.

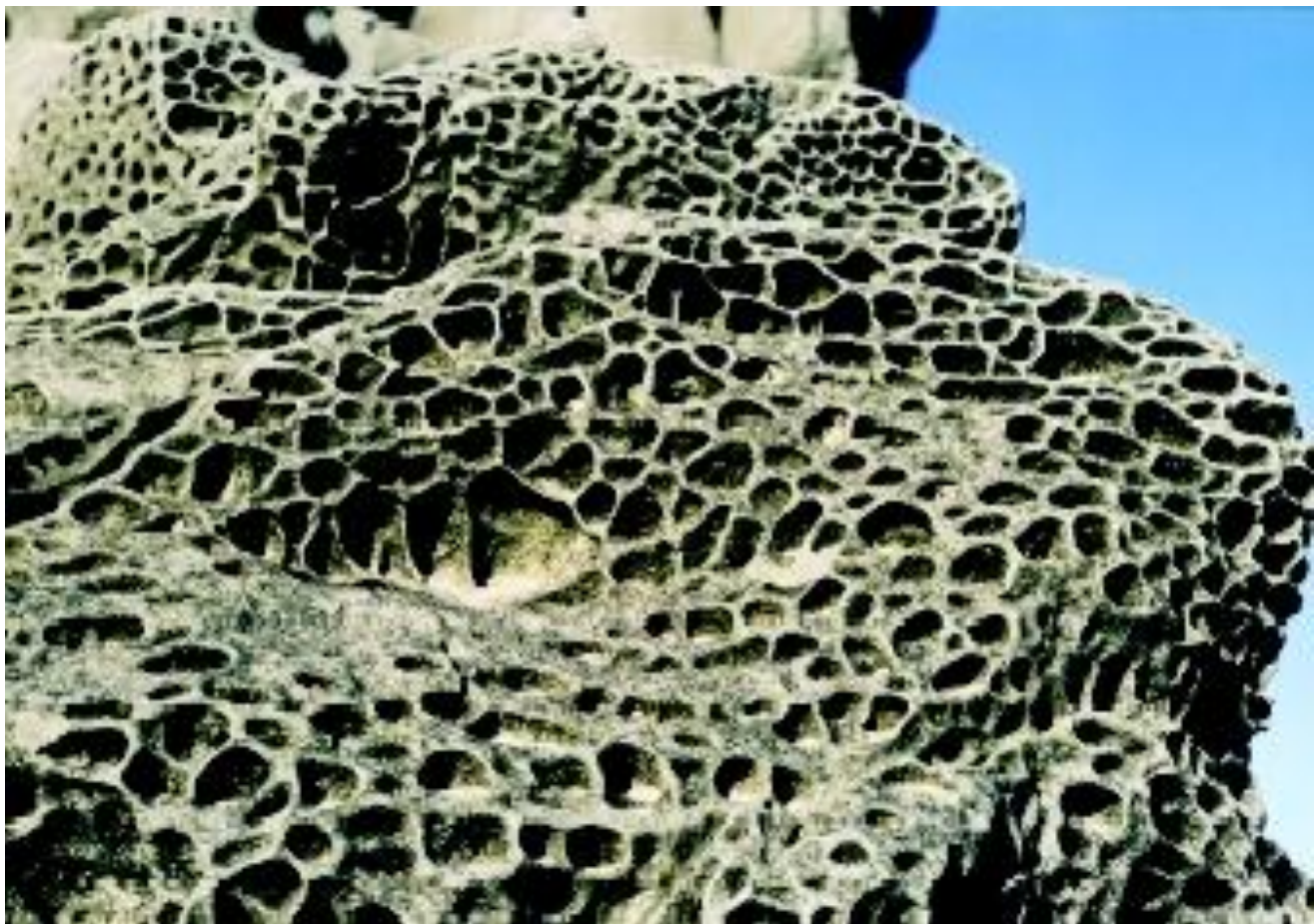
Frequently water seeps into the pores and existing cracks in rocks. As the temperature drops the water freezes and expands. The pressure exerted by ice because of volume expansion is strong enough to break down even large rocks



Chemical Weathering

In chemical weathering the original rock minerals are transformed into new minerals by chemical reaction. Water and carbon dioxide from the atmosphere form carbonic acid which reacts with the existing rock minerals to form new minerals and soluble salts.

Soluble salts present in groundwater and organic acids formed from decayed organic matter also cause chemical weathering.

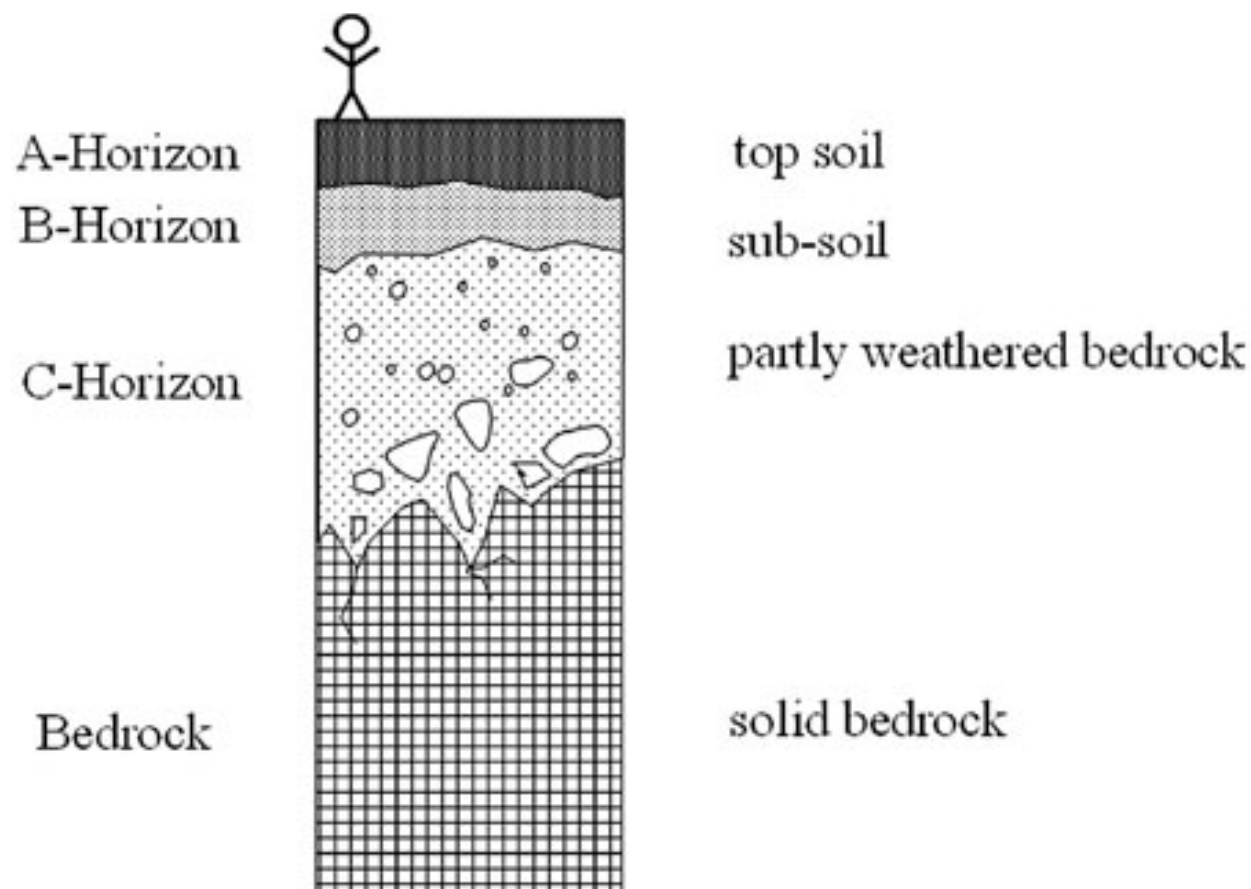


Weathering and Transportation

The products of weathering may stay in the same place or may be moved to other places by ice, water, wind and gravity.

Soils formed by weathered products at their place of origin are called residual soils. An important characteristic of residual soil is the gradation of particle size.

Fine-grained soil is found at the surface, and the grain size increases with depth. At greater depths angular rock fragments will also be found.



Weathering and Transportation

Transported soils may be classified into several groups depending on their mode of transportation and deposition:

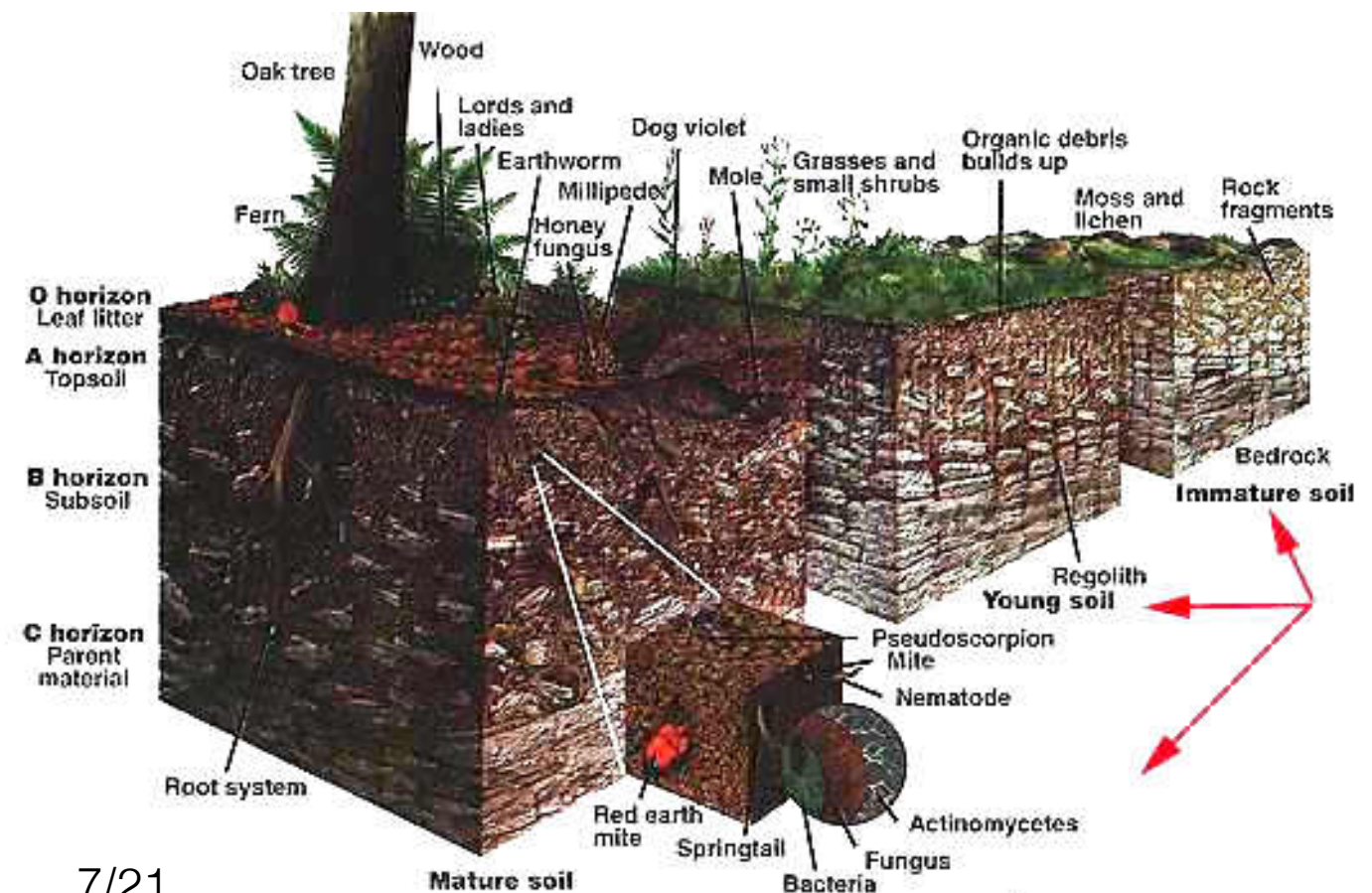
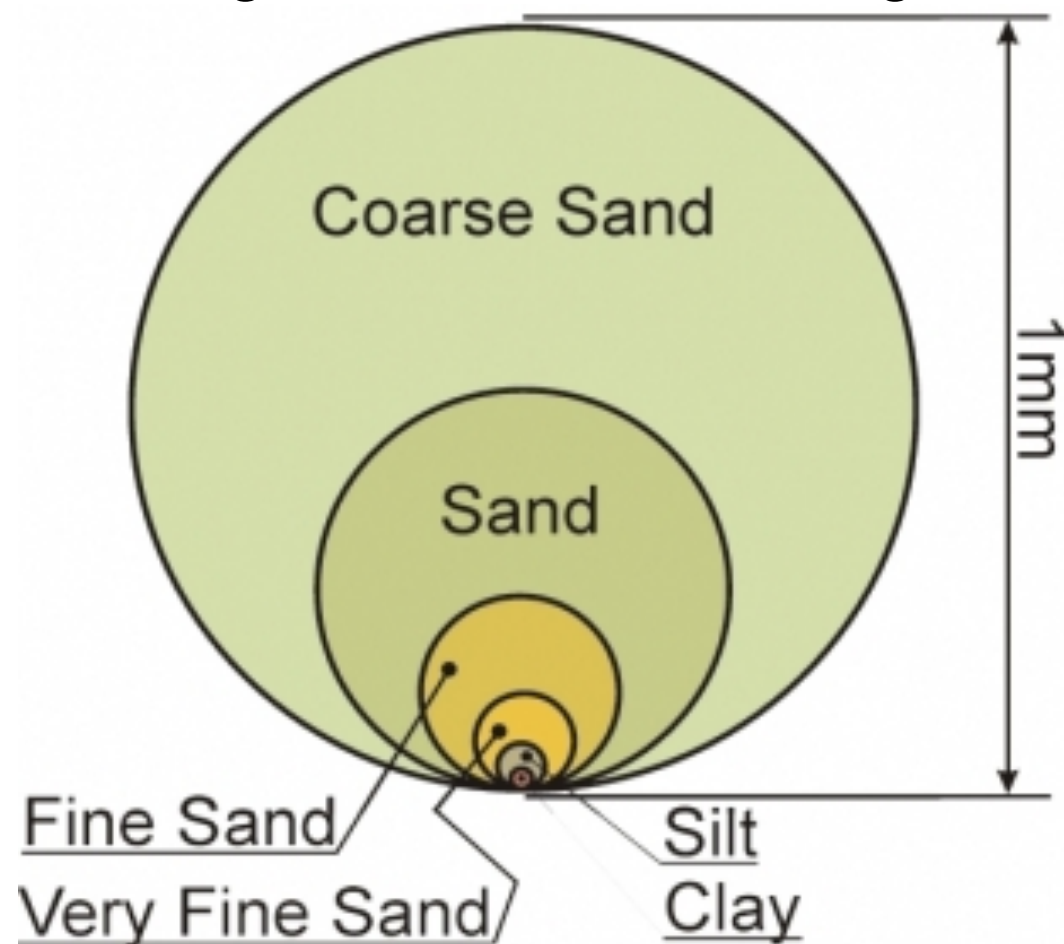
1. Glacial soils; formed by transportation and deposition of glaciers
2. Alluvial soils; transported by running water and deposited along streams
3. Lacustrine soils; formed by deposition in quiet lakes
4. Marine soils; formed by deposition in the sea
5. Aeolian soils; transported and deposited by wind
6. Colluvial soils; formed by movement of soil from its original place by gravity such as during landslides

Weathering & Soil Particle Size

The weathering process is not limited to igneous rocks. As seen in the rock cycle, sedimentary and metamorphic rocks also weather in a similar manner.

The weathering process changes solid rock masses into smaller fragments of various sizes, from large boulders to very small clay particles. Uncemented aggregates of these small grains in various proportions form different types of soil.

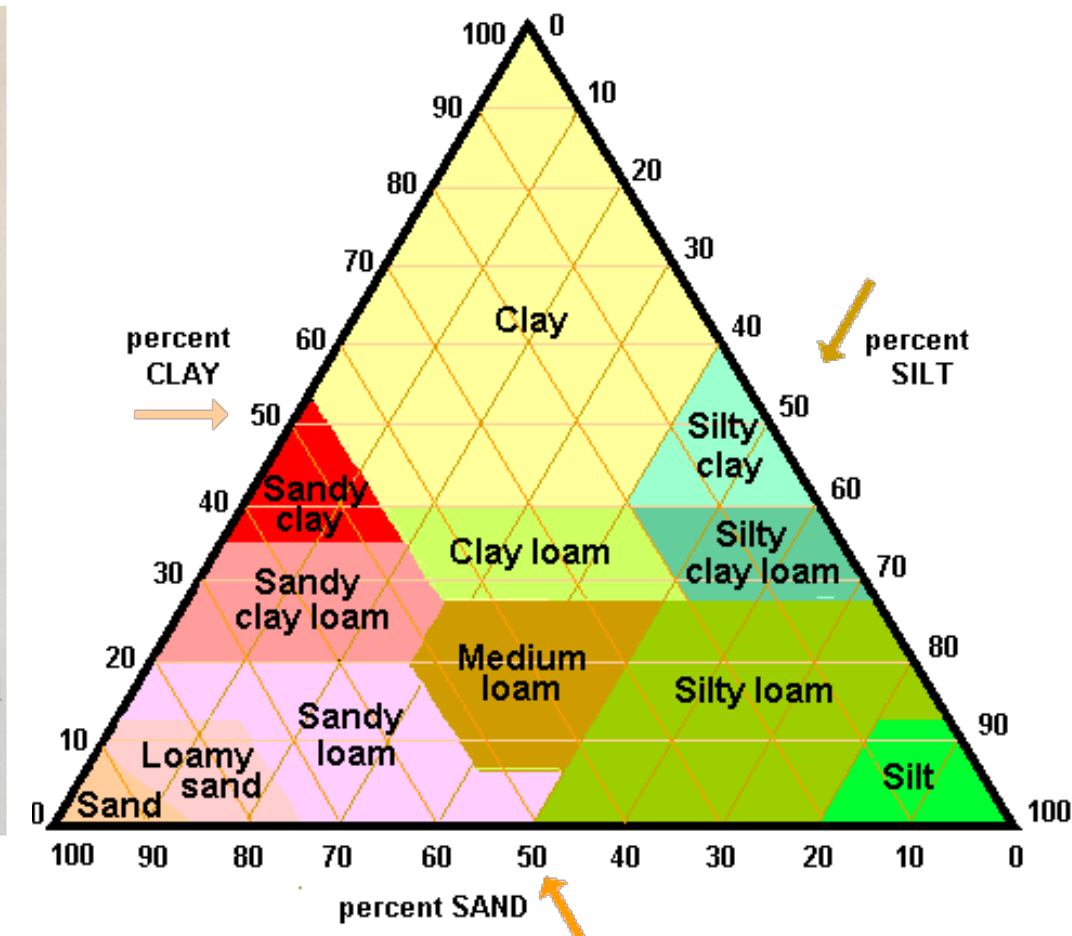
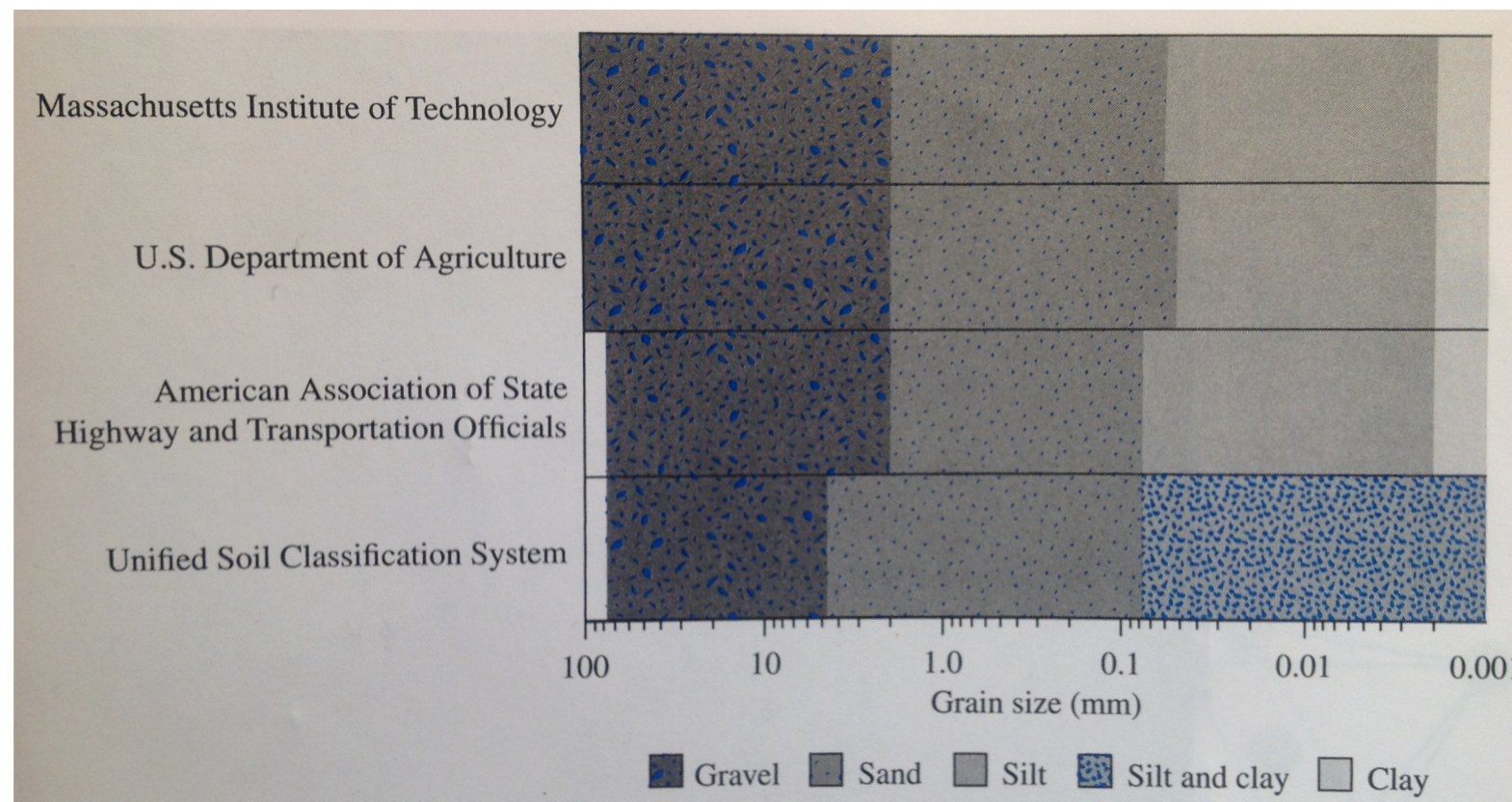
The clay minerals, which are a product of chemical weathering of feldspars, ferromagnesian and micas, give the property of *plasticity* to soil.



Soil Particle Sizes and Types

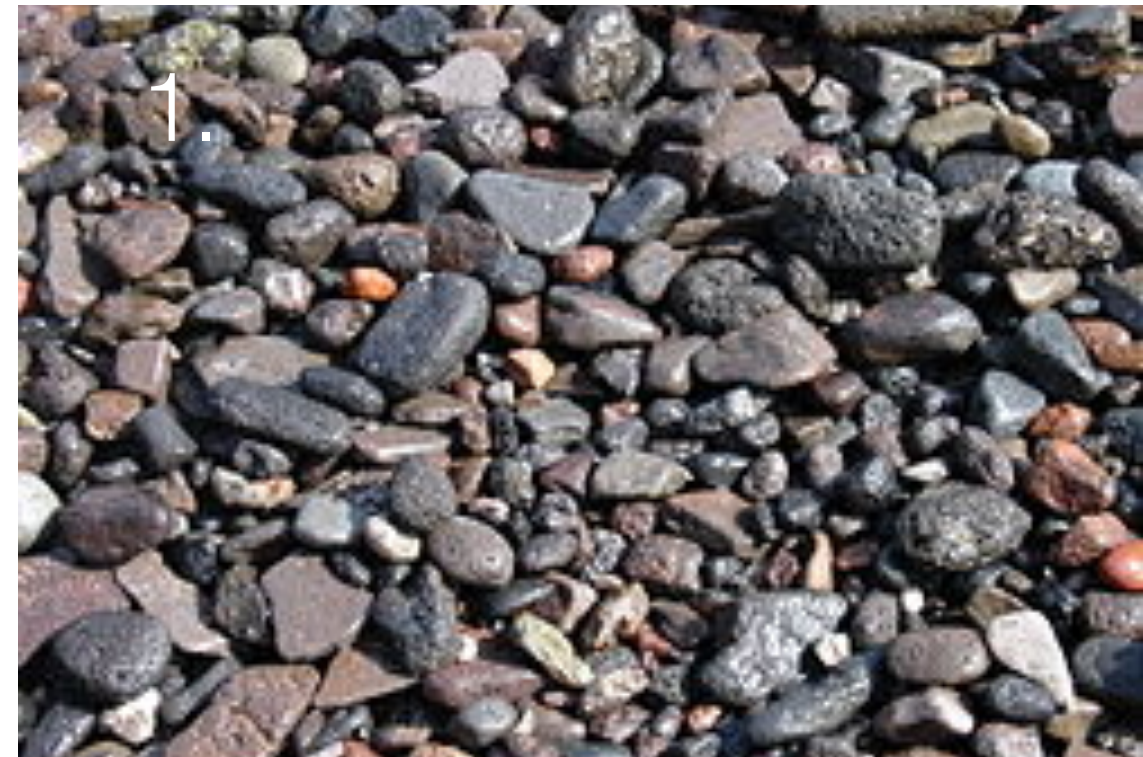
The sizes of particles that make up soil vary over a wide range. Soils generally are called gravel, sand, silt or clay depending on the predominant size of particles in the soil.

To describe soils by their particle size, several organisations have developed particle size classifications. The Unified Soil Classification System USCS is now accepted by the Australian Institution of Engineers.



Gravel, Sand and Silt

1. Gravels are pieces of rock with occasional particles of quartz, feldspar and other minerals.
2. Sand particles are made mostly of quartz and feldspar.
3. Silts are the microscopic soil fractions that consist of a very fine quartz grains and some flake-shaped particles



Clays

Clays generally are defined as particles smaller than 0.002 mm. However in some cases particles between 0.002 and 0.005 mm in size are also referred to as clay.

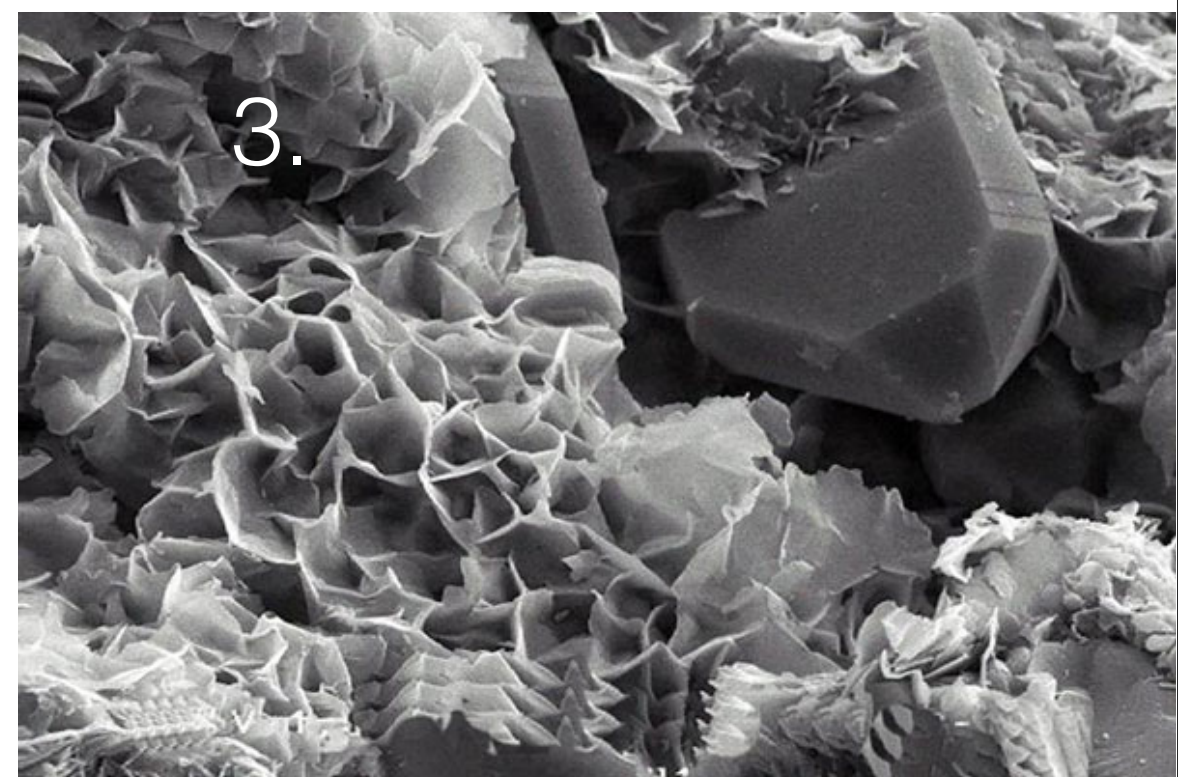
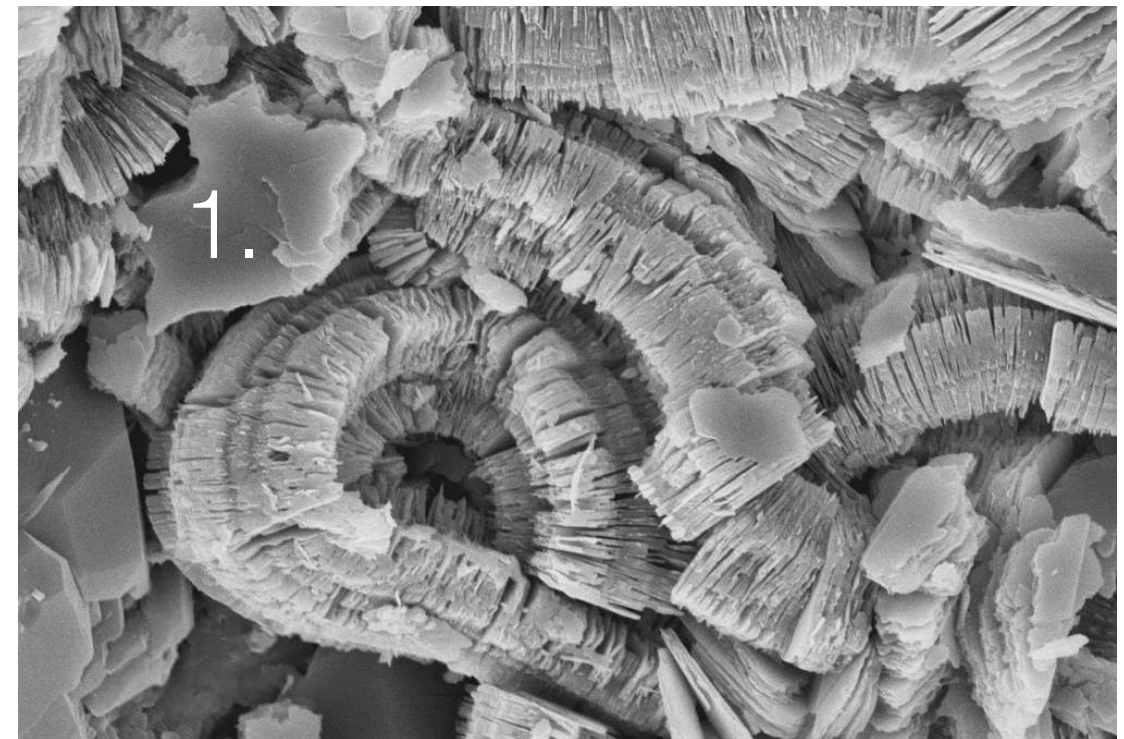
Clays have been defined as those particles which develop *plasticity* when mixed with a limited amount of water. Particles classified as clay on the basis of their size may not necessarily contain clay minerals.



Clay Minerals

There are three important clay minerals: In order of their reactivity, which governs their plasticity and expansiveness, they are;

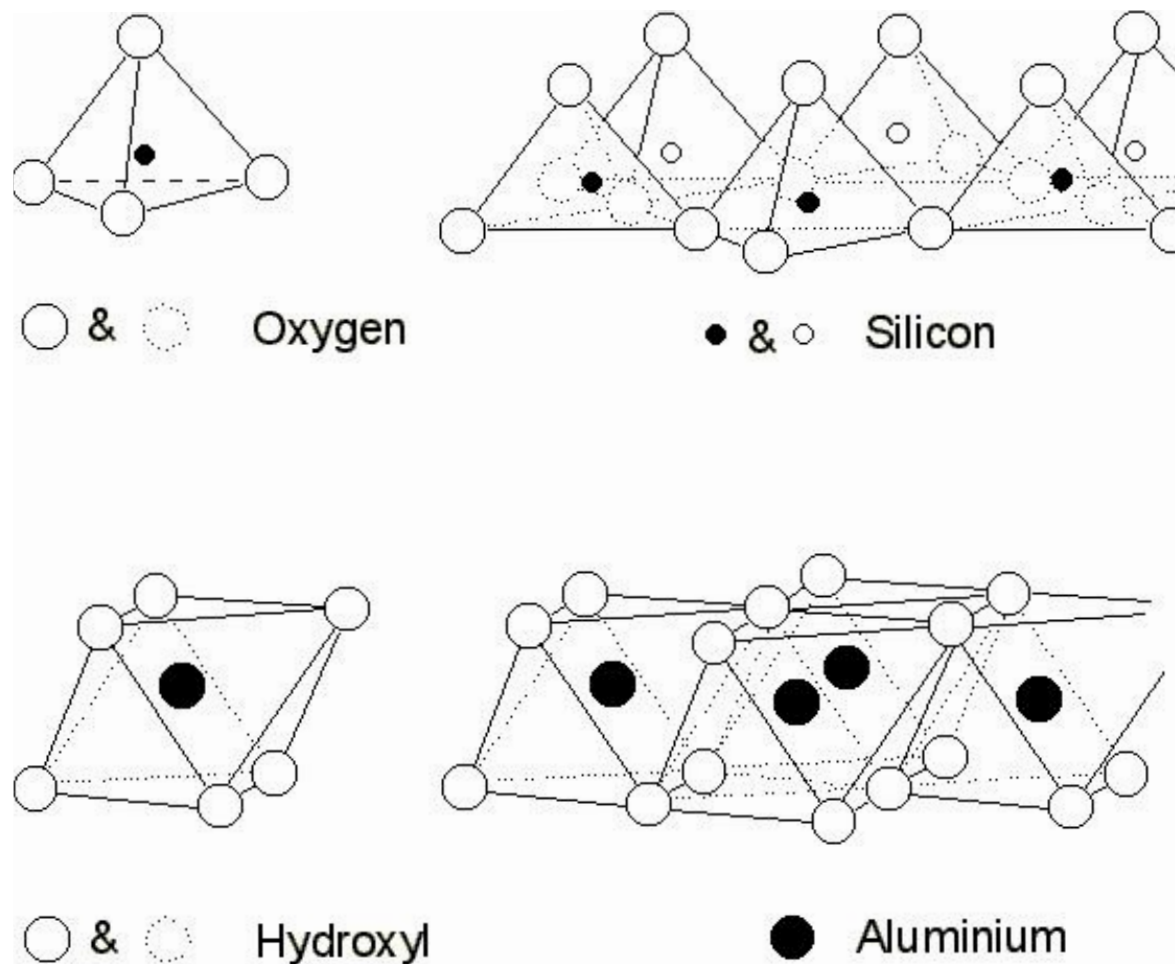
1. Kaolinite; stable, low reactivity
2. Illite (Smectite); some reactivity
3. Montmorillonite; highly reactive and expansive



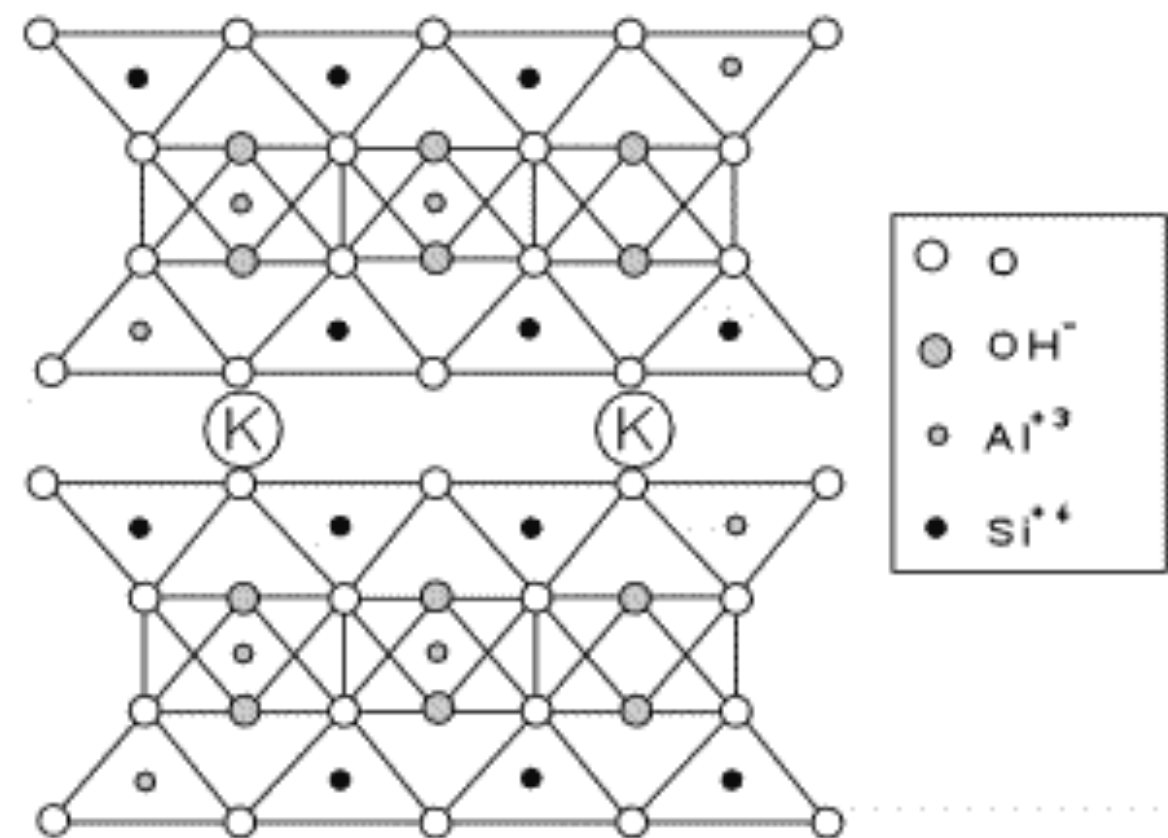
Clay Minerals

Clay minerals are complex aluminium silicates composed of two basic units:

1. Silica tetrahedra, consisting of four oxygen atoms surrounding a silicon atom. The combination of tetrahedral silicon units gives a *silica sheet*.
2. Aluminium octahedra, consisting of six hydroxyls surrounding an aluminium atom. The combination of the octahedral aluminium hydroxyl units gives an *octahedral or Gibbsite sheet*.



Muscovite $\text{KAl}_2\text{AlSi}_3\text{O}_{10}(\text{OH})_2$

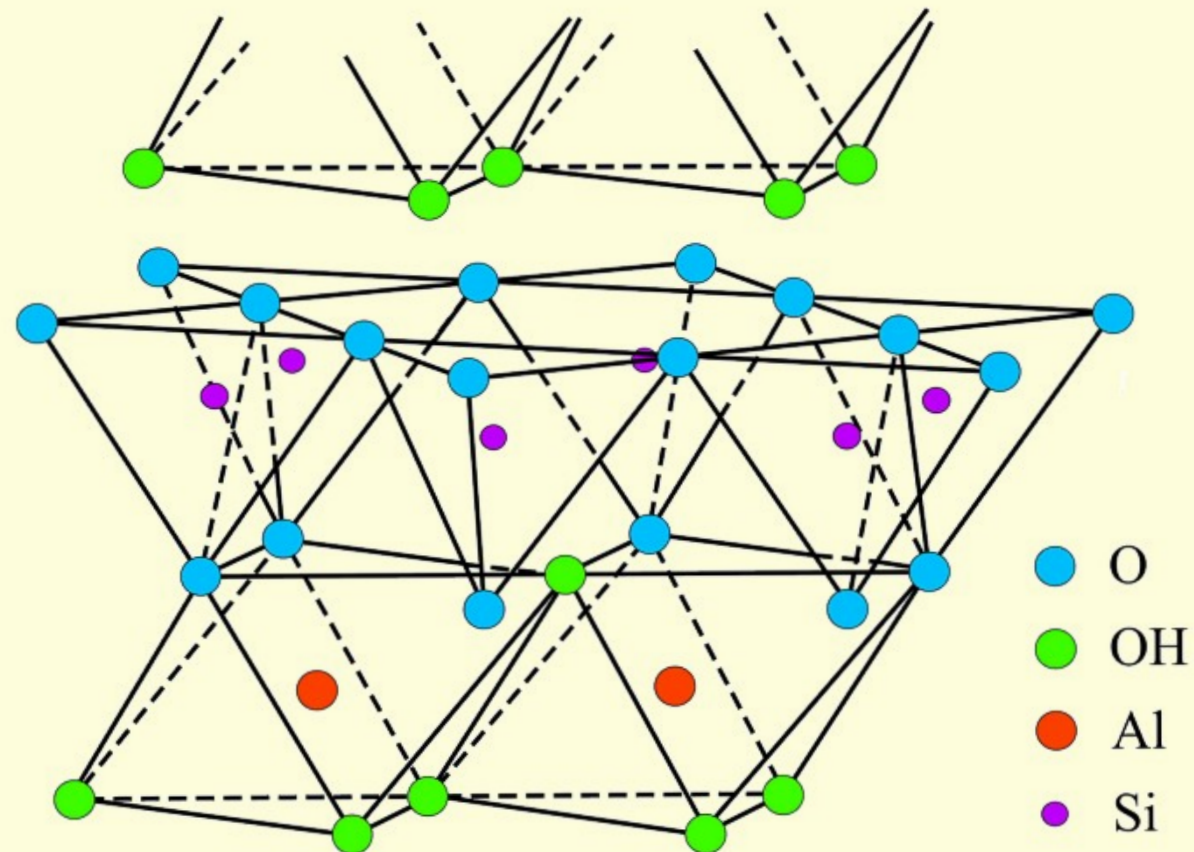


Kaolinite

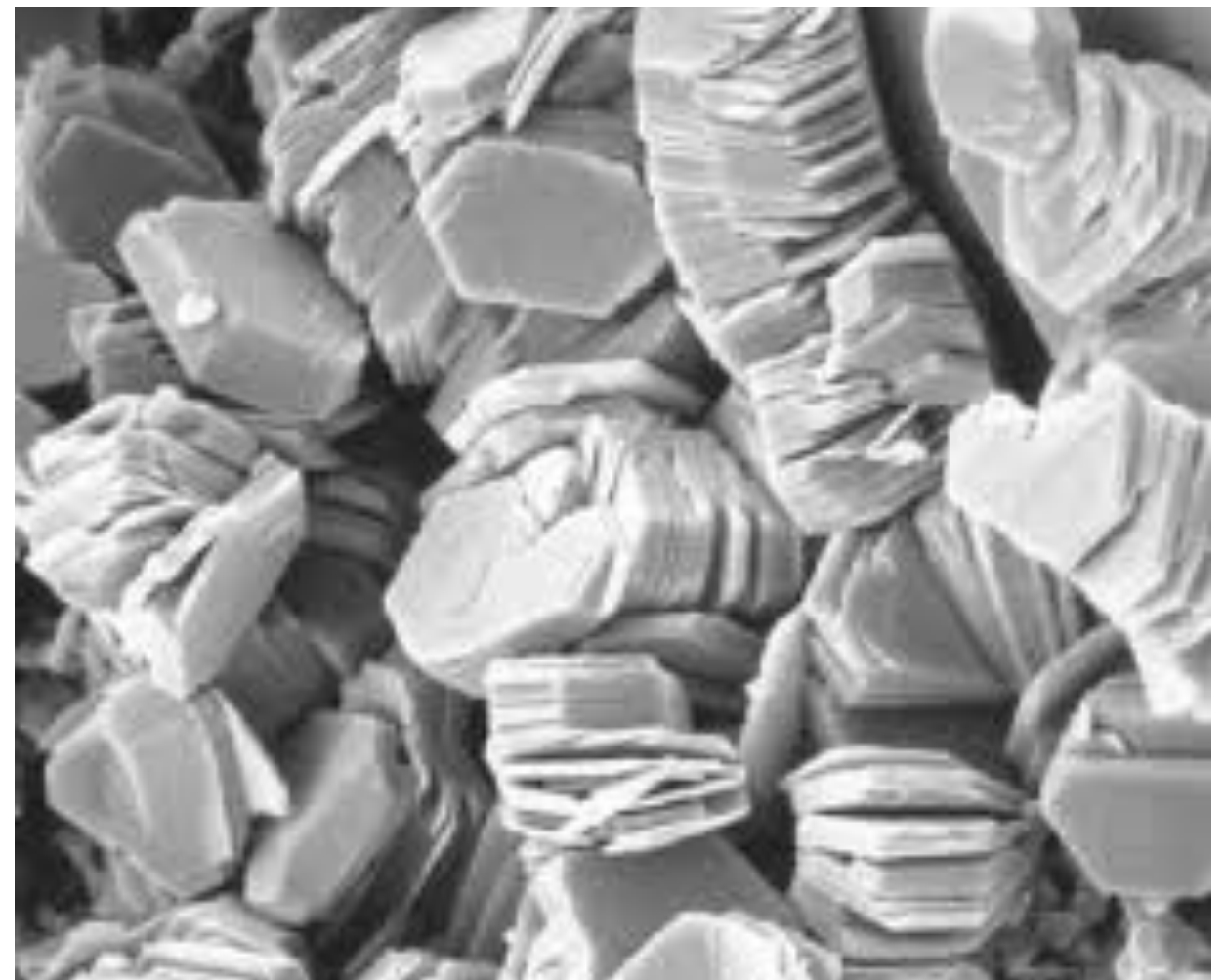
Kaolinite consists of repeating layers of elemental silica-gibbsite sheets in a 1:1 lattice. The layers are held together by hydrogen bonding.

Kaolinite occurs as platelets with a lateral dimension of 1000 to 20,000 Å and a thickness of 100 to 1000 Å. The surface area per unit mass, defined as *specific surface*, is about 15 m²/g for kaolinite.

STRUCTURE OF A KAOLINITE LAYER



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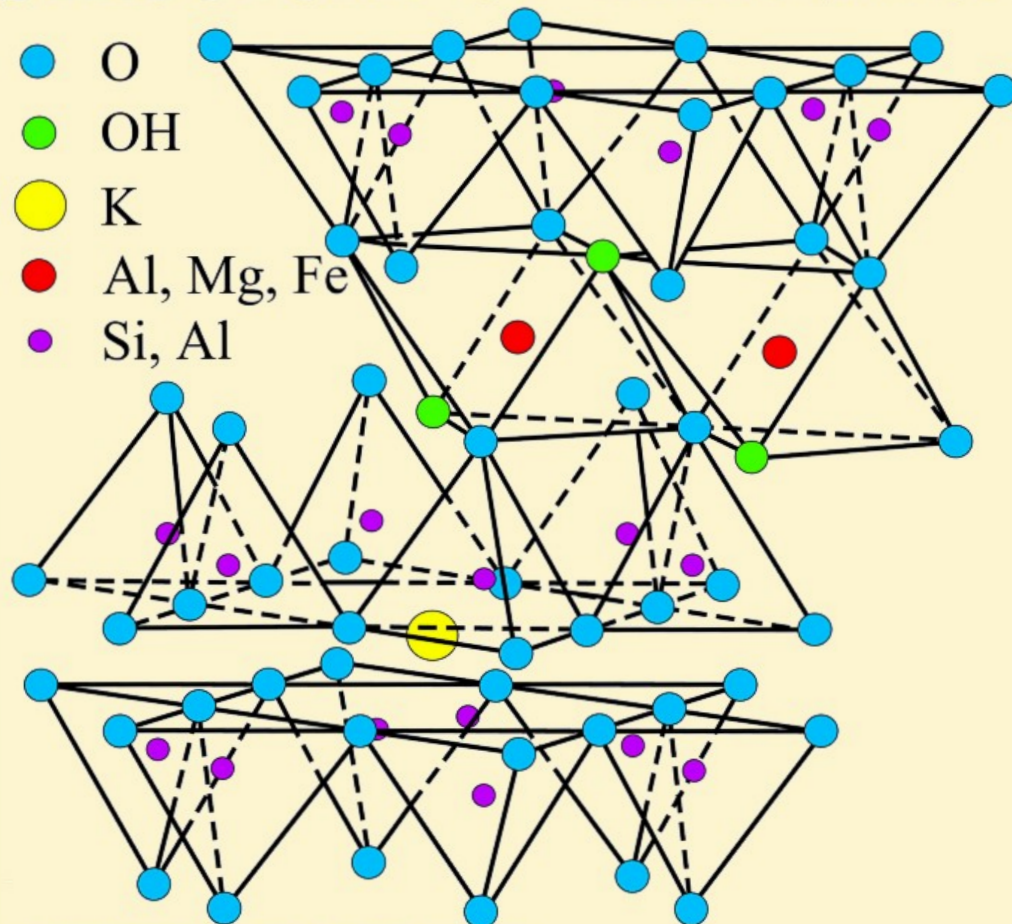
Illite/Smectite

Illite consists of a gibbsite sheet bonded to two silicon sheets, one at the top and another at the bottom. It is sometimes called clay mica. The illite layers are bonded by potassium ions.

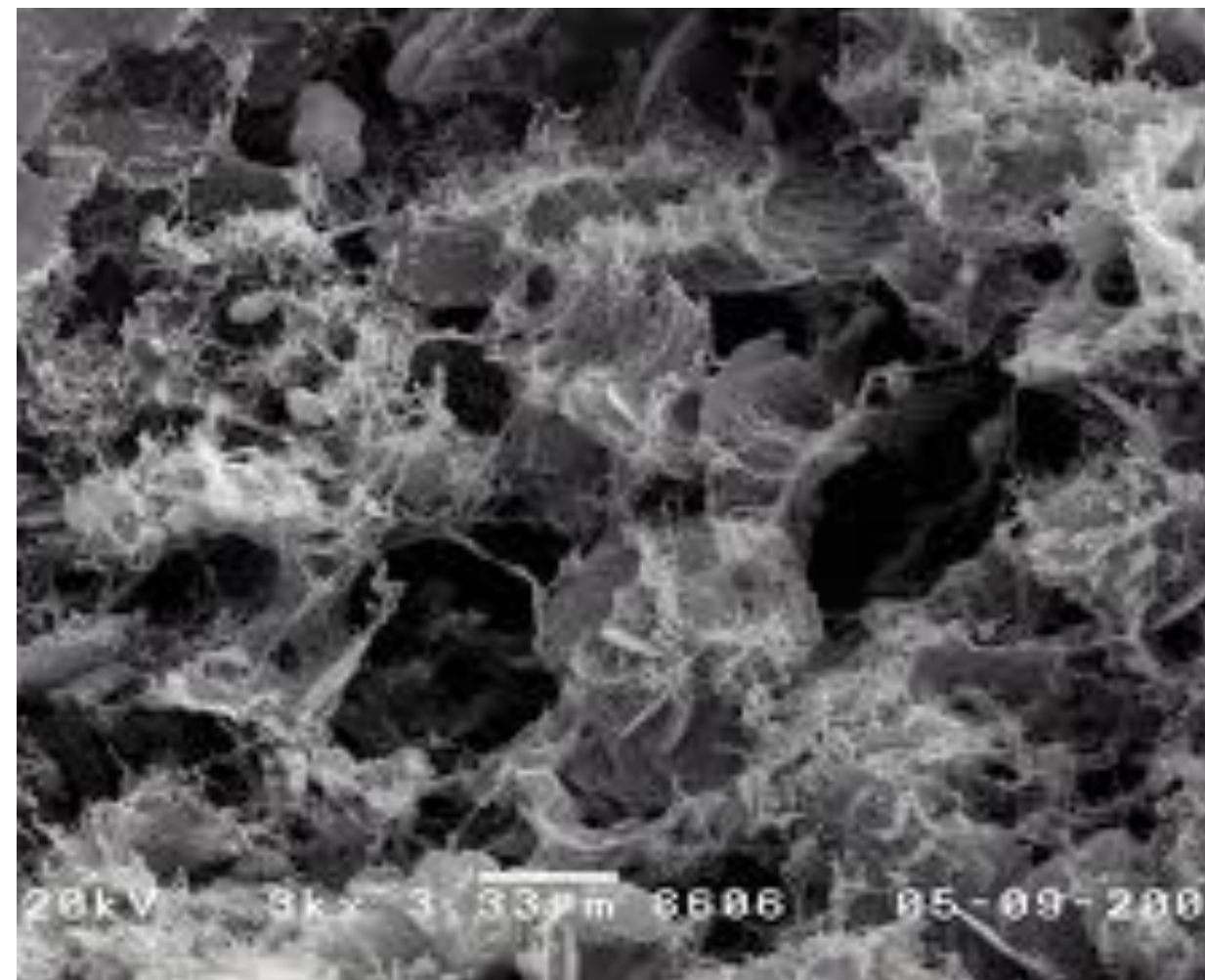
The negative charge to balance the potassium ions comes from the substitution of aluminium for some silicon in the tetrahedral sheets. Substitution of one element for another with no change in crystalline form is known as *isomorphous substitution*.

Illite particles generally lateral dimensions ranging from 1000 to 5000 Å and thicknesses from 50 to 500 Å. The specific surface is about 80 m²/g.

STRUCTURE OF ILLITE/MICA



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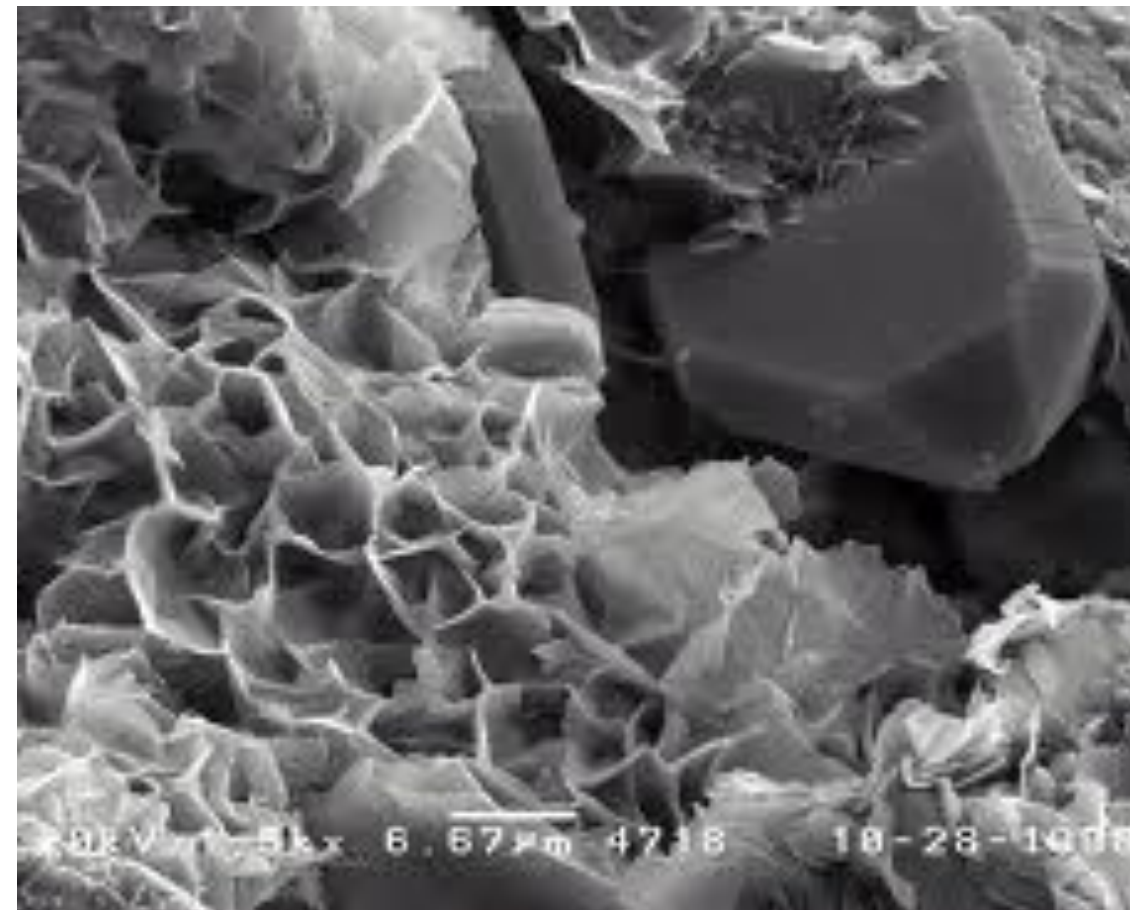
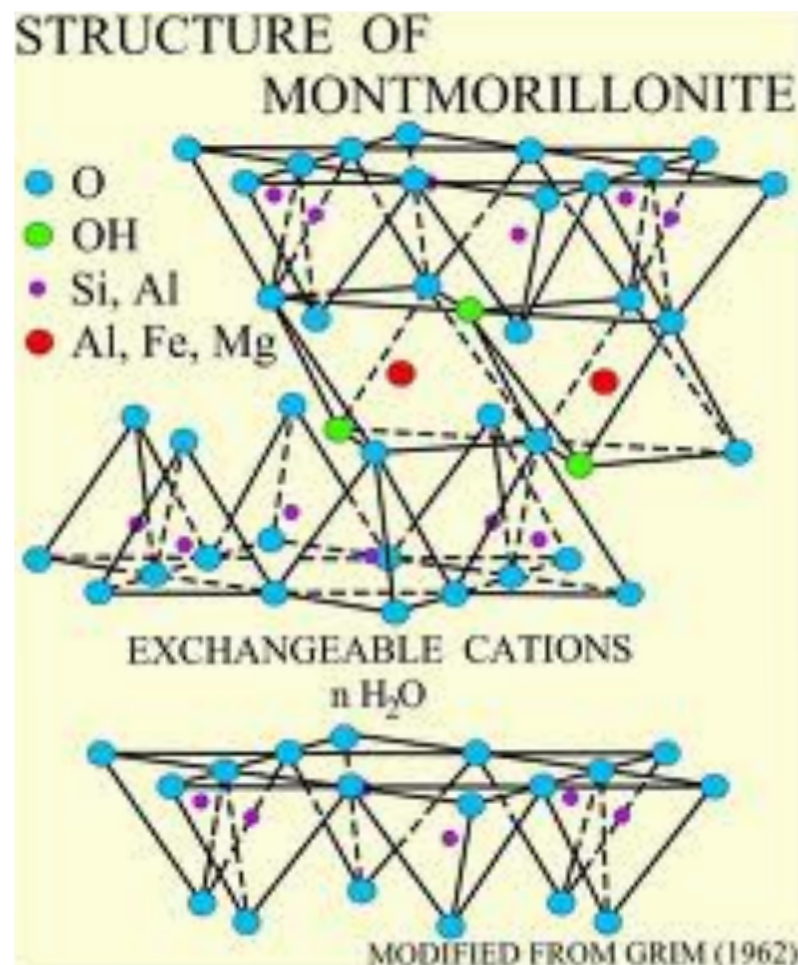


Montmorillonite

Montmorillonite has a structure similar to that of illite, with isomorphous substitution of magnesium and iron for aluminium in the octahedral sheets.

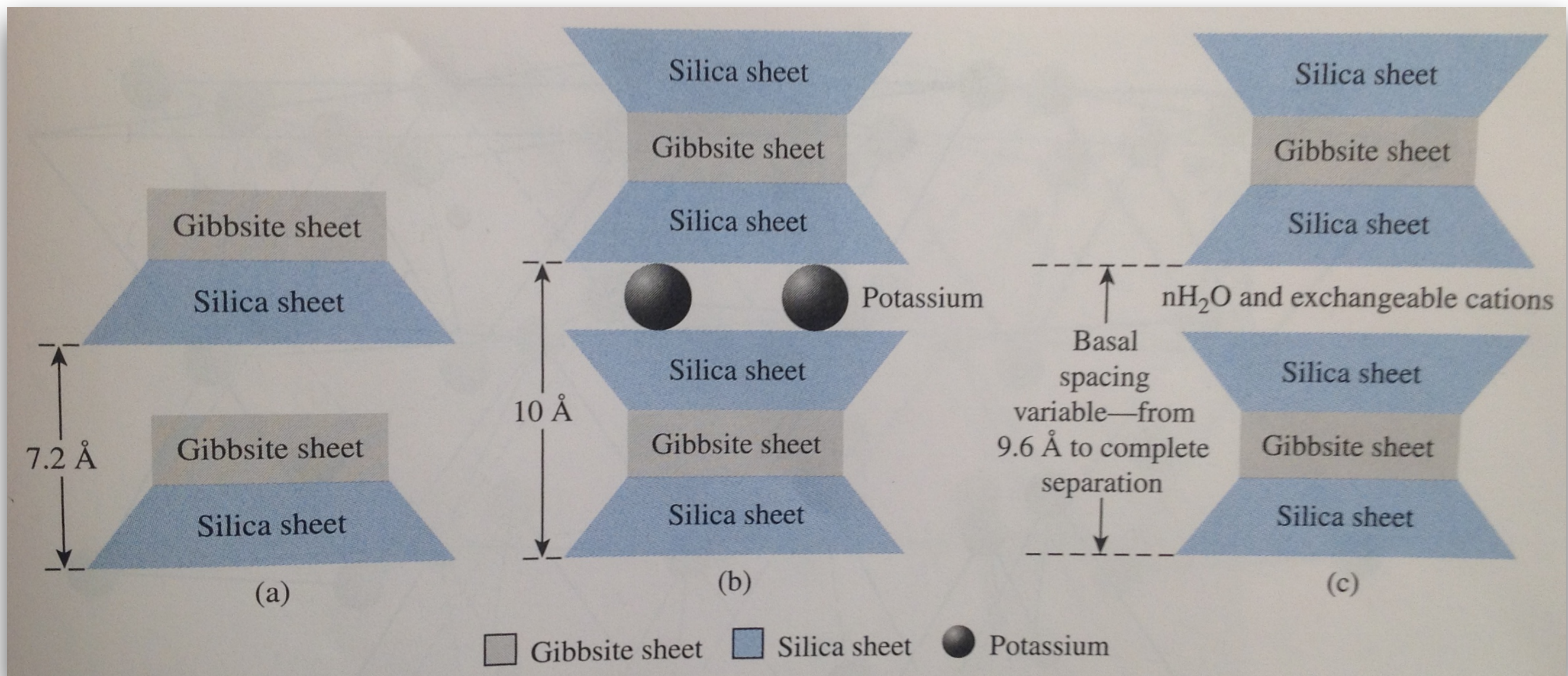
Unlike Illite, potassium is not present so bond strength is low and a large amount of water is attracted into the space between the layers.

Particles of montmorillonite have lateral dimensions of 1000 to 5000 Å and thicknesses of 10 to 50 Å. The specific surface is about 800 m²/g.



Clay Shrink-Swell Properties

The crystalline structure of clays and the physical-chemical reaction of structure with environmental variables determines the degree to which clays shrink and swell when wet - ie the clay's expansiveness.



Clay Electrochemical Properties

Clay particles carry a net negative charge on their surfaces. This is the result both of isomorphous substitution and a break in continuity of the structure at its edges.

Larger negative charges are derived from larger specific surfaces. Some positively charged sites are also at the edges of the particles.

In dry clay, the negative charge is balanced by exchangeable cations such as calcium, magnesium, sodium and potassium surrounding the particles. When water is added to clay these cations and a few anions float around the clay particles.

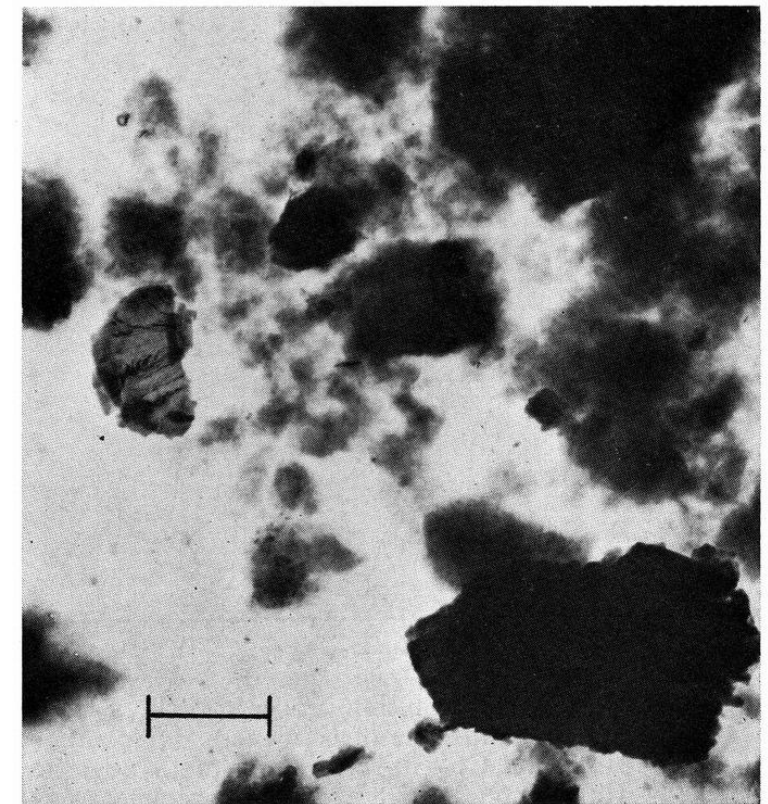
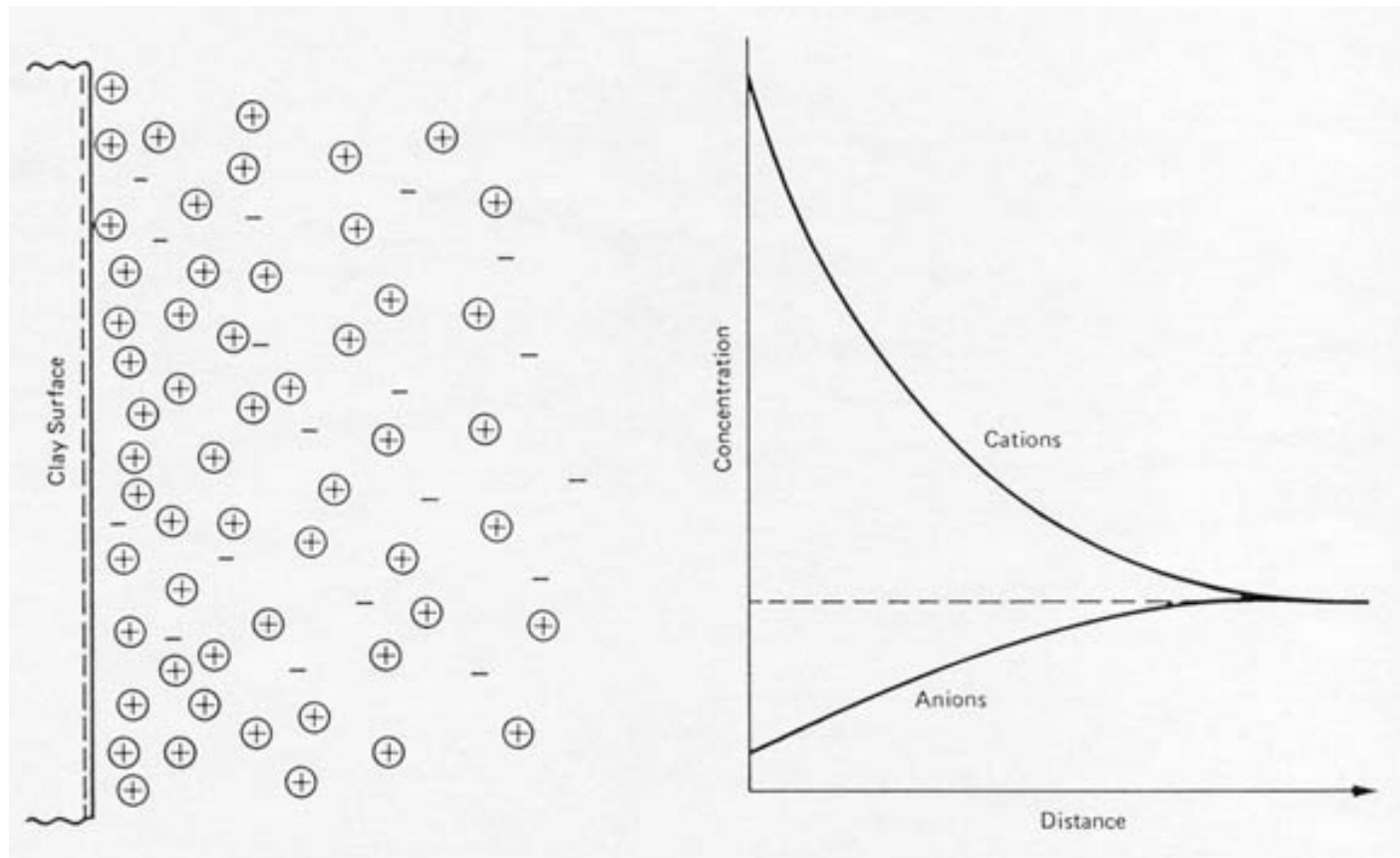
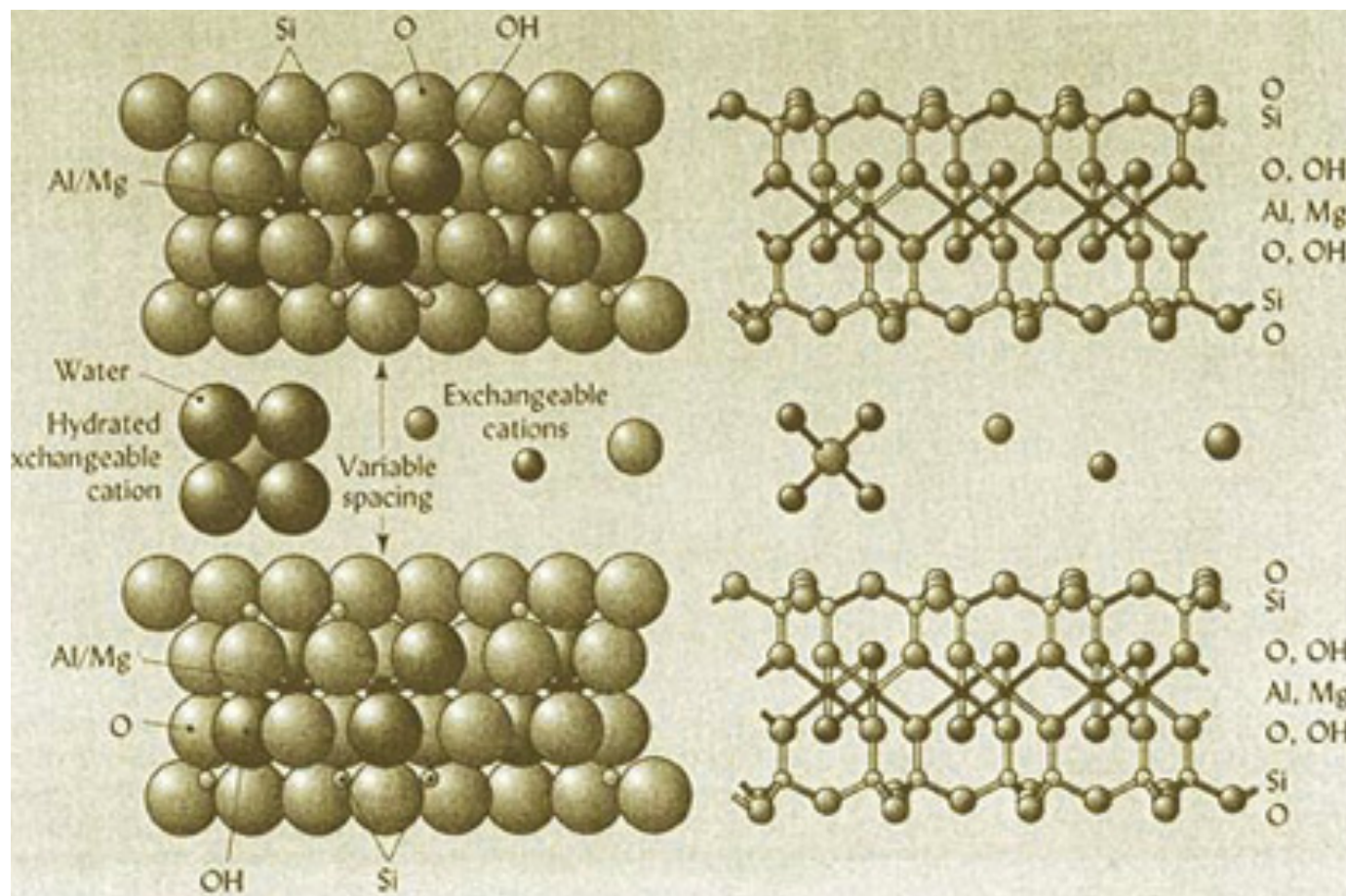


FIG. 7.—Electron micrograph of montmorillonite from clay interbedded with sandstones (16) showing diffuse, fluffy outlines. Bar equals one micron.

Clay Electrochemical Properties

The configuration of dissolved charges around a clay crystal is called a diffuse double layer, double because the net negative surface charge generates a shallow layer of positive charges which in turn attracts a secondary, more diffuse layer of negative charges out into the solution.

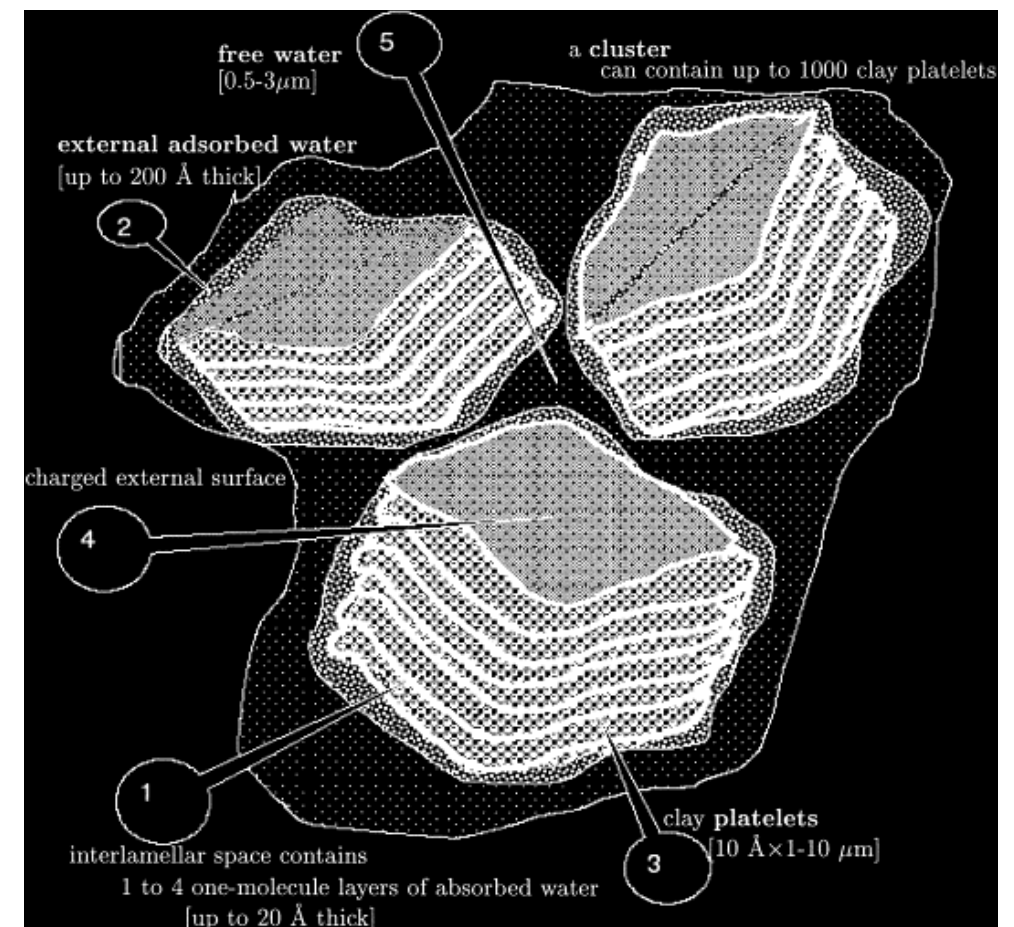
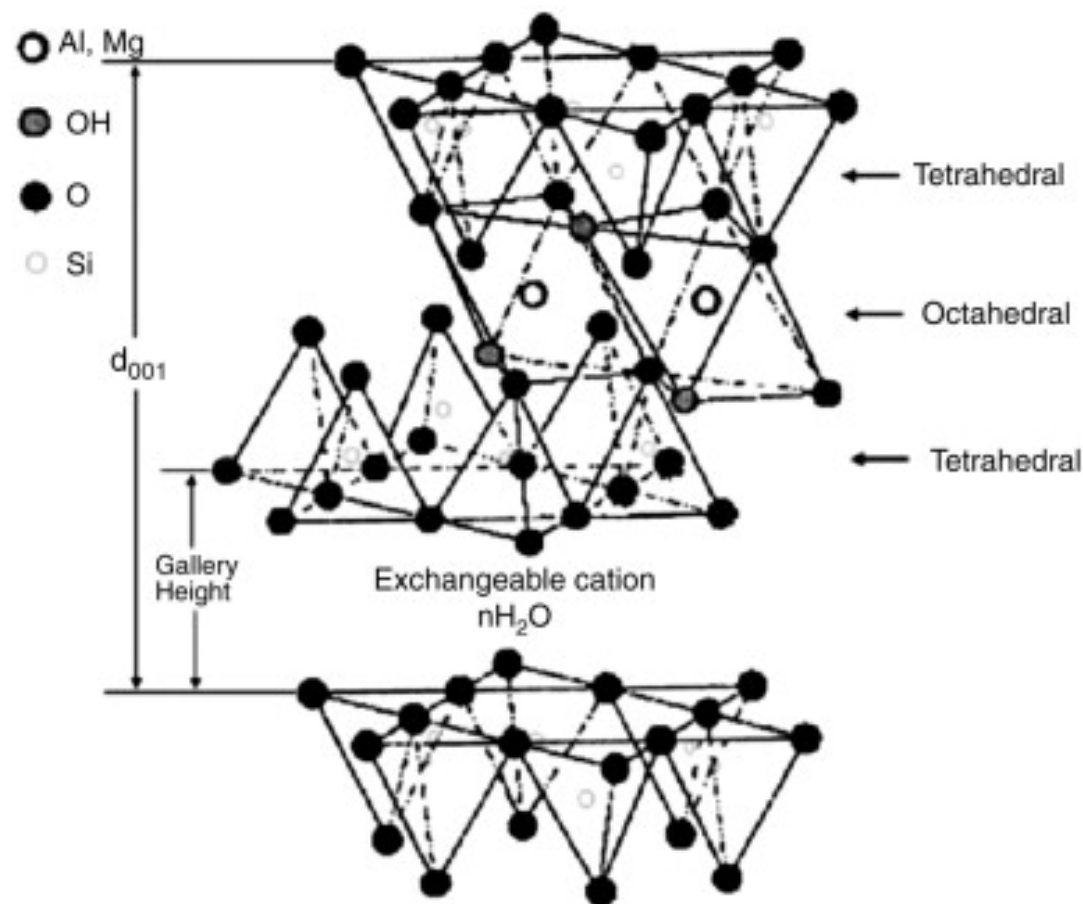
Dipolar water molecules are attracted both by the negatively charged surface of the clay particles and by the cations in the double layer. A third mechanism by which water is attracted to clay particles is hydrogen bonding.



Clay Electrochemical Properties

The force of attraction between water and clay decreases with distance from the surface of the particles. All the water held to clay particles by these forces of attraction is known as double-layer water.

The innermost layer of double layer water, which is held very strongly by clay, is known as adsorbed water. This water is more viscous than free water.



Soil Engineering and Clays

It needs to be well recognised that the presence of clay minerals in a soil aggregate has a great influence on the engineering properties of the soil as a whole. When moisture is present, the engineering behaviour of a soil will change greatly as the percentage of clay mineral content increases.

For practical purposes when the clay content is about 50% or more the sand and silt particles float in a clay matrix and the clay minerals primarily dictate the engineering properties of the soil.



Readings

Chapter 2.1 - 2.3 Das

Internet research keywords: soil formation, soil particle sizes, clay mineralogy.

