

**A few more details on clays,  
Soil Colloids and their  
properties**

**What expandable clays do  
to surface area**

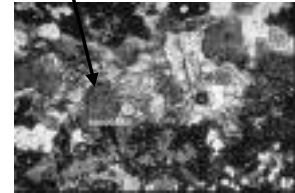
**Kaolinite**

- Size 0.5-5  $\mu\text{m}$
- External surface  
– 10-30  $\text{m}^2/\text{g}$
- Internal surface  
– –



**Smectite**

- Size 0.1-1  $\mu\text{m}$
- External surface  
– 70-120  $\text{m}^2/\text{g}$
- Internal surface  
– 550-650  $\text{m}^2/\text{g}$

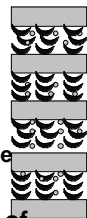


Both clays consist of 200 repeating units

Size of units is similar

- Size of unit is 2 x 2 x 4
- You add water
  - Spreads apart layers of smectite
  - Kaolinite does not expand
- What is the total surface area of kaolinite vs smectite?
- 2x(2x4) vs 2x(2x4)x200

**Smectite**



**Kaolinite**



**Phyllosilicates**

- Si in tetrahedra =  $\text{Si}^{4+}$
- $\text{Al}^{3+}$  in octahedra = dioctahedra
- $\text{Mg}^{2+}$  in octahedra = trioctahedra

**By definition phyllosilicates consist of tetrahedral and octahedral sheets**

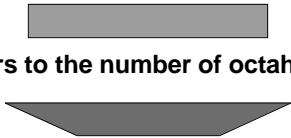
- But if you look at the formulas for many minerals you can see that things other than Si, Al, and Mg are in many mineral/clay structures

**Common soil phyllosilicates**

- Mica - Illite 2:1
- Chlorite 2:1:1
- Vermiculite 2:1
- Smectite 2:1
- Kaolinite 1:1

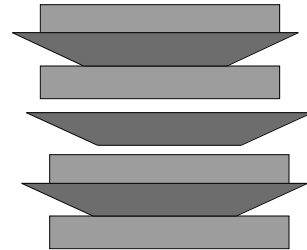
**2:1 - basic unit**

- **2** refers to the number of tetrahedra
- **1** refers to the number of octahedra
- These are cemented together with shared oxygens



**Common soil phyllosilicates**

- Chlorite 2:1:1



**Common soil phyllosilicates**

- Kaolinite 1:1



**Common soil phyllosilicates**

- Mica - Illite 2:1
- Vermiculite 2:1
- Smectite 2:1



## Changes in Chemical composition

- Although tetrahedra contain primarily Si, and octahedra contain primarily Al and Mg
- Other ions can substitute into the basic mineral structure
- This is called isomorphous substitution

## Isomorphous substitution

- Cations with similar size but generally smaller charge substitute for Al, Mg, and Si
- The configuration of O and OH stays the same
- Internal unbalanced charges
- Some examples -

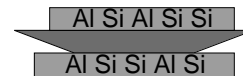
## Mica 2:1

- Al has substituted for 20% of Si in tetrahedral sheet where
- This means that it has a high charge
- K<sup>+</sup> that is in between layers is strongly held by the charge
- Non expanding



## Mica 2:1

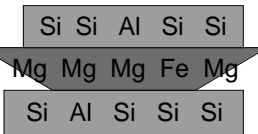
- Figure out what the charge will be
  - Al<sup>3+</sup> Si<sup>4+</sup>
- It is supposed to be all Si<sup>4+</sup>



- This unit has a 4<sup>-</sup> net charge

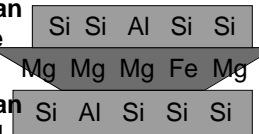
## Another example - Vermiculite

- General formula
- Octahedral sheet:
  - Mg<sub>2.7</sub> Fe<sup>3+</sup><sub>0.4</sub>
- Tetrahedral sheet:
  - Si<sub>3</sub>Al



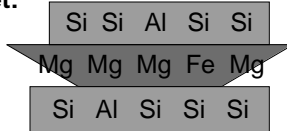
## Here substitutions are in all sheets

- Elements other than Si are found in the tetrahedra sheets
- Elements other than Al or Mg are found in the octahedra sheets



## Add up the charges for Vermiculite

- Octahedral sheet
  - Mg<sub>2.7</sub> Fe<sup>3+</sup><sub>0.4</sub>
- Mg is 2+, Fe here is 3+
  - Net positive
- Tetrahedral sheet:
  - Si<sub>3</sub>Al
- Si is 4+, Al is 3+
  - Net negative



## A vermiculite clay particle (micelle)

- Will always have a net negative charge
- Charge is a result of substitution for Si, Al, and Mg in phyllosilicate sheets
- Isomorphous substitution
- As a result clay will function like an ion in solution

## Certain clays have more than others

- 2:1 dioctohedral (Al in tetrahedra)
  - Montmorillonite 0.4 (average per unit charge)
  - Vermiculite 0.7
  - Fine mica 0.8
- 1:1
  - Kaolinite 0

## Isomorphous substitution

- Results in a permanent charge
- Primary source of a soil's ability to hold nutrients
- This ability to hold nutrients is referred to as Cation Exchange Capacity (CEC)
- Basis for active, superactive in soil taxonomy

## Isomorphic substitution -

- One of the sources of charge on soil colloids
- Isomorphic substitution occurs on phyllosilicate clays
- Other soil colloids and other clays also have charges
- We will talk about those

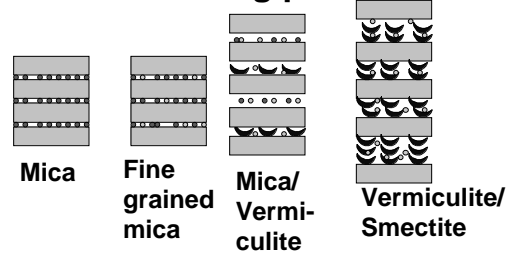
## But first

- Evolution of clay minerals
  - Alteration
  - Precipitation
- Description of other soil colloids

## Alteration

- Process by which new clays are formed by slowly altering the form of parent material

## Weathering process

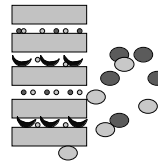


Things come apart, alter from original form

## Clays formed by alteration of mica

- Fine grained mica
- Chlorite
- Vermiculite
- Smectite - montmorillonite
- Intermediate combinations

## As weathering is taking place - ions are coming into solution



- These ions can precipitate and form clay minerals
- Precipitation/recrystallization is the other mechanism for secondary clay formation

## Examples of clays formed through precipitation

- Dissolve 2:1, lose K, Mg, Ca and Si
- Get Kaolinite
- Lose even more Si
- Get Al and Fe oxides like
  - Hematite ( $\text{Fe}_2\text{O}_3$ )
  - Goethite ( $\text{FeOOH}$ )
  - Gibbsite ( $\text{Al(OH)}_3$ )

## Other clay minerals

- Allophane (new version)
- Imogolite (older version)
  - Usually formed from volcanic ash
    - High in Si (OH)<sub>x</sub> and Al(OH)<sub>x</sub>
  - Sometimes seen in Spodosols


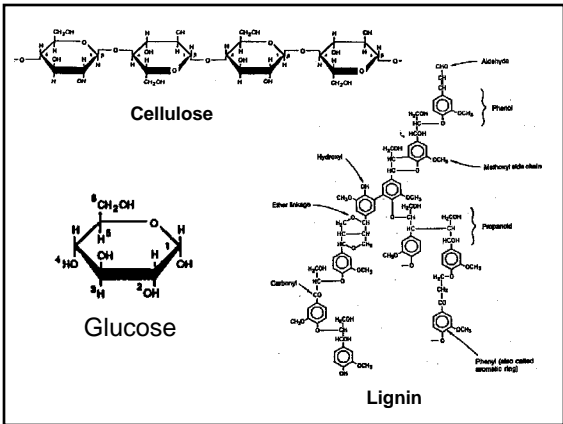


### Amorphous clays

- Allophane, Imogolite, and Fe oxides
- Short range minerals
  - Unit structure has very few repeats in crystal structure
  - Structure is not very rigid or crystalline
    - High surface area
    - Many OH groups on surface

### Organic colloids

- Humus - long chain organic compound formed by breakdown of organic matter

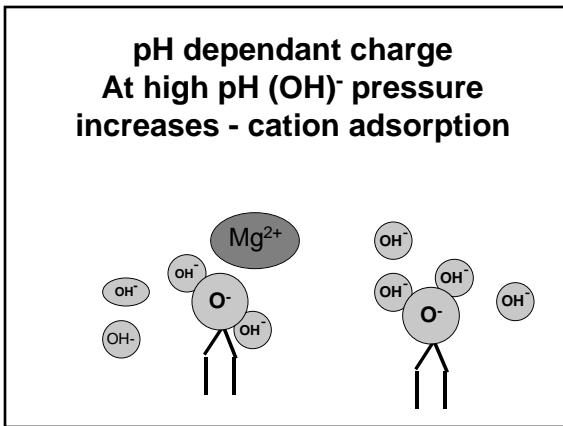
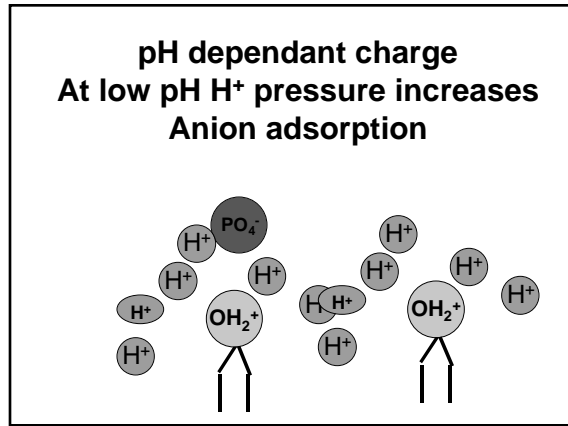
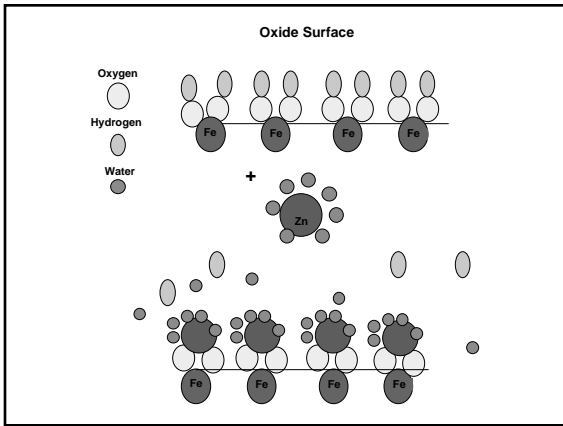
### How soils have charges

#### 2 types of charges

- Permanent charge
  - Isomorphous substitution
  - Phyllosilicate minerals
- pH dependant charge
  - Oxide minerals
  - Humus

### Charge from isomorphous substitution

- Cations (+) in soil solution will be attracted to surface of clay colloids to neutralize their charges

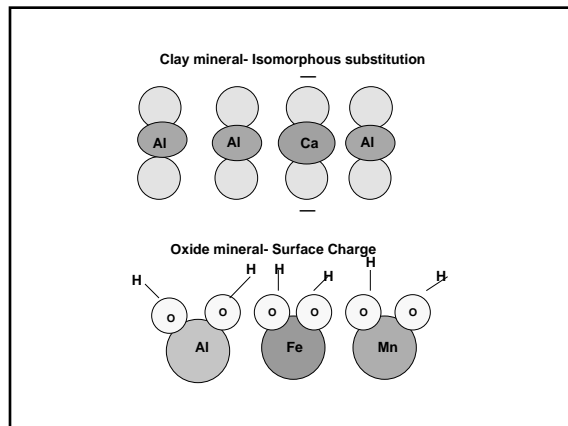


**Functional groups**

- Can attract cations at high soil pH
- Can attract anions at low soil pH
  - Not bisexual
  - amphoteric

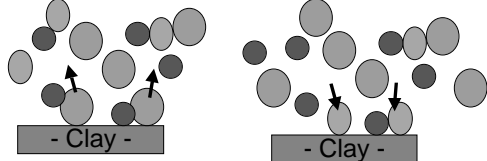
**Soil organic matter**

- Has similar type of charges as oxides
- Number of cation adsorption sites will increase as pH increases



### Cation exchange

- Soil solution is generally 0.01M in strength
- Bunch of cations floating around

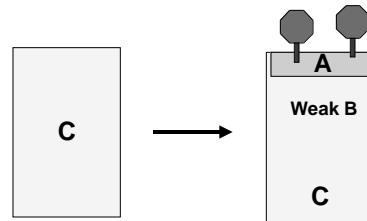


### Cation exchange capacity (CEC)

- Amount of cations soil (all fractions) can hold
- Expressed as centimoles of charge per kilogram of soil
  - Centi = 100
- Reflective of
  - nutrient holding capacity of soil
  - Buffering capacity of soil

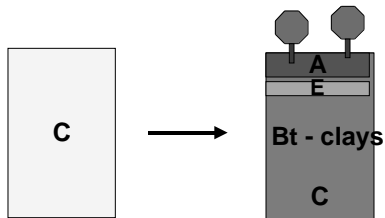
### Brady fig 8.16

### How weatherable minerals will affect soil formation



Coarse sand parent material

### Sandy parent materials with a mix of weatherable minerals



### Alfisol from sandstone and a range of weatherable minerals in CO

- High Smectite
- Near neutral pH
- Clay films, skins
- High nutrient holding capacity



**Entisol from  
sandy glacial  
till in CT**

- **Highly acidic**
- **Some red color**
- **No clay films**
- **Low nutrient  
holding capacity**

