# Chemical properties of soils

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# Why do we have to know the chemical properties of soils?

- **History of soil itself.**
- **Holding and supply of nutrients.**
- **Acidification, alkalization, salinization of soils.**
- **Soil pollution (organic, heavy metal pollutions)**
- **Soil improving methods.**

Understanding the soil chemical properties is necessary for the above matter.

# Soil mineral components

## Their change with soil formation

# Igneous rocks

## Plutonic rocks

Granites

Diorite

Gabbro

## Volcanic rocks

Rhyolite

Dacite

Andesite

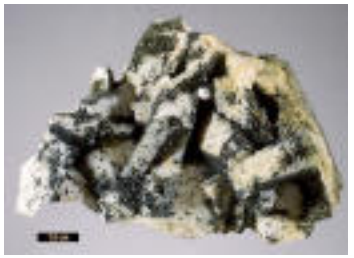
Basalt

# Rock forming minerals

Quarts

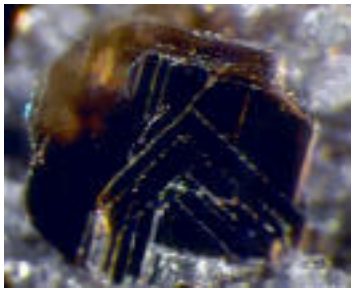
Orthoclase

Microcline



Plagioclase

White mica

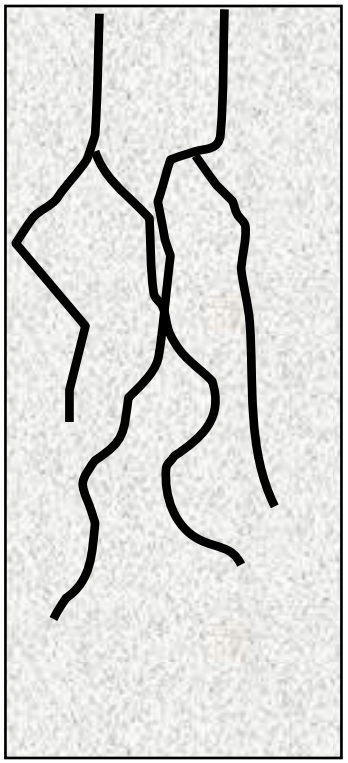


Biotite


Amphibole

Pyroxene

Olivine



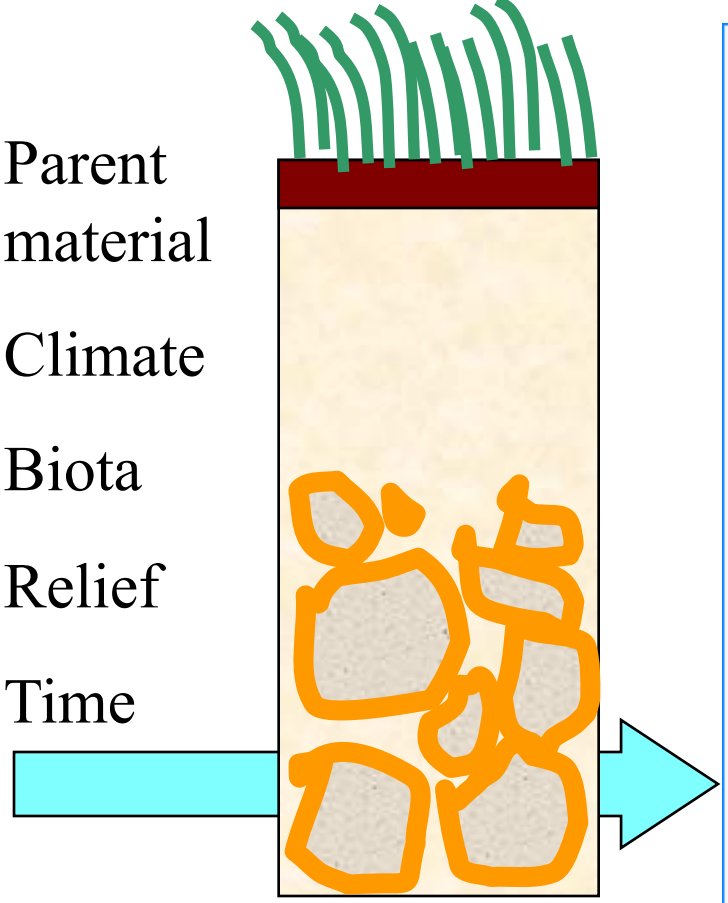
Parent material

Climate

Biota

Relief

Time



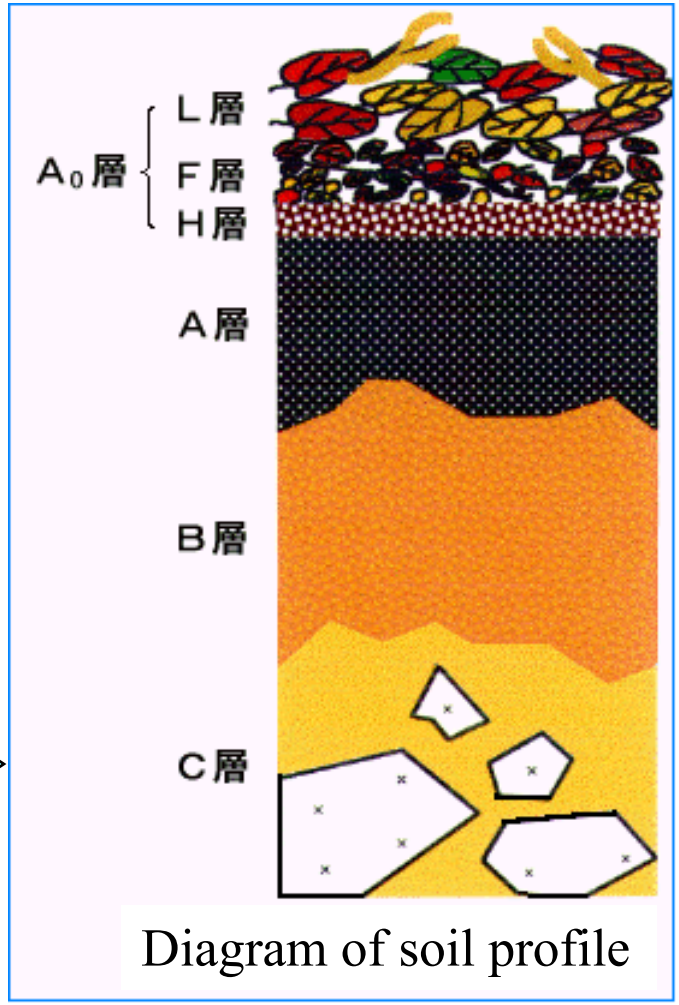



Diagram of soil profile

**Weathering of rocks** Tens of thousands years

**Soil formation**

Several thousands years

**Formation of soil layers**

**Formation of clay minera**

**Accumulation of soil orga matter**

**Process of soil formation**

# Formation of clay minerals

**Formed through the reaction of rock and water near the surface of earth crust.**

- **Diagenesis (deep underground, at high temperature and high pressure)**
- **Hydrothermal activity**

  **(Reaction with water at high temperature)**
- **Weathering (at normal temperature and pressure)**

# Surface area of soil particles and clay

| | Maximum radius | Surface area (when packed in 1 $m^3$) |
|---|---|---|
| Gravel | 10 mm | 157 $m^2$ |
| Coarse sand | 1 mm | 1570 $m^2$ |
| Fine sand | 0.1 mm | 1.57 ha |
| Silt | 0.01 mm | 15.7 ha |
| Clay | 0.001 mm | 1.57 $km^2$ |
| Kaolinite | 0.05 – 0.5 μm | 75 $km^2$ |
| Montmorillonite | 0.1 – 0.25 μm | 1051 $km^2$ |
| Allophane | < 0.0025 μm | 1433 $km^2$ |

# Specific surface area of soil particles and clay

| | Maximum radius | Specific surface area ($m^2/g$) | CEC ($cmol\ kg^{-1}$) |
|---|---|---|---|
| Gravel | 10 mm | $1.15 \times 10^{-4}$ | |
| Coarse sand | 1 mm | $11.5 \times 10^{-4}$ | |
| Fine sand | 0.1 mm | $115 \times 10^{-4}$ | |
| Silt | 0.01 mm | 0.115 | |
| Clay | 0.001 mm | 1.15 | |
| Kaolinite | 0.05 – 0.5 µm | 55 | 2 - 10 |
| Montmorillonite | 0.1 – 0.25 µm | 770 | 60 - 100 |
| Allophane | < 0.0025 µm | 1050 | 30 - 135 |

# Colloid

**Particles with diameter of $10^{-7}$ – $10^{-9}$ m dispersed in air, liquid and solid, and their dispersed state.**
Molecular colloid is composed of macro molecules. Particle colloid is composed of solid or liquid fine particles. Micelle colloid is composed of many associated molecules.

**0.1~0.001 μm, 100~ 1 nm , 1000~ 10 Å**

# Soil colloids

- **Clay minerals**
- **Humic substances**

**Both are indigenous substances on the surface of earth.**

**Adsorb cations, anions and organic matter.**

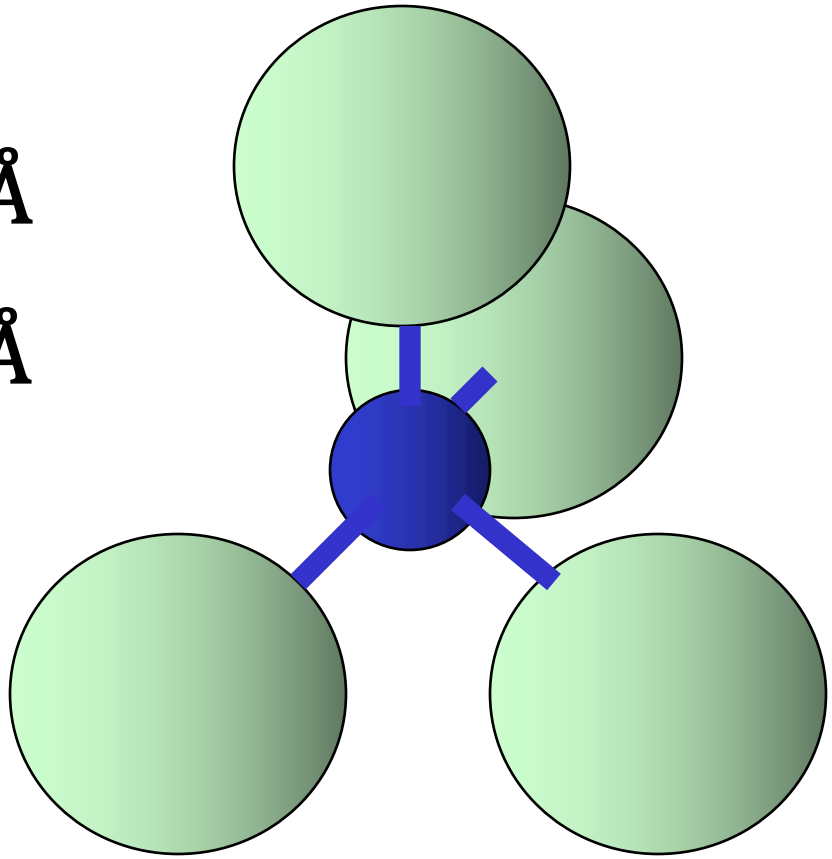
**Indispensable for the soil environment suitable for life activity.**

**Si-O 1.62Å**

Ion radius

$Si^{4+}$ 0.40Å

$O^{2-}$ 1.24Å



**Si tetrahedron**

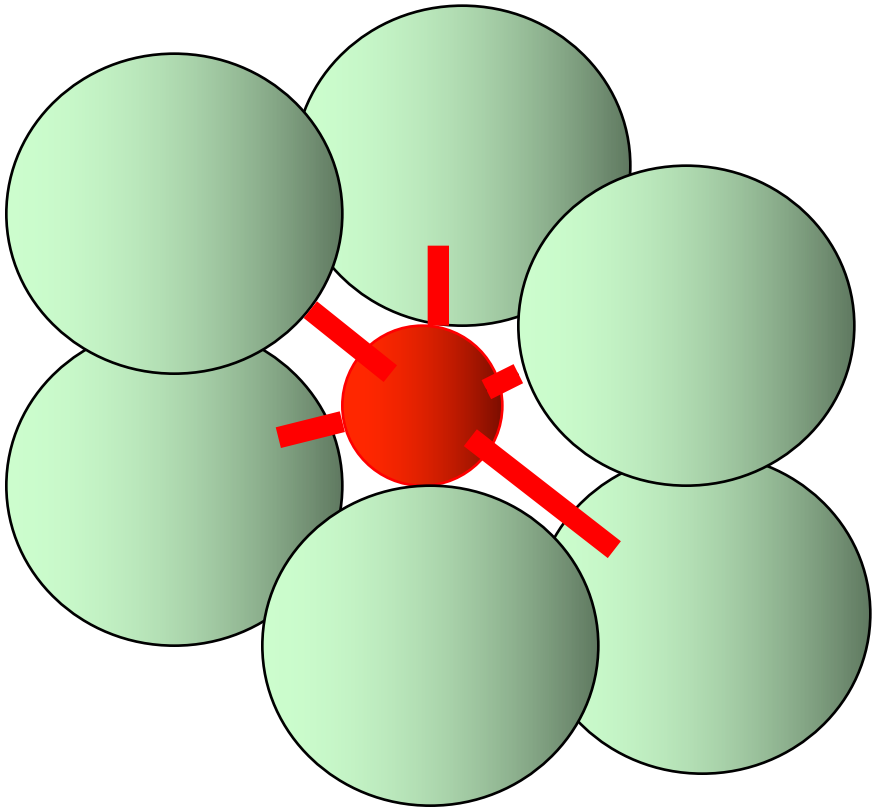
**$SiO_2$: 50 – 60 % in rocks**

# Al-O 1.75 Å

Ion radius

$Al^{3+}$ 0.51Å

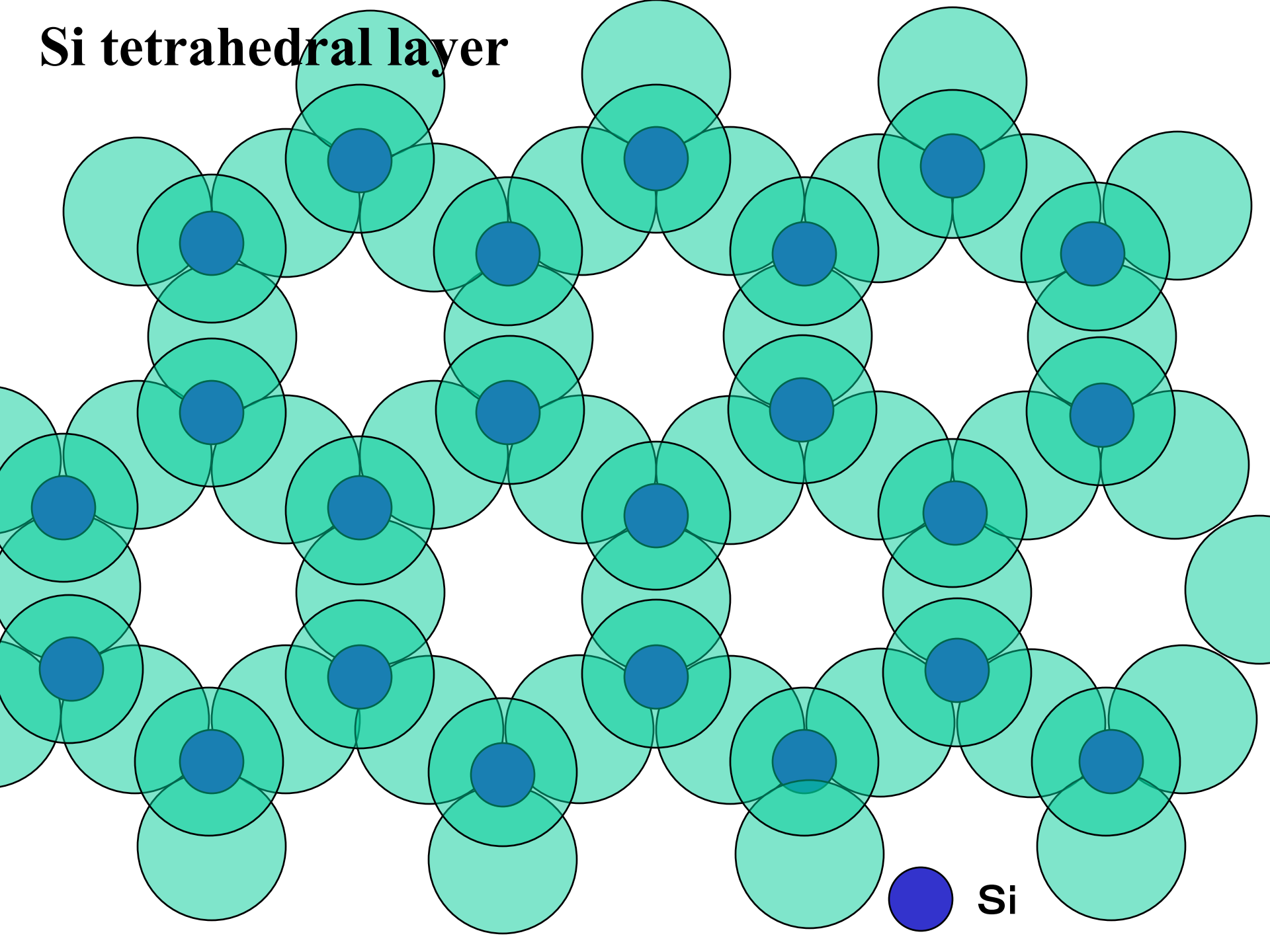
$O^{2-}$ 1.26Å



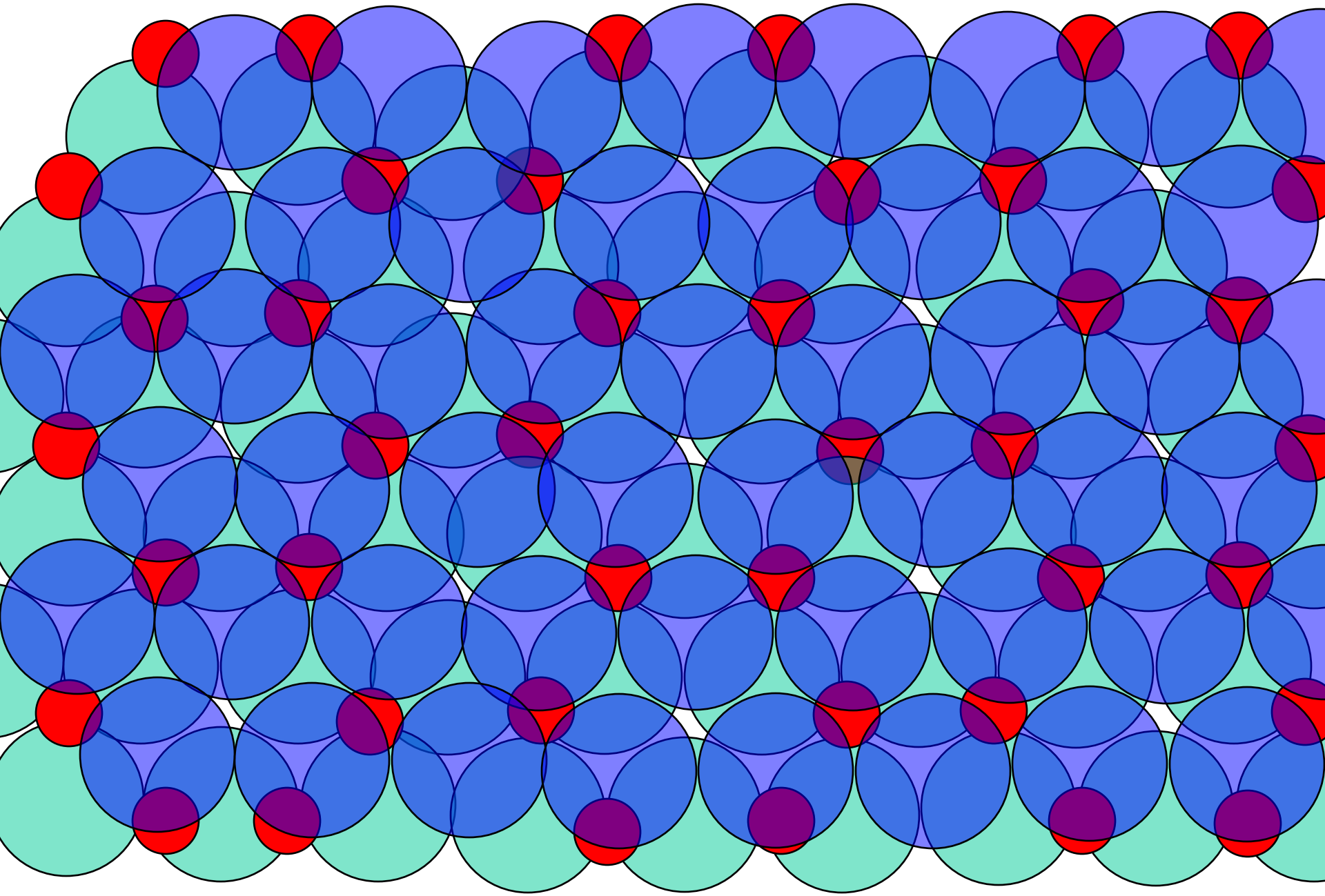
**Al octahedron**

**$Al_2O_3$: 15 – 20 % in rocks**

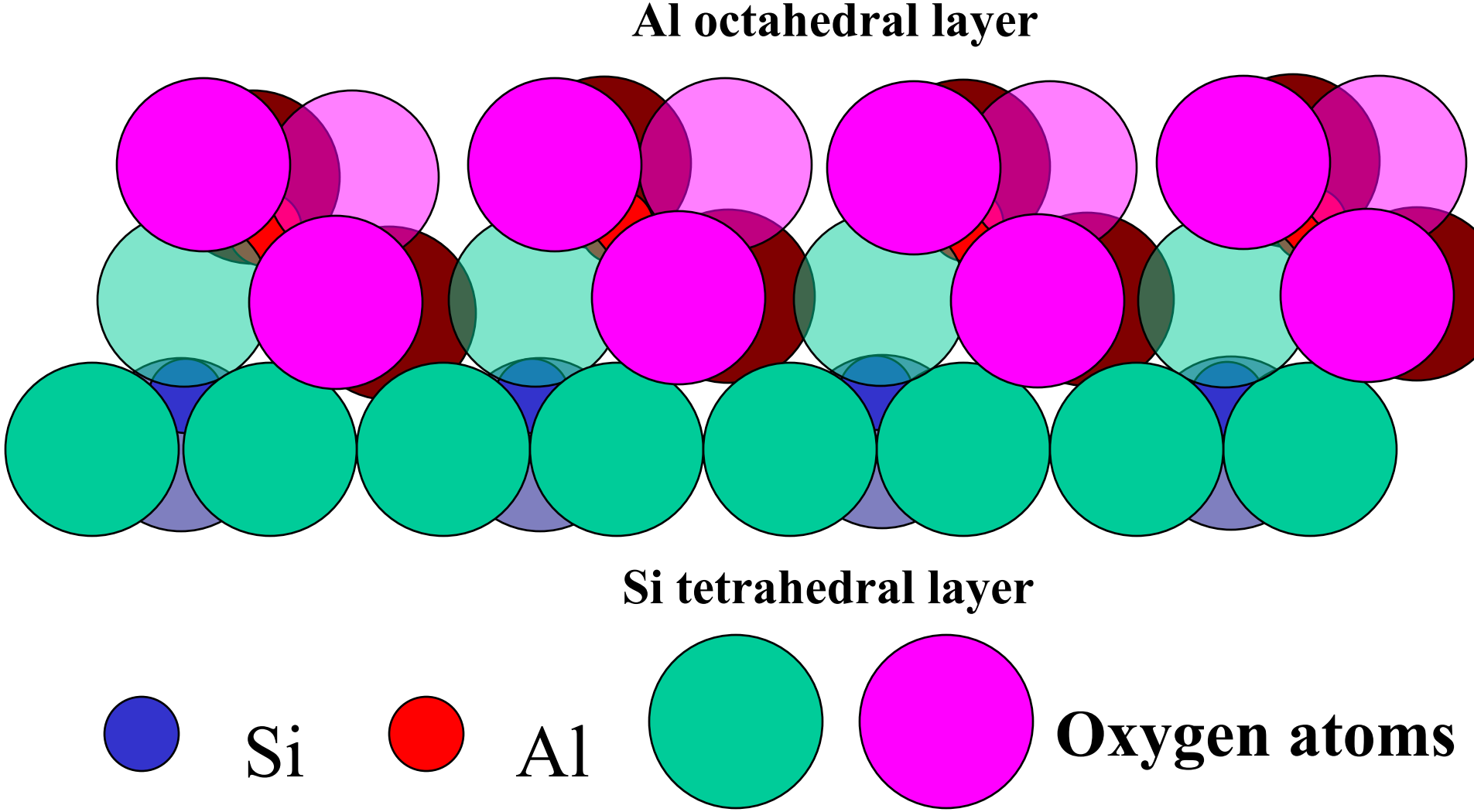
# Si tetrahedral layer



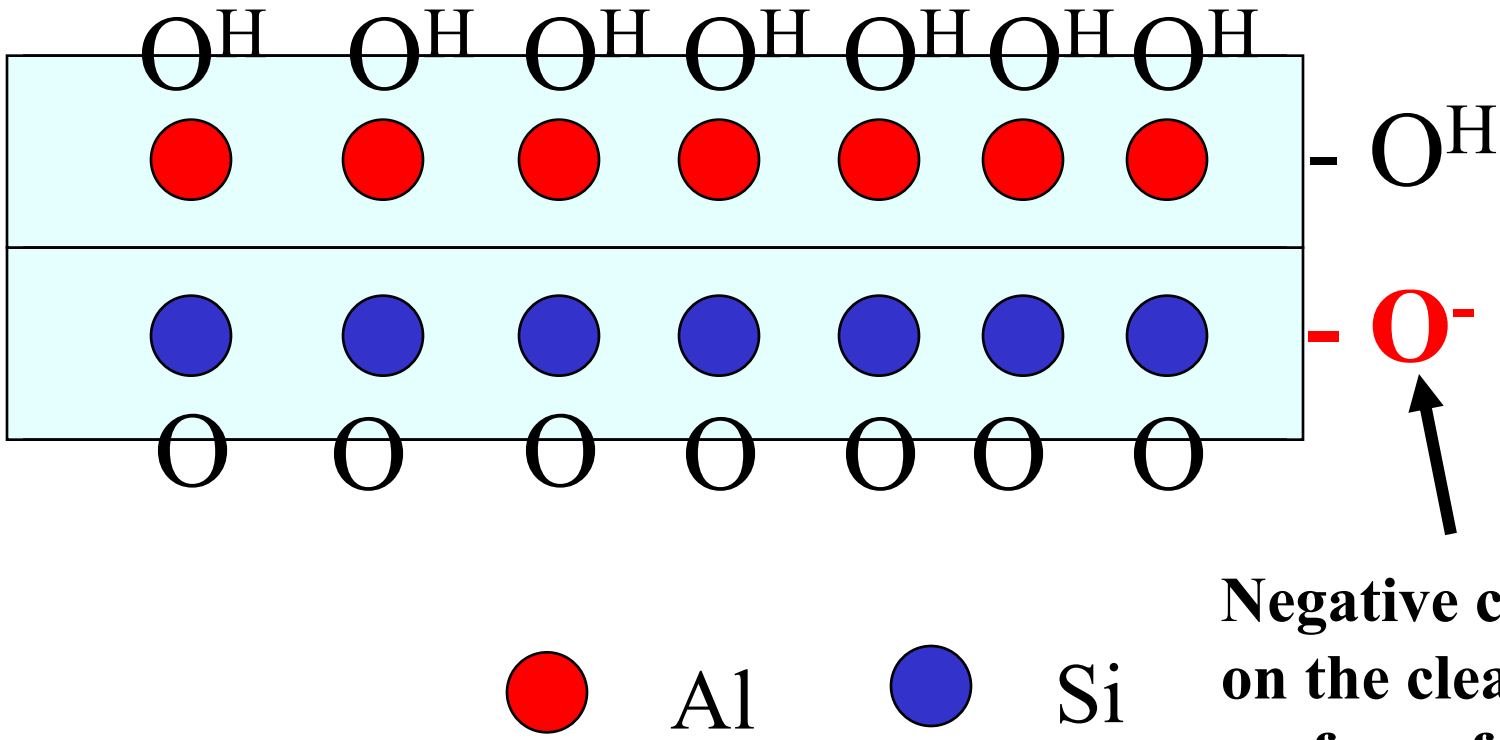
# Al octahedral layer



# Cross section of Al:Si 1 : 1 lattice



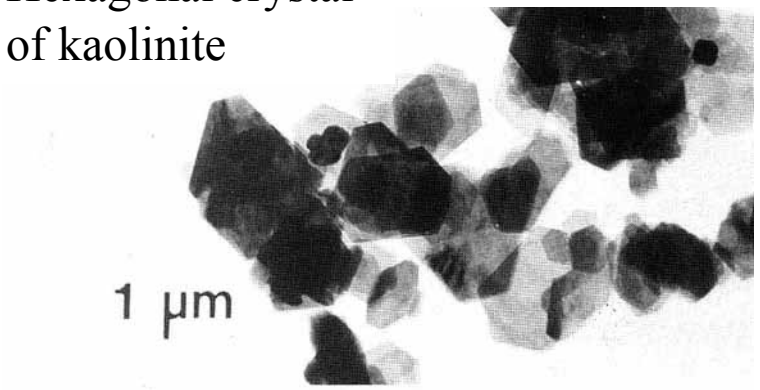
# Structure of 1:1 type clay minerals



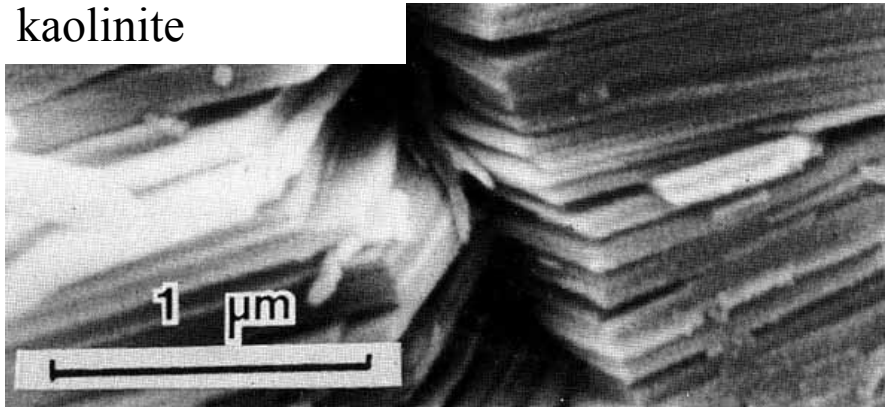
# Cause of negative charge in kaolinite

$SiO^-$ **on the cleaved surface of crystals.**

Hexagonal crystal of kaolinite

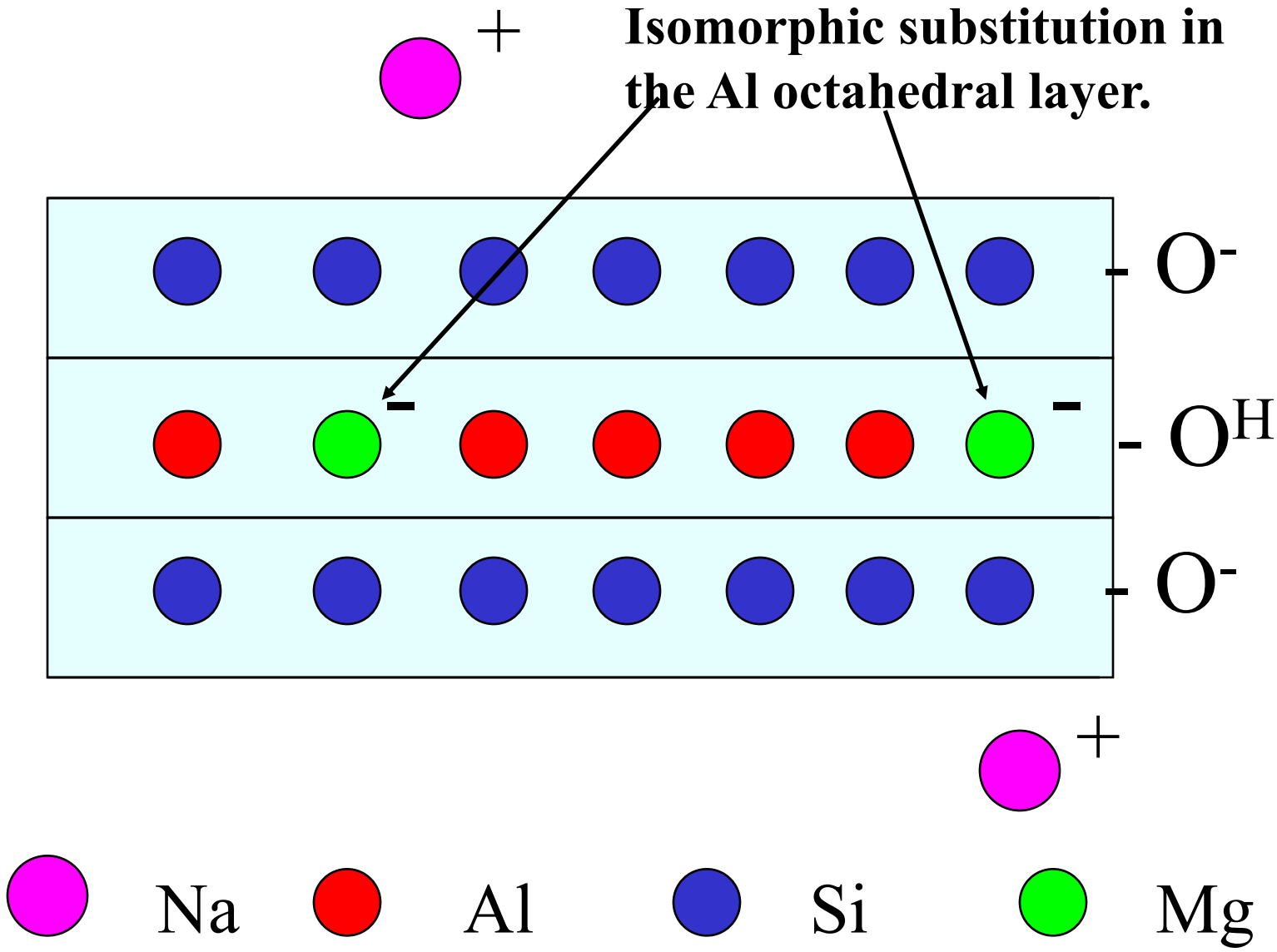



Stacked layers of kaolinite

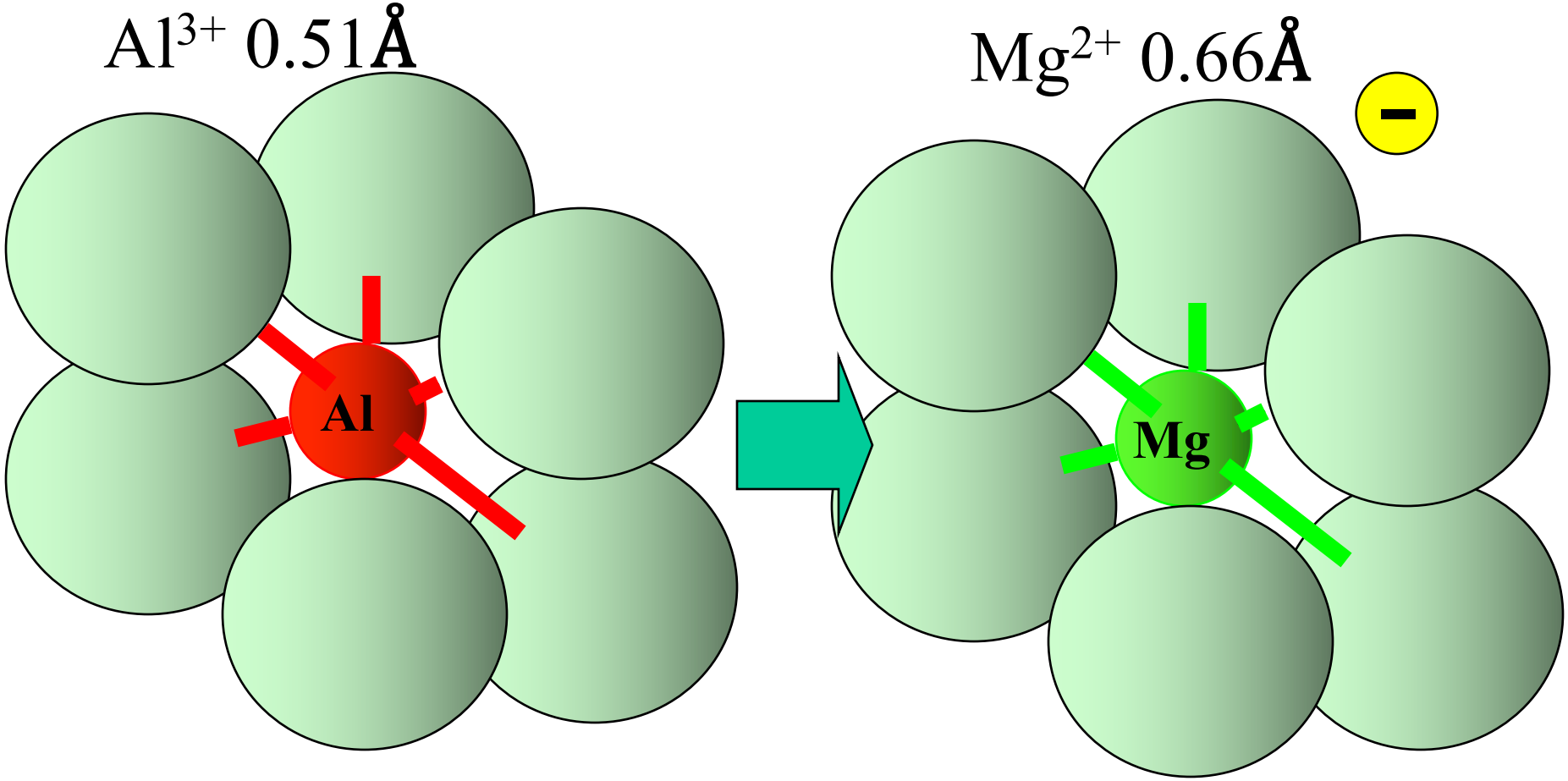



# Kaolinite

# 2:1 type clay minerals (eg. Montmorillonite)

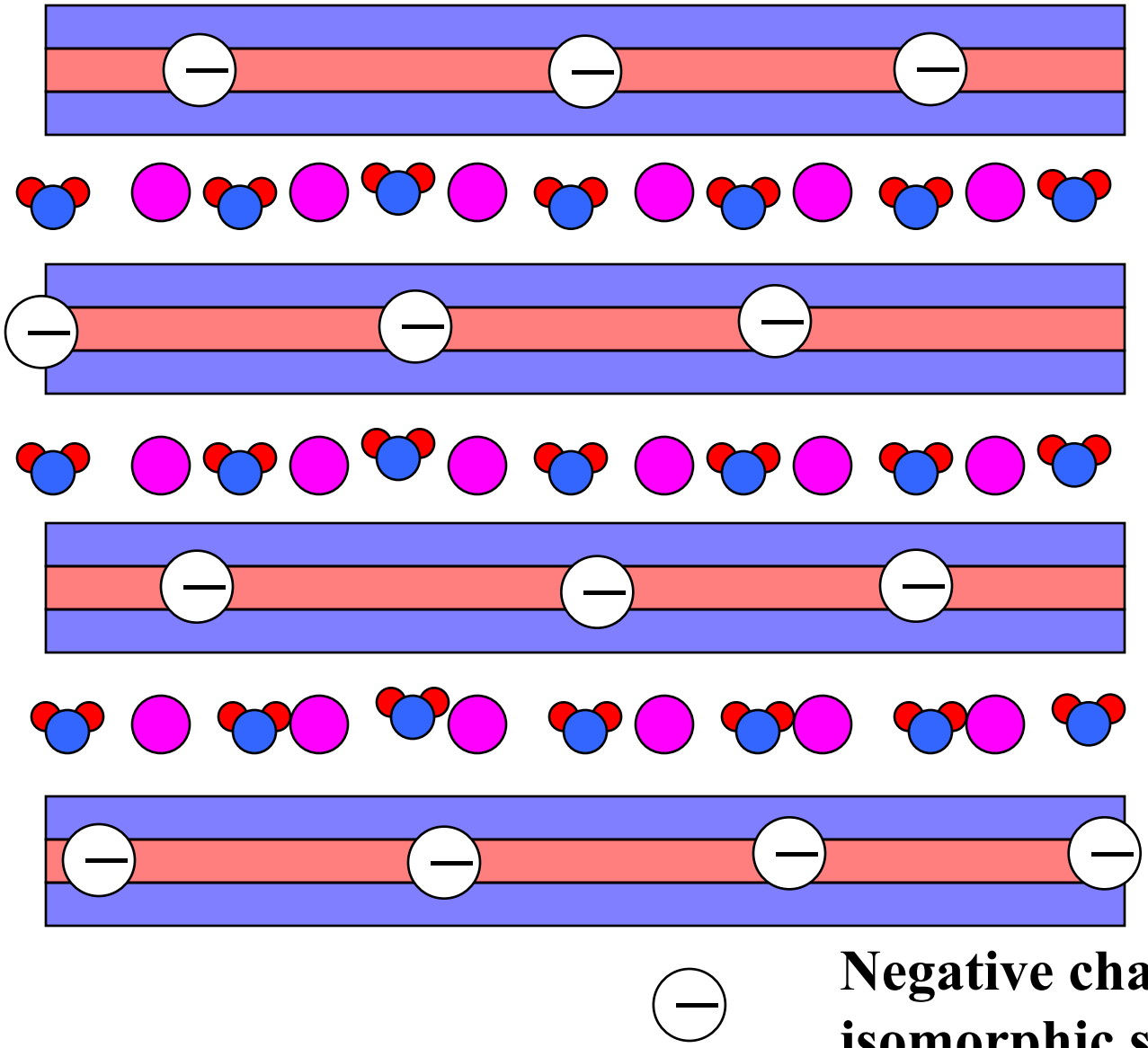


# Cause of negative charge in montmorillonite

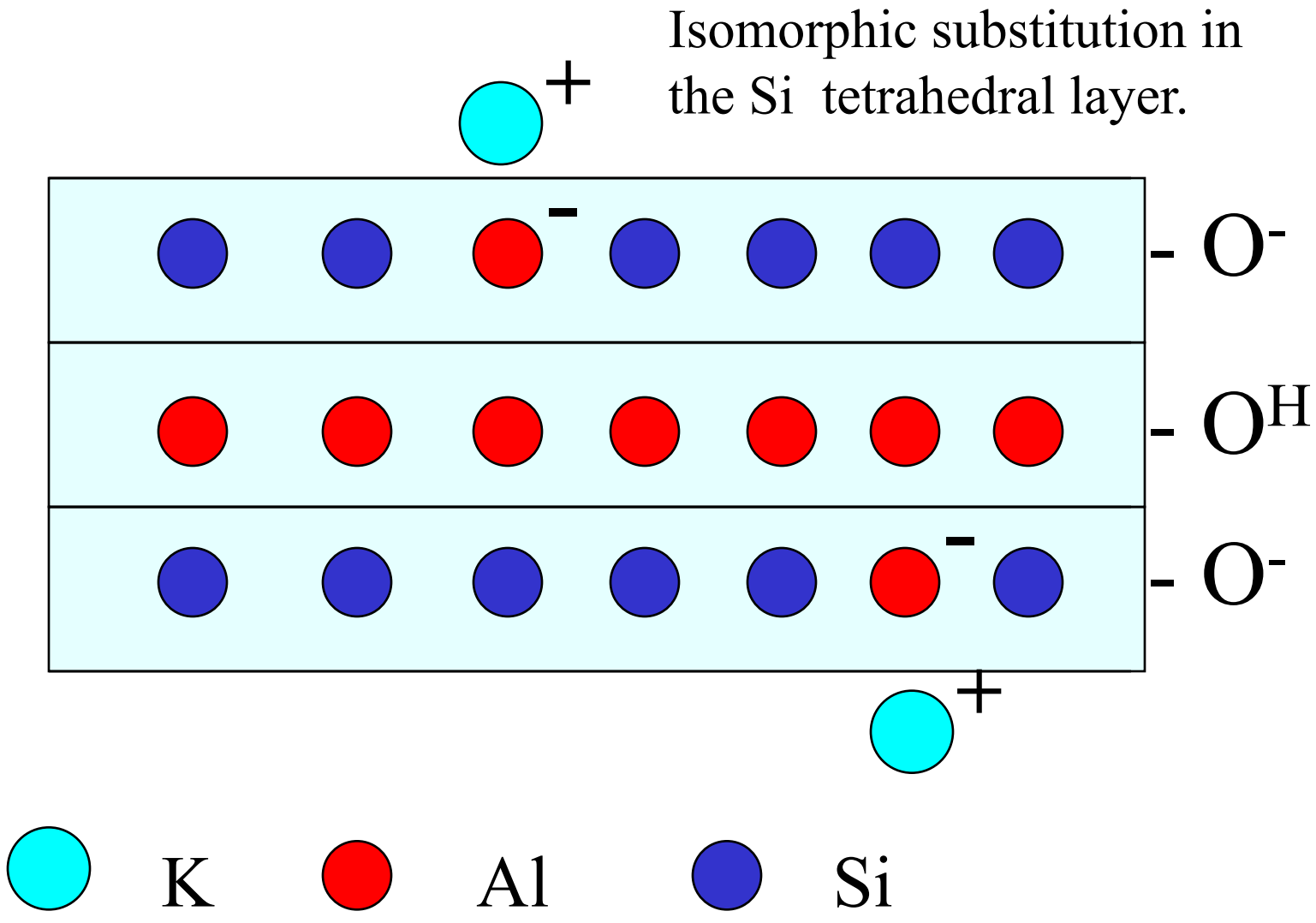



**Isomorphic substitution in the Al octahedral layer.**

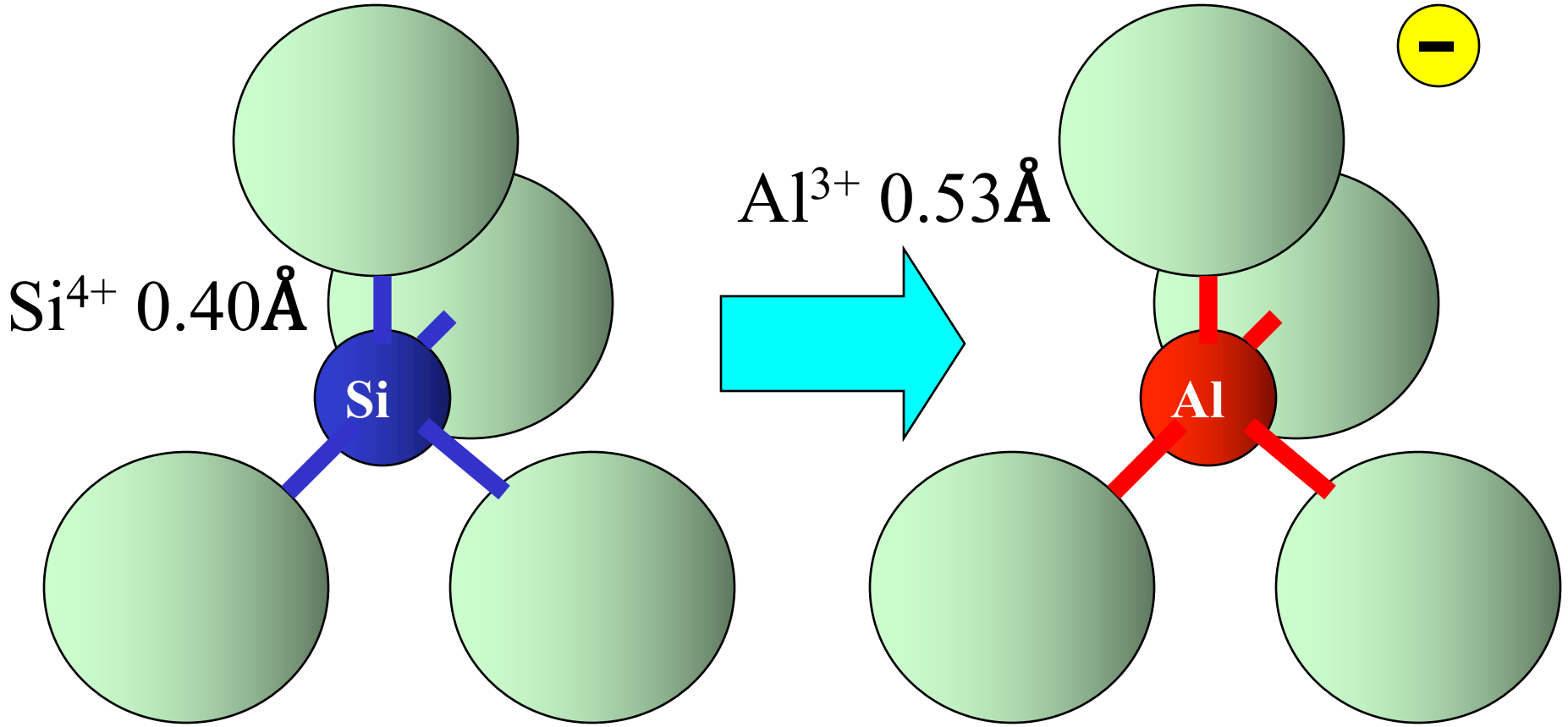
# Structure of montmorillonite



# 2:1 type clay minerals (Illite, Vermiculite)

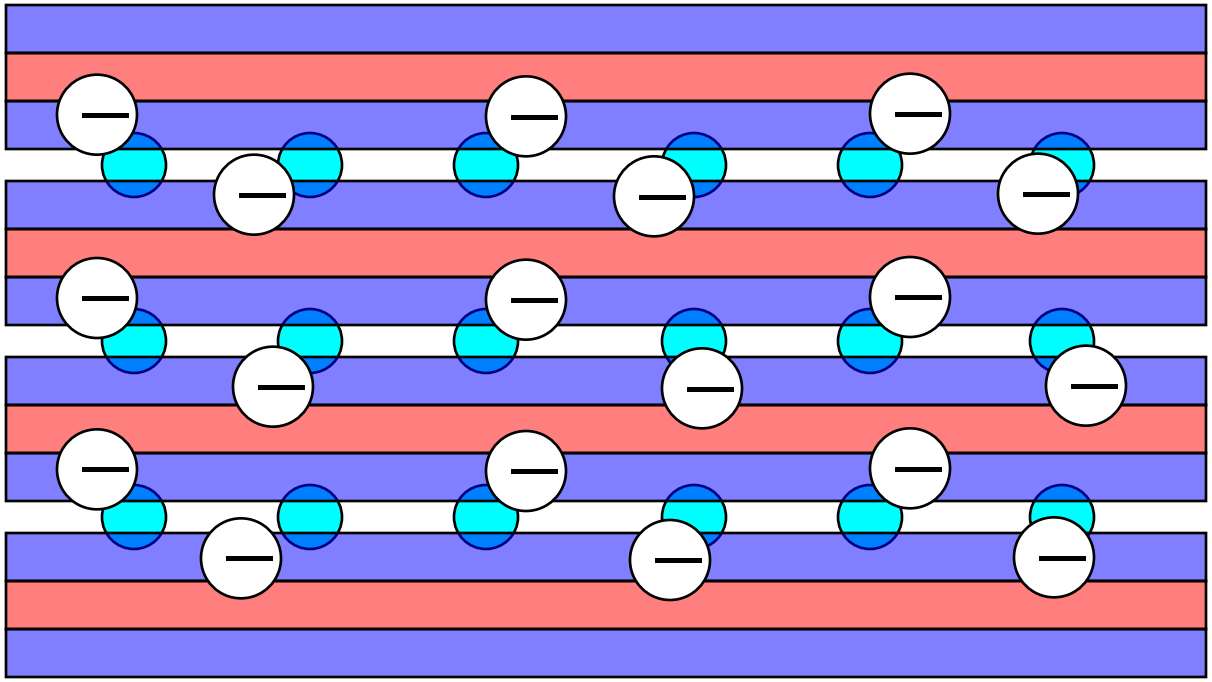


# Cause of negative charge in illite.




Isomorphic substitution in the Si tetrahedral layer.

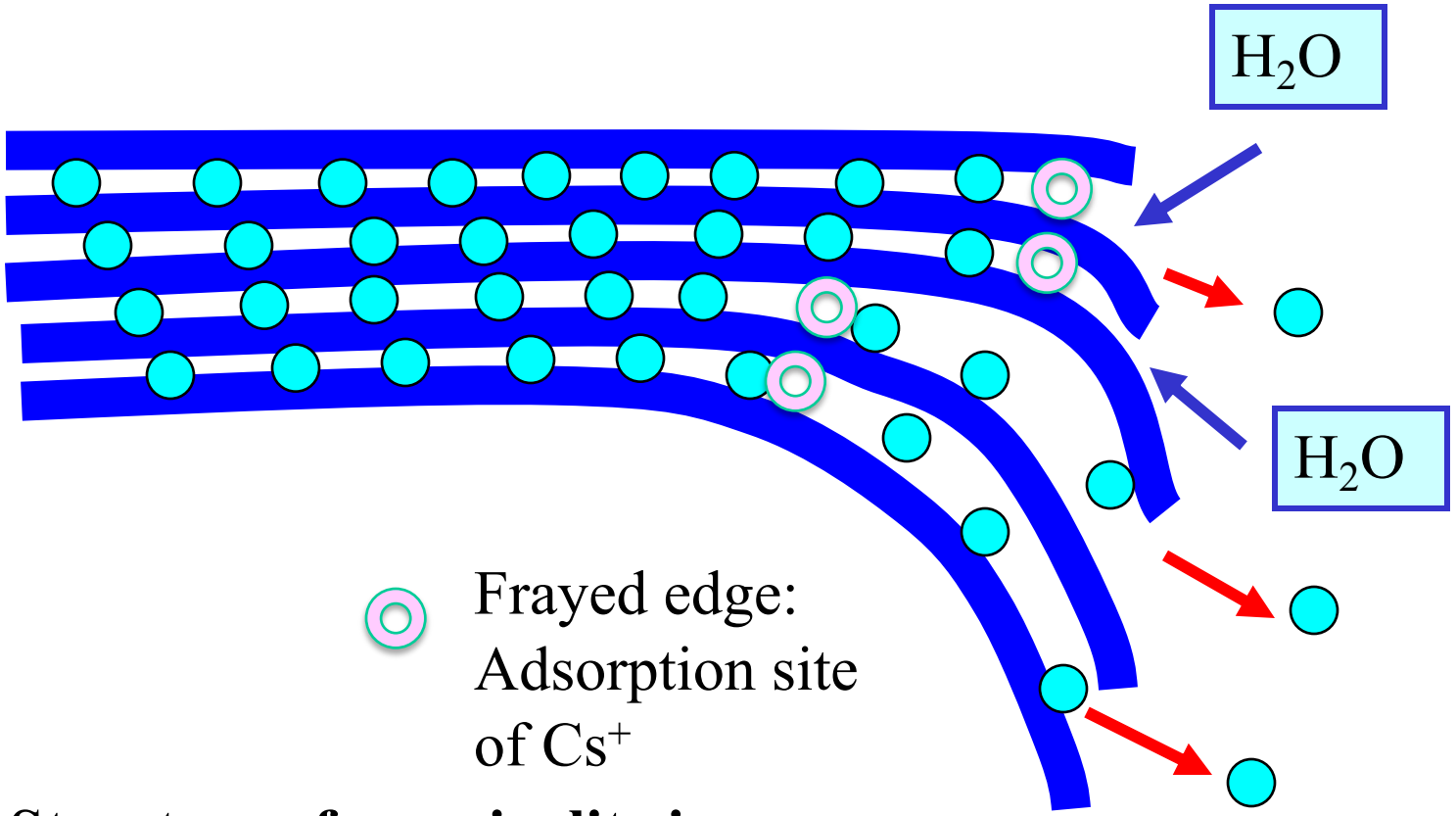
# Structure of illite (mica type clay minerals)



$K^+$

**Negative charge due to isomorphic substitution**

# Structure of vermiculite




**Structure of vermiculite is destroyed, and $K^+$ is eluted out.**

# Adsorption of $Cs^+$ at the frayed edge

- Wedge like site in the loosened part of the stacked layers of vermiculite is called “frayed edge”.
- Hydrated cations can not enter this site.
- Unhydrated Cs+ ion just fit this opening (niche).
- Dr. Nakao Atsushi http://www.kpu.ac.jp/cmsfiles/contents/0000002/2873/nakao.pdf