GEOL 414/514

THE GEOCHEMISTRY OF CLAY MINERALS

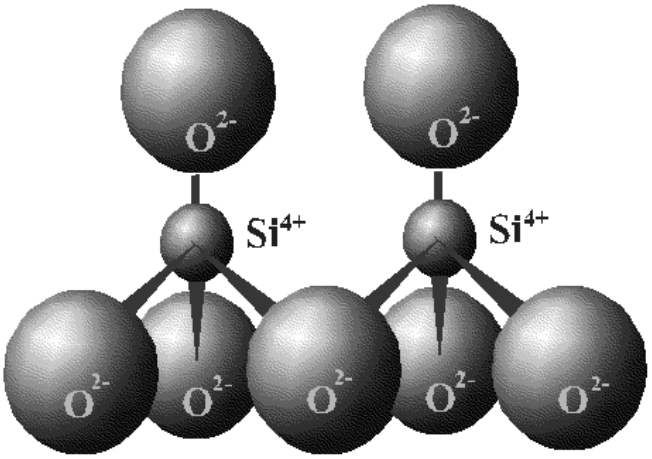
Chapter 9

LANGMUIR

SOIL CLAY MINERALS

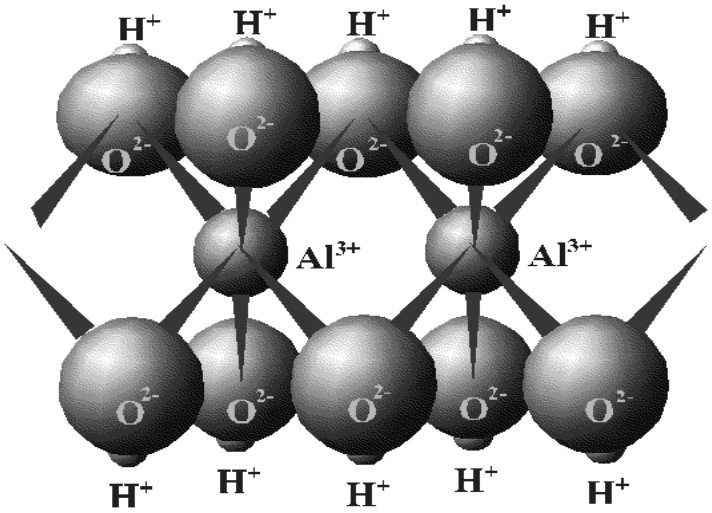
- Size = < 2μm; many are colloidal (< 1 μm) in size
- Layered silicate minerals (most important group)
- Have high charge-density to mass ratio
- Are reactive; adsorb charged substances; colloid behavior and transport
  - Basic building blocks:
    - Silica tetrahedron
    - Aluminum octahedron
- Bond sharing is key to structural properties
- Most bond sharing is <u>within</u> layers

SILICA TETRAHEDRON



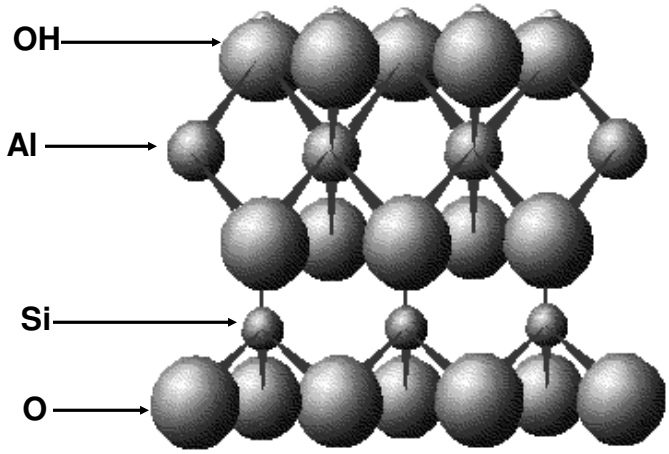
Two tetrahedral units - sharing of Si and most O

ALUMINUM OCTAHEDRON



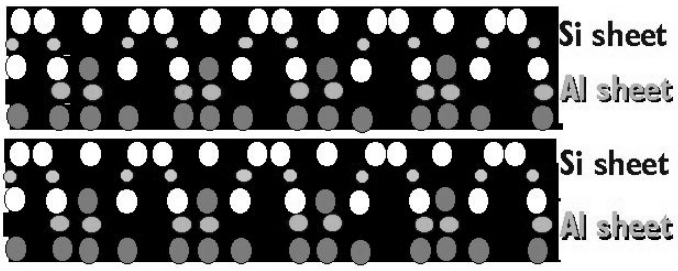
Two octahedral units - sharing of Al and most OH

TETRAHEDRON PLUS OCTAHEDRON



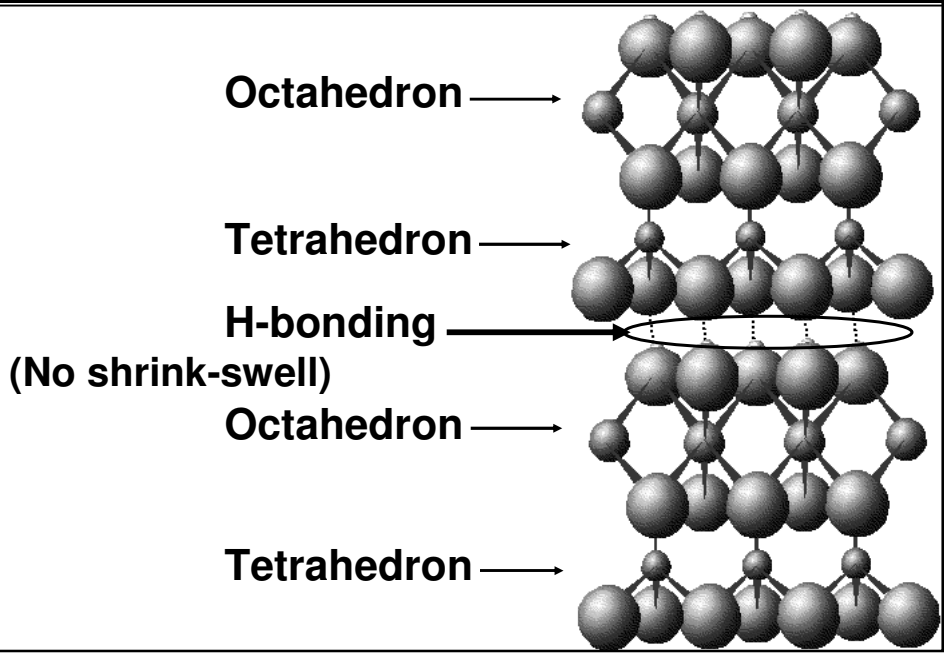
(structure of kaolinite)

KAOLINITE CLAY STRUCTURE

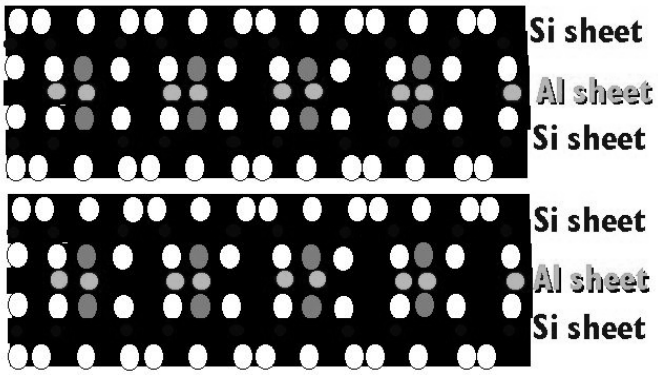


1:1 type clay - kaolinite

HYDROGEN BONDING IN KAOLINITE

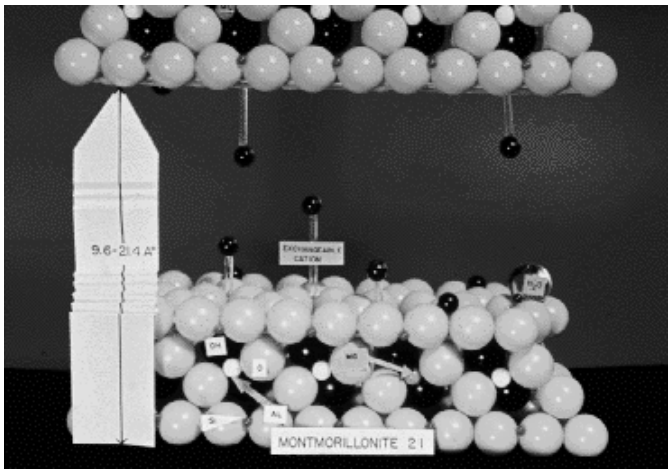


MONTMORILLONITE CLAY STRUCTURE



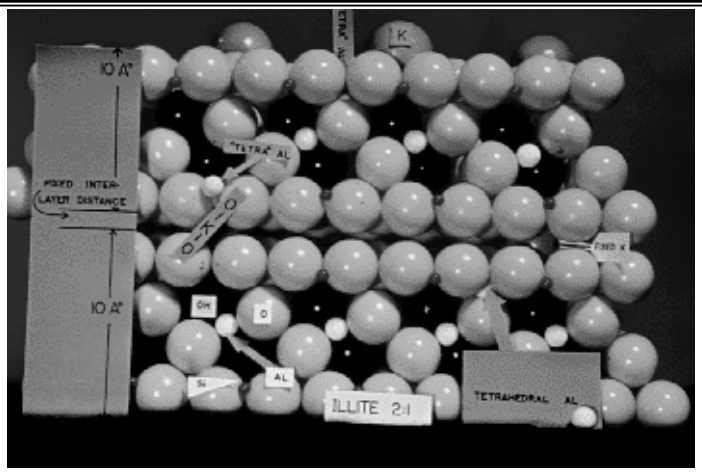
2:1 type clay - montmorillonite

MONTMORILLONITE CLAY STRUCTURE



- **Swelling capacity: interlayer distance doubles (9.6 to 21.4 Å)**
- **From dry to wet: 5 X volume increase**

ILLITE CLAY STRUCTURE

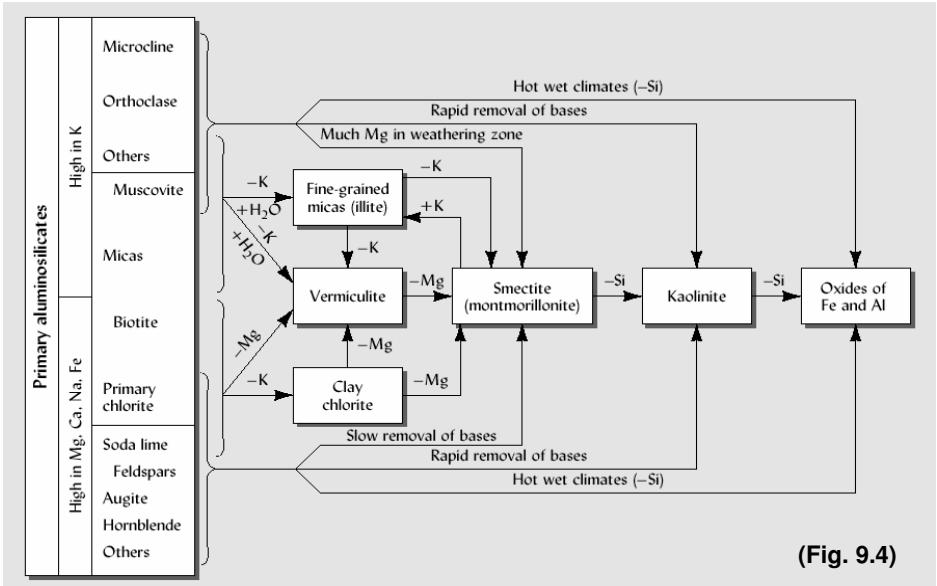


K^+ between layers held tightly;
Holds layers together

THREE-LAYER PHYLLOSILICATES

- **Cation substitution in octahedral layer**
  - **Dioctahedral: (gibbsite-type layers) two cations of M^{+3} per half-unit cell**
    - **Kaolinite; smectite group - montmorillonite, beidellite, nontronite; muscovite; illite**
  - **Trioctahedral: (brucite-type layers) three cations of M^{+2} per half-unit cell**
    - **serpentine group; vermiculite group; smectite group - saponite, hectorite; biotite**

WEATHERING PRODUCTS OF PRIMARY MINERALS & FORMATION OF CLAYS



(Fig. 9.4)

OCCURRENCE OF COMMON CLAY MINERALS

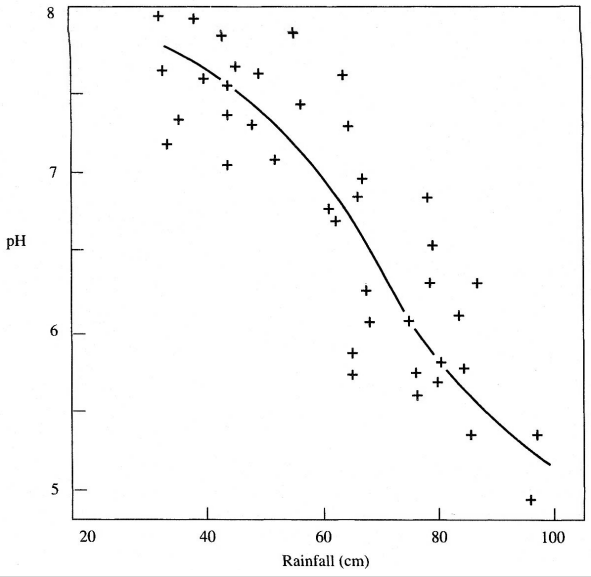
Note from previous diagram (Fig. 9.4)

- **Silicate clays are formed in soils by two processes:**
  - **Alteration:**
    - **minerals such as muscovite are altered by weathering processes**
    - **resulting colloid is a 2:1 type clay**
  - **Recrystallization:**
    - **minerals are completely broken down and new minerals are formed by recrystallization of the weathering products**
- **Mixed-layer and interstratified clays are very common due to nature of alteration processes**

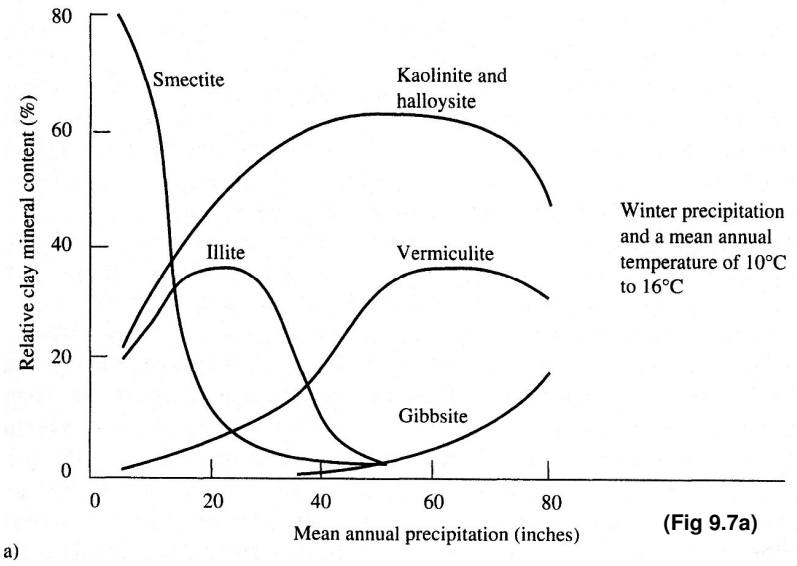
OCCURRENCE OF COMMON CLAY MINERALS

Effect of rainfall on soil pH.

Degree of weathering intensity increases with decrease in soil pH



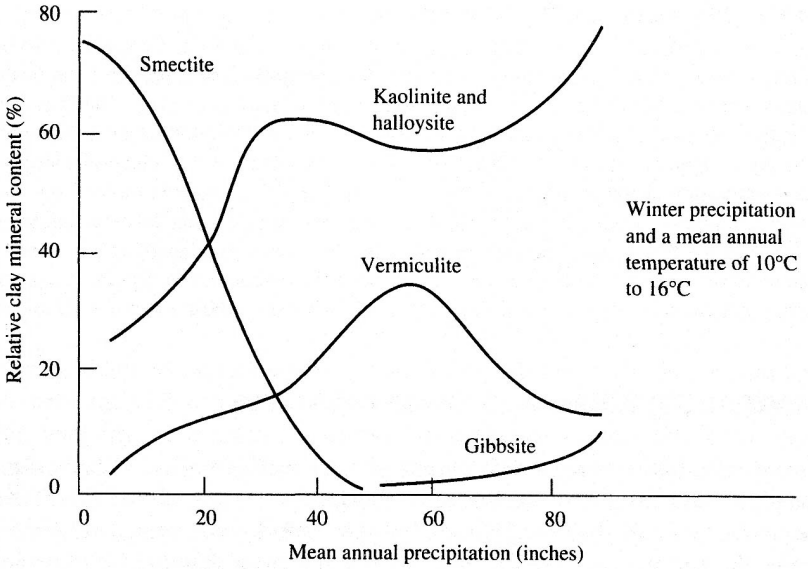
CLAY MINERAL FORMATION FROM QUARTZ- & FELDSPAR-RICH ROCKS



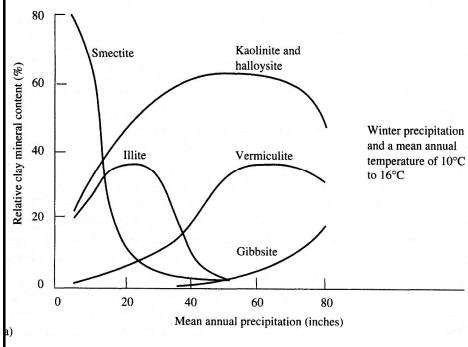
a)

(Fig 9.7a)

CLAY MINERAL FORMATION FROM FE- & MG-RICH IGNEOUS ROCKS

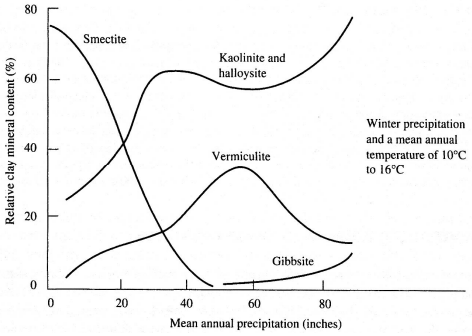


CLAY MINERAL FORMATION FROM TWO DIFFERENT GROUPS OF ROCK TYPES



Quartz- & feldspar-rich rocks (Fig. 9.7a)

Fe- & Mg-rich igneous rocks (Fig 9.7b)



CLAY MINERAL EQUILIBRIA & PHASE DIAGRAMS

Assumptions when using phase diagrams

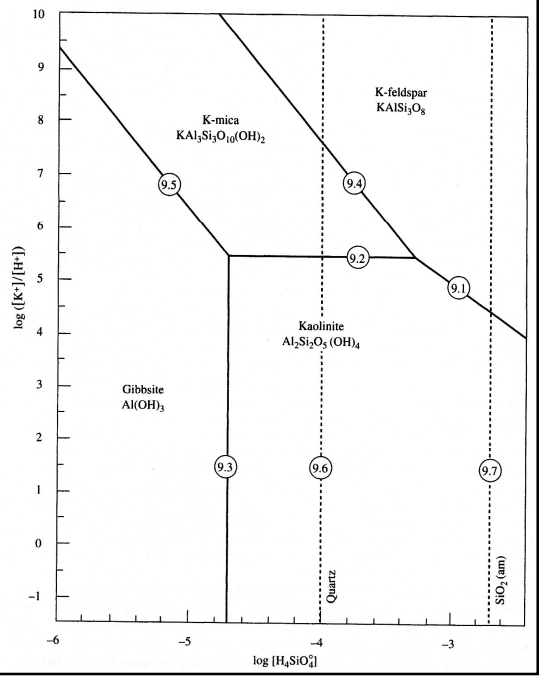
1. **Mineral/aqueous-solution phase diagrams assume chemical equilibrium can be obtained among all phases shown**
2. **The phases plotted are assumed to be pure & fixed in composition, and to correspond to the phases being considered in the natural system of interest**
3. **Accurate & meaningful thermodynamic data are available for all the solids and aqueous species being considered**
4. **In many such diagrams, Al is assumed insoluble and conserved within reactant & product solid phases**

STABILITY FIELDS OF SELECTED CLAY MINERALS

A common, simple phase diagram of soil minerals

Remember previous assumptions

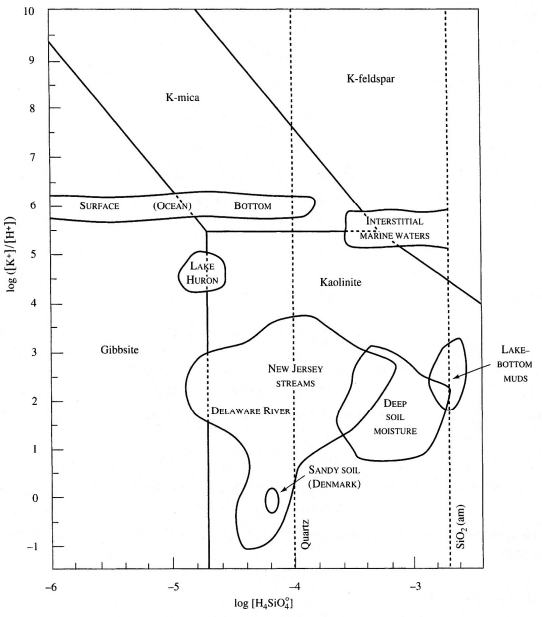
(Fig. 9.8)



STABILITY FIELDS OF SELECTED CLAY MINERALS

Previous stability diagram including compositions of some natural waters

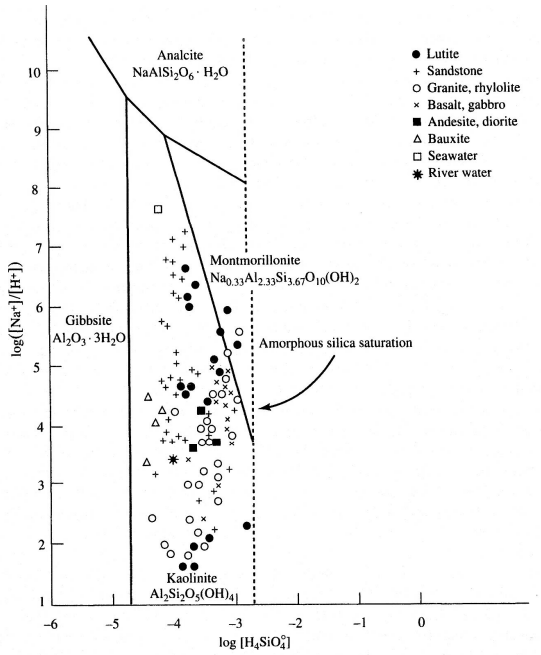
What is the utility of plots such as this?



STABILITY FIELDS OF SELECTED CLAY MINERALS

Points are from analysis of groundwaters from various rock types.

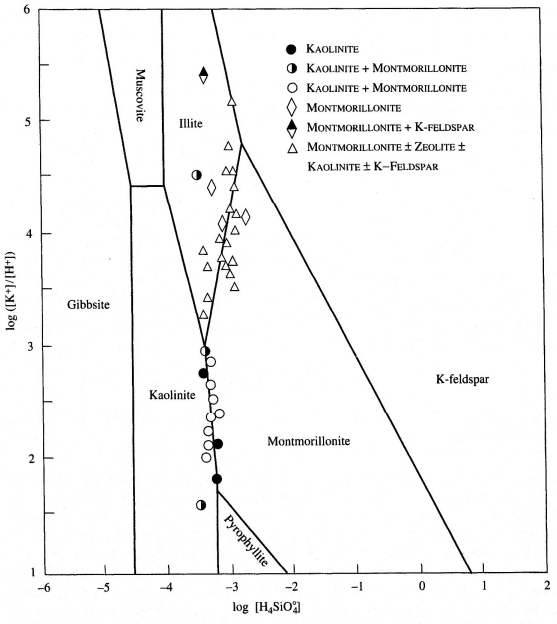
Most water analyses fall within the kaolinite field



STABILITY FIELDS OF SELECTED CLAY MINERALS

Points are from analyses of waters in contact with clays

Data suggests equilibrium between the different pairs of clays



RELATIVE ABUNDANCE OF PRIMARY AND SECONDARY MINERALS