

بسمه تعالی

دانشگاه شهید با هنر کرمان

دانشکدهٔ فنی و مهندسی – بخش مهندسی معدن

ترم اول ۱۳۹۵

ژئوتکنیک

(۲)

دکترسعید کریمی نسب

Soil Formation

Parent Rock

Residual soil

~ in situ weathering (by physical & chemical agents) of parent rock

Transported soil

~ weathered and transported far away by wind, water and ice.

Parent Rock

~ formed by one of these three different processes

igneous

formed by cooling of molten magma (lava)

e.g., granite

sedimentary

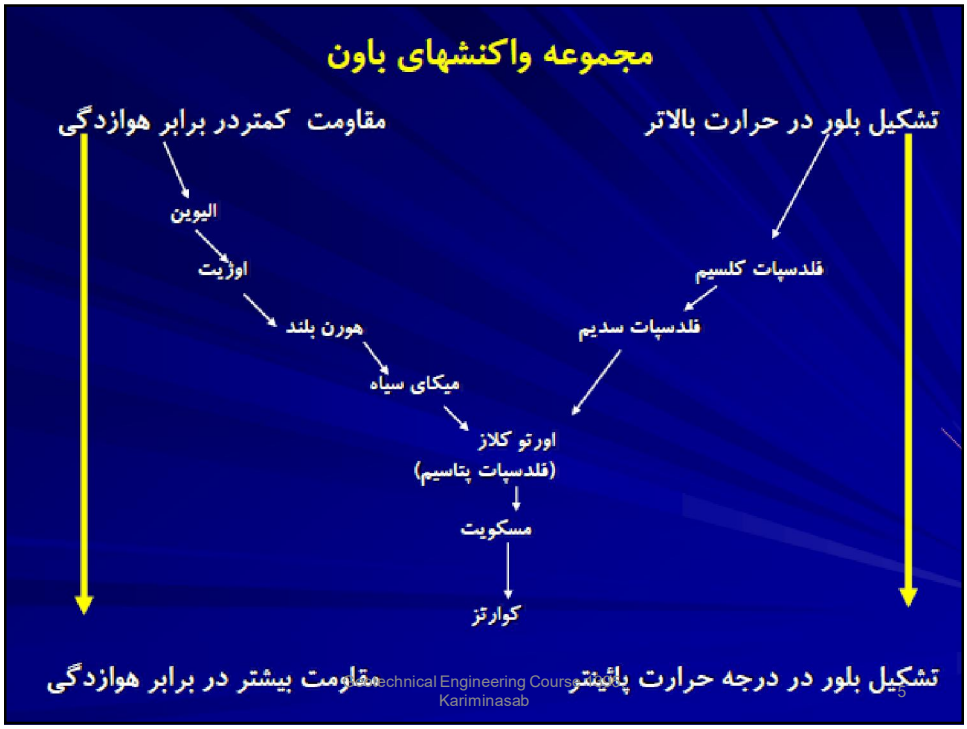
formed by gradual deposition, and in layers

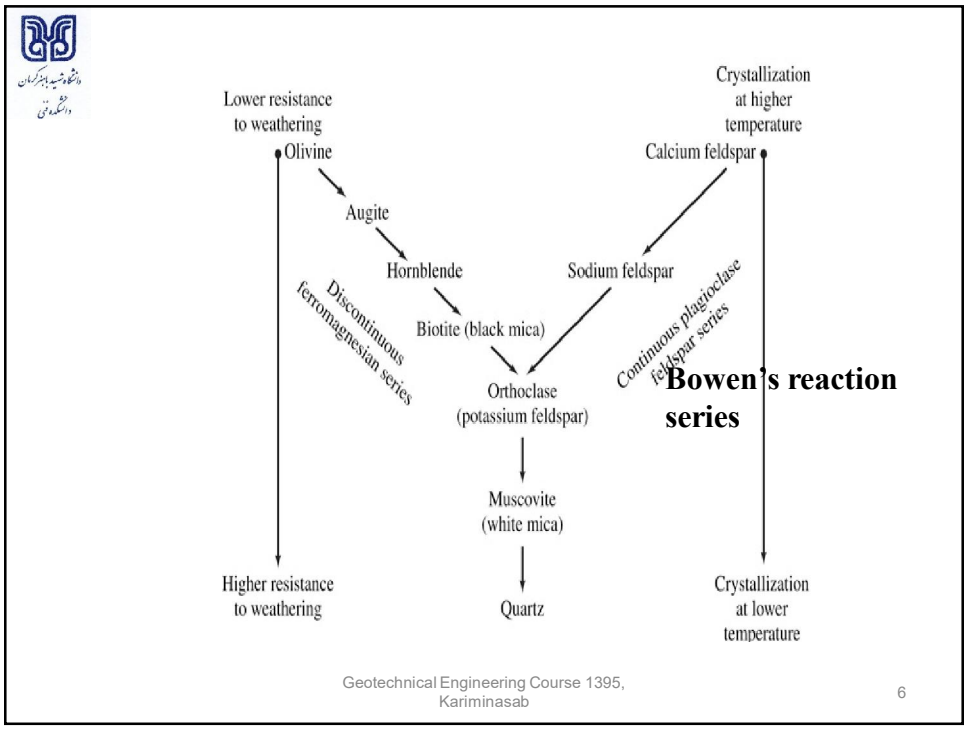
e.g., limestone, shale

metamorphic

formed by alteration of igneous & sedimentary rocks by pressure/temperature

e.g., marble

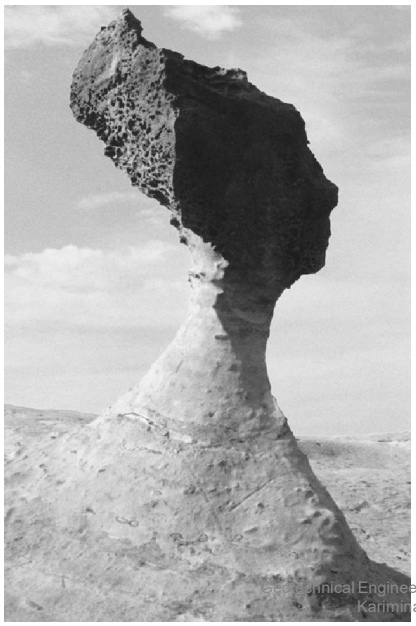




Bowen's reaction series



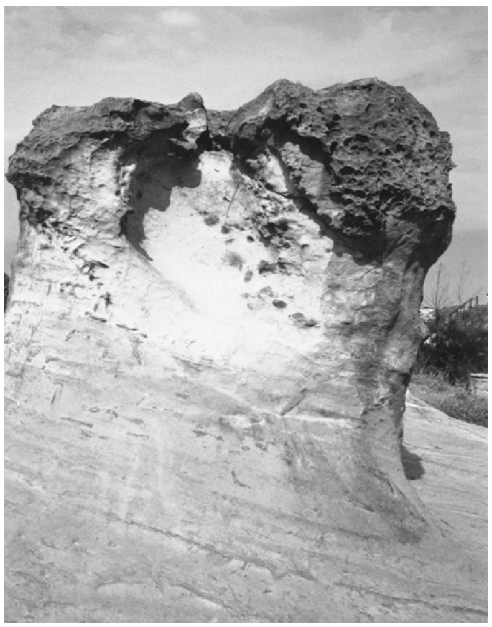
Mechanical erosion due to ocean waves and wind at Yehliu, Taiwan



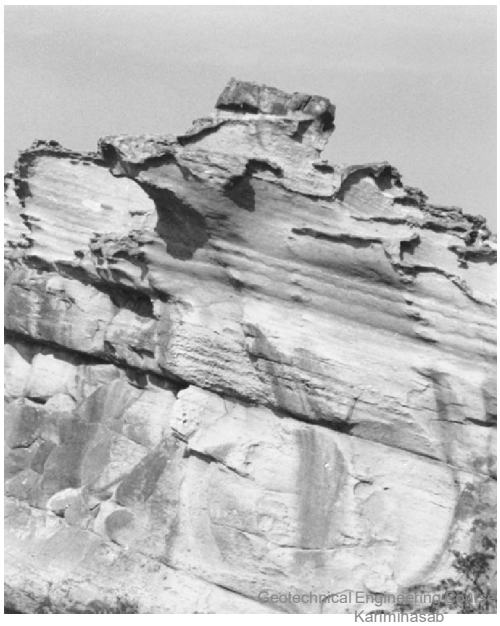
Mechanical erosion due to ocean waves and wind at Yehliu, Taiwan



Mechanical erosion due to ocean waves and wind at Yehliu, Taiwan



Mechanical erosion due to ocean waves and wind at Yehliu, Taiwan



Mechanical erosion due to ocean waves and wind at Yehliu, Taiwan



Mechanical erosion due to sea waves and wind at Qeshm, Iran

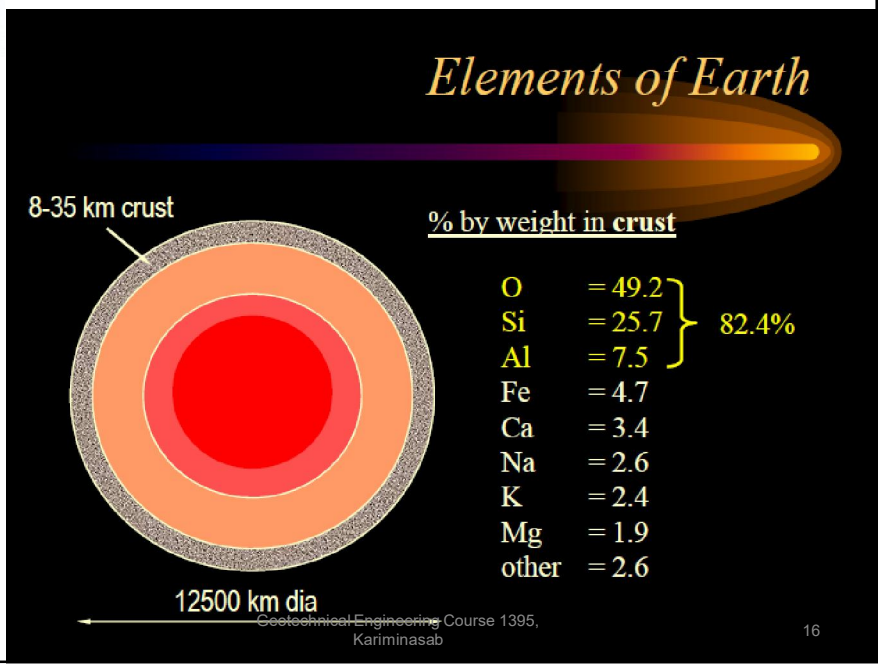
ذرات خاک و اندازه آنها

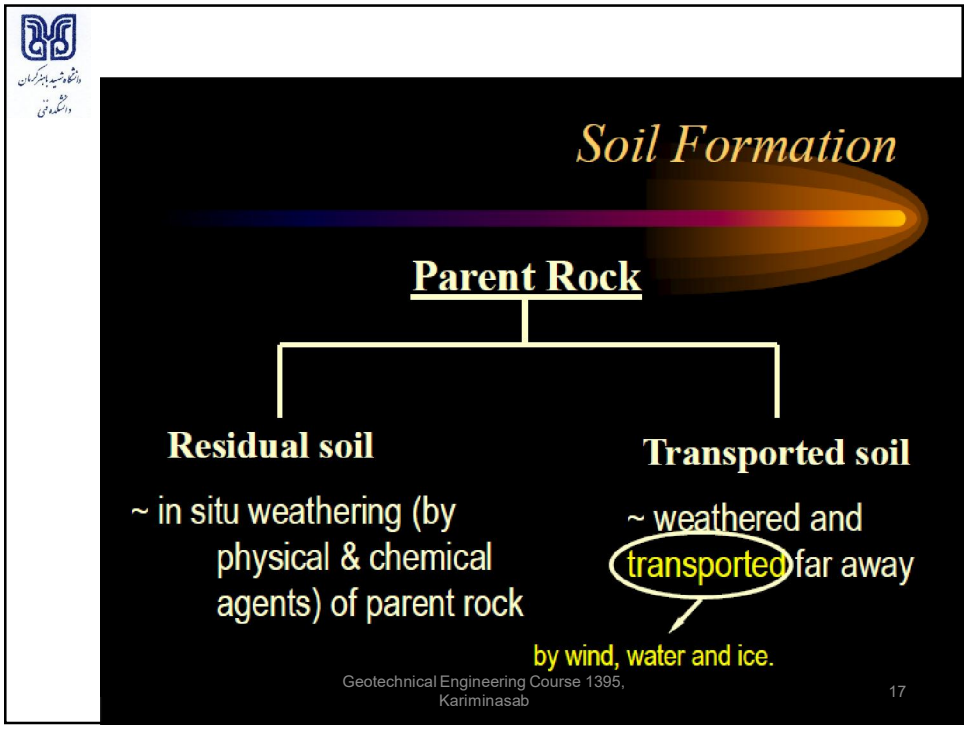
- شن ،ماسه،سیلت و رس را خاک می نامند، با توجه به اینکه کدامیک غالب باشند آنرا به آن نام می نامند .
- در مبحث مکانیک خاک، مهمترین طبقه بندی خاک، طبقه بندی بر مبنای اندازه ذرات دانه ها ست .
- این طبقه بندی تلویحاً کانیهای تشکیل دهنده خاک را نیز شامل می شود.در حال حاضر حدود پیشنهادی توسط سیستم طبقه بندی متحد مکانیک خاک متداولترین است که در مورد پذیرش اداره استاندارد آمریکا ASTM قرار گرفته است.

طبقه بندی متحد (یونیفاید)

رس و لای	< 0.075 mm
ماسه	0.075 - 4.75 mm
شن	4.75 – 76.2 mm

Clay Mineralogy




Soil Formation
Parent Rock
Residual soil
~ in situ weathering (by physical & chemical agents) of parent rock
Transported soil
~ weathered and transported far away
by wind, water and ice.
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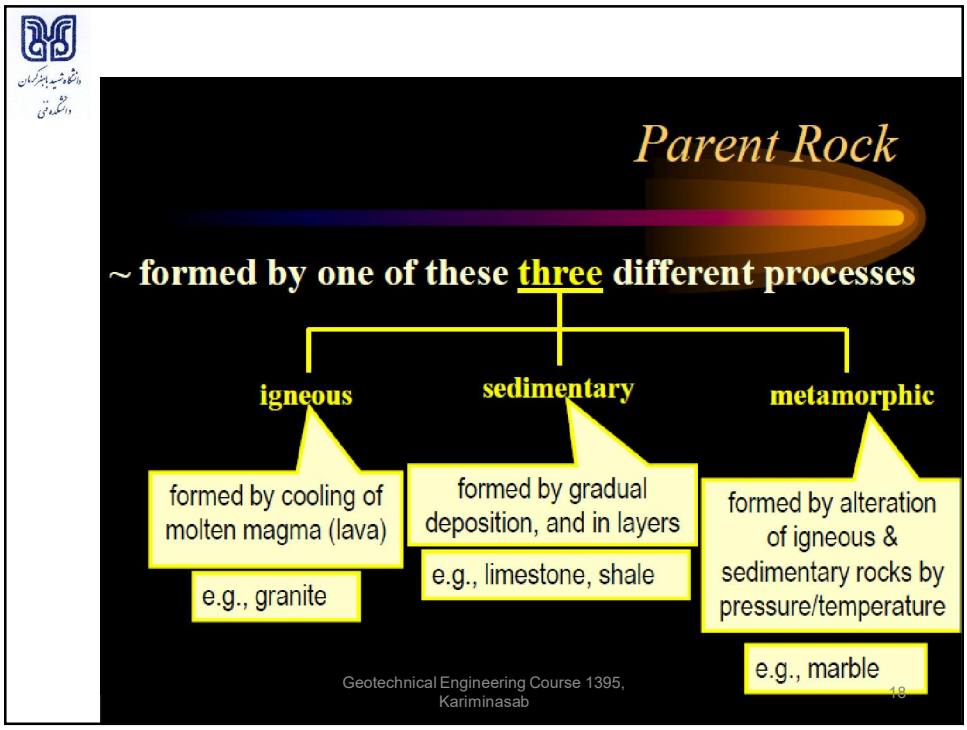
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igneous
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formed by cooling of molten magma (lava)
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formed by gradual deposition, and in layers
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formed by alteration of igneous & sedimentary rocks by pressure/temperature
e.g., marble
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Residual Soils

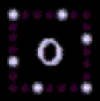
Formed by in situ weathering of parent rock

Transported Soils

Transported by:	Special name:
➢ wind	"Aeolian"
➢ sea (salt water)	"Marine"
➢ lake (fresh water)	"Lacustrine"
➢ river	"Alluvial"
➢ ice	"Glacial"

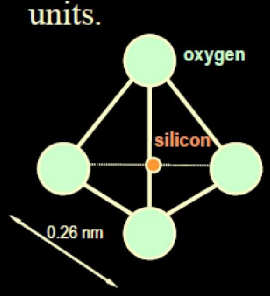
Atomic Structure

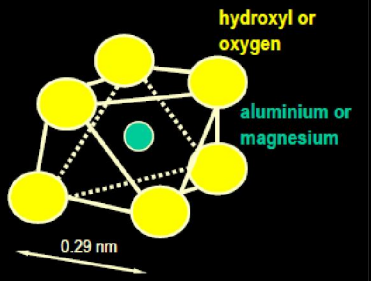




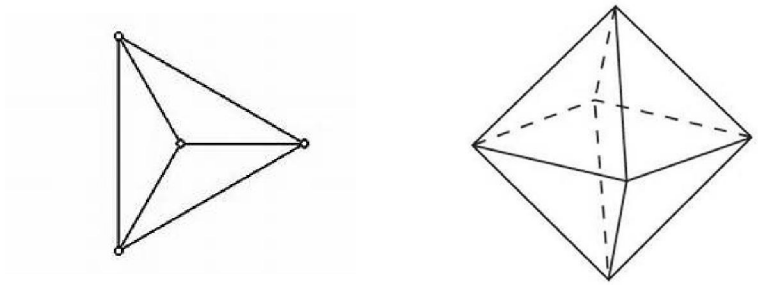
Basic Structural Units

Clay minerals are made of two distinct structural units.



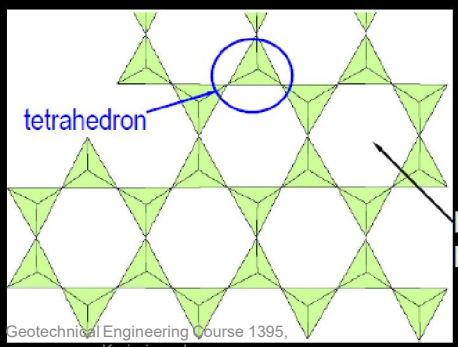


Silicon tetrahedron **Aluminium Octahedron**



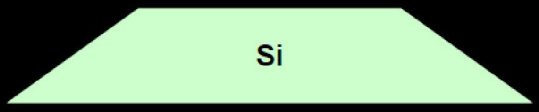
Tetrahedral Sheet

Several tetrahedrons joined together form a tetrahedral sheet.



Tetrahedral & Octahedral Sheets

For simplicity, let's represent silica **tetrahedral sheet** by:



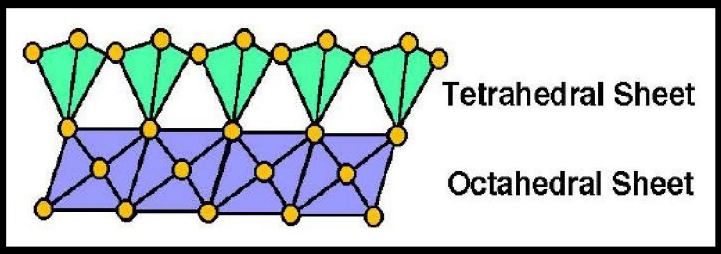
and alumina **octahedral sheet** by:



Different Clay Minerals

Different combinations of tetrahedral and octahedral sheets form different clay minerals:

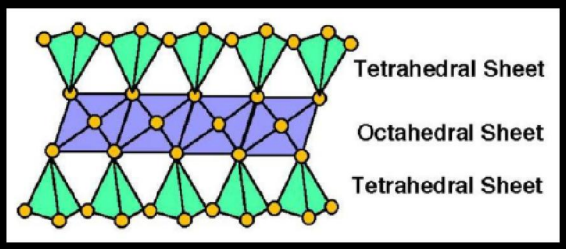
1:1 Clay Mineral (e.g., kaolinite, halloysite):



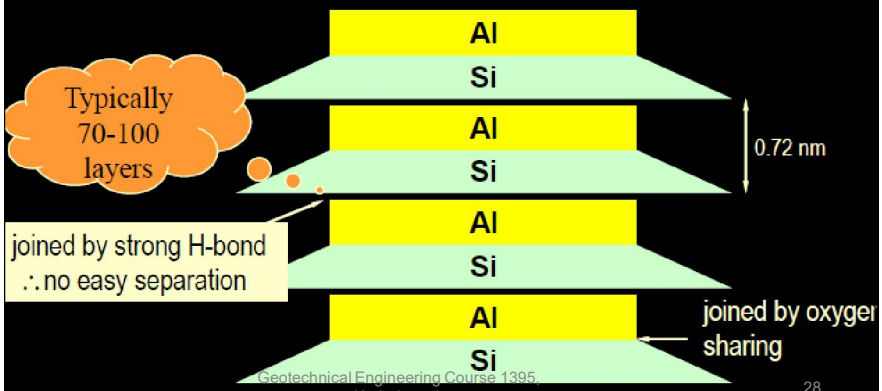
Different Clay Minerals

Different combinations of tetrahedral and octahedral sheets form different clay minerals:

2:1 Clay Mineral (e.g., montmorillonite, illite)



Kaolinite



Kaolinite

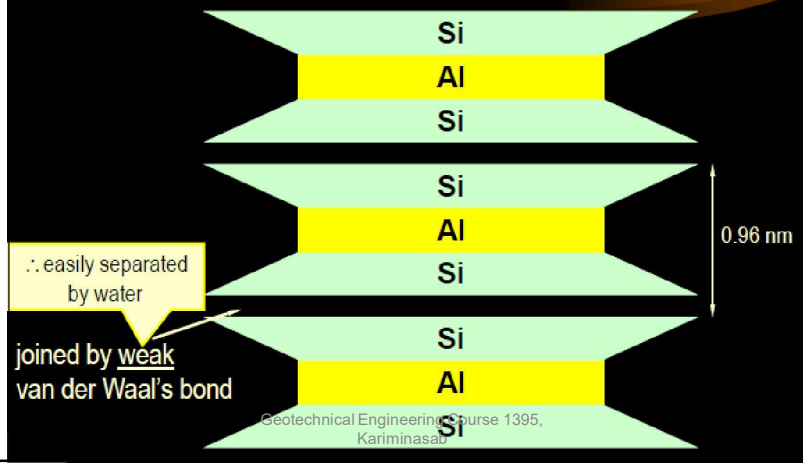
- used in paints, paper and in pottery and pharmaceutical industries
- $(OH)_8Al_4Si_4O_{10}$

Halloysite

- kaolinite family; hydrated and tubular structure
- $(OH)_8Al_4Si_4O_{10}.4H_2O$

Montmorillonite

- also called **smectite**; expands on contact with water



Montmorillonite

- A highly reactive (expansive) clay
- $(OH)_4Al_4Si_8O_{20}\cdot nH_2O$

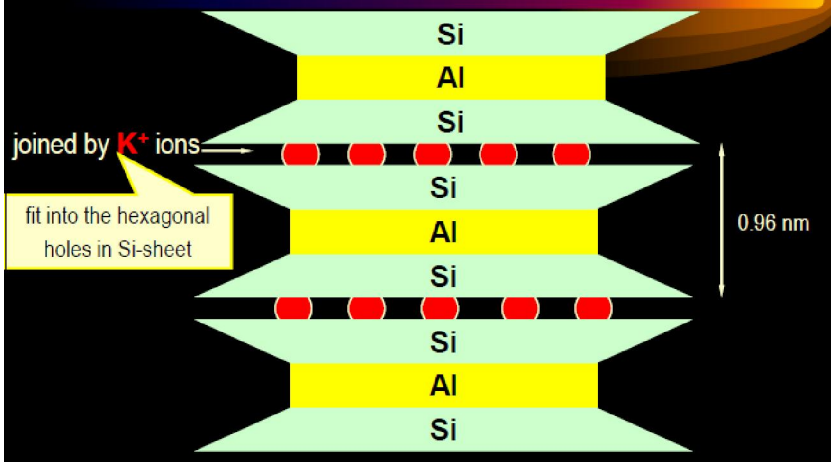
swells on contact with water

high affinity to water

Bentonite

- montmorillonite family
- used as drilling mud, in slurry trench walls, stopping leaks

Illite



Others…

Chlorite

- A 2:1:1 (???) mineral.

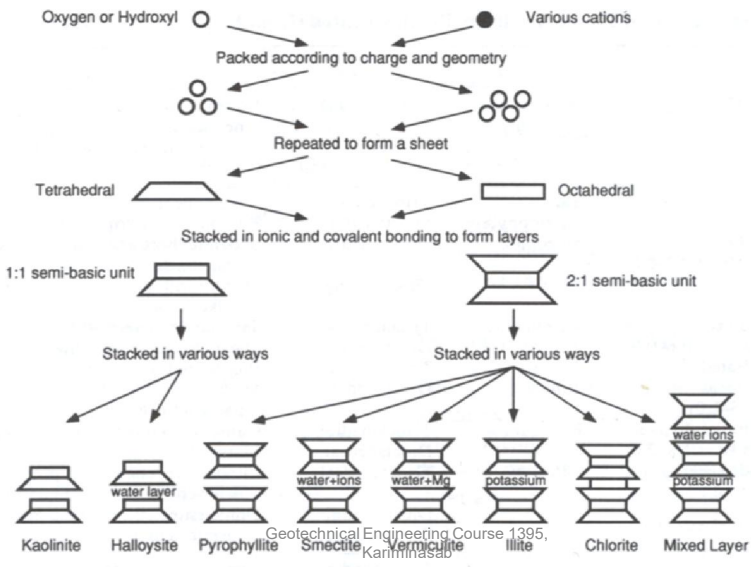
Si Al Al or Mg

Vermiculite

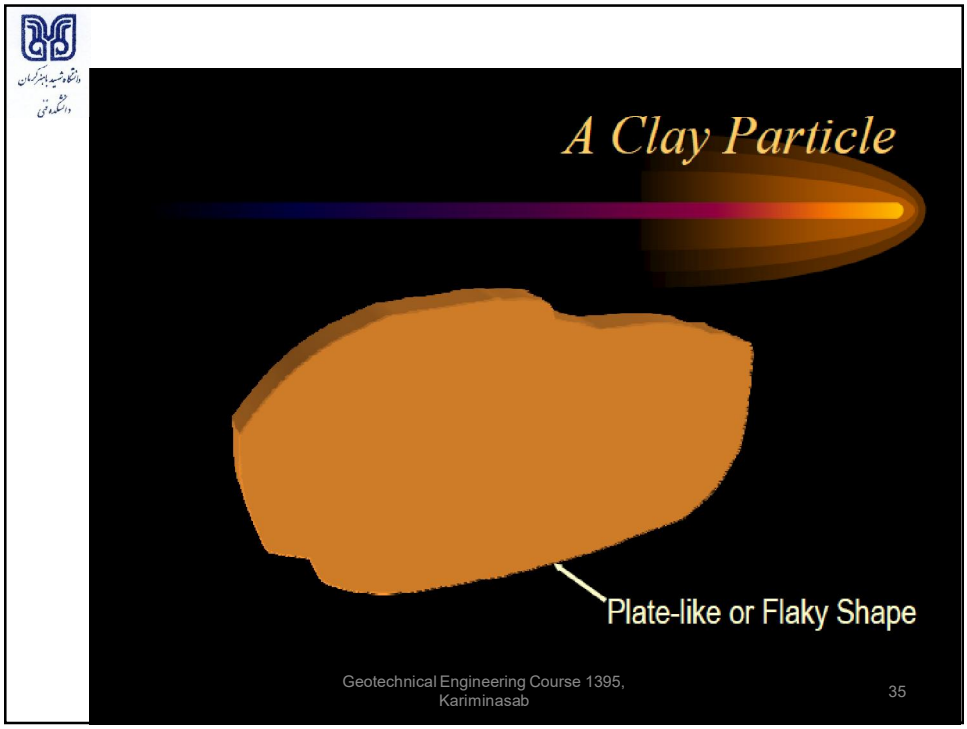
- montmorillonite family; 2 interlayers of water

Attapulgite

- chain structure (no sheets); needle-like appearance



Noncrystalline clay - allophane


A Clay Particle
Plate-like or Flaky Shape
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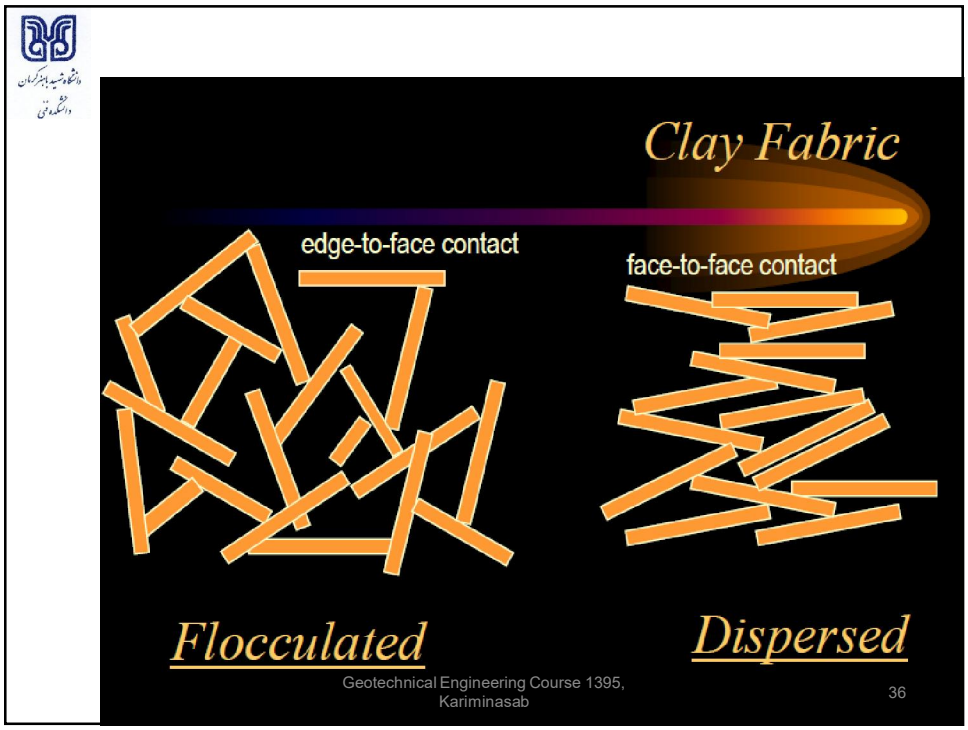
Clay Fabric
edge-to-face contact
face-to-face contact
Flocculated
Dispersed
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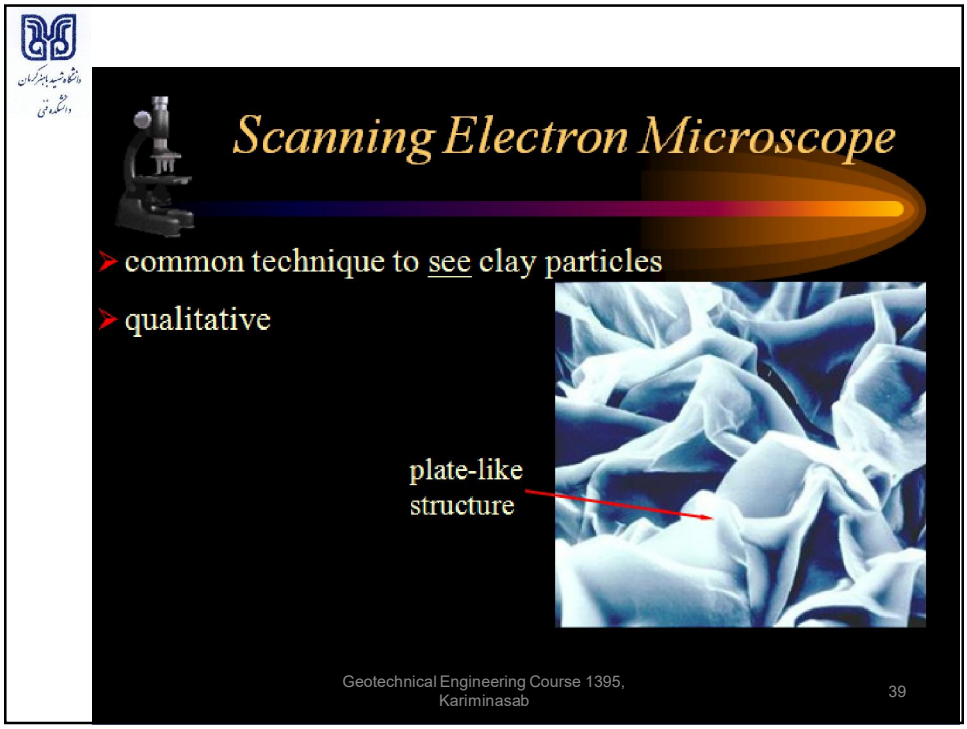
Clay Fabric

- Electrochemical environment (i.e., pH, acidity, temperature, cations present in the water) during the time of sedimentation influence clay fabric significantly.
- Clay particles tend to align perpendicular to the load applied on them.

Identifying Clay Minerals


Scanning Electron Microscope
common technique to see clay particles
qualitative
plate-like structure
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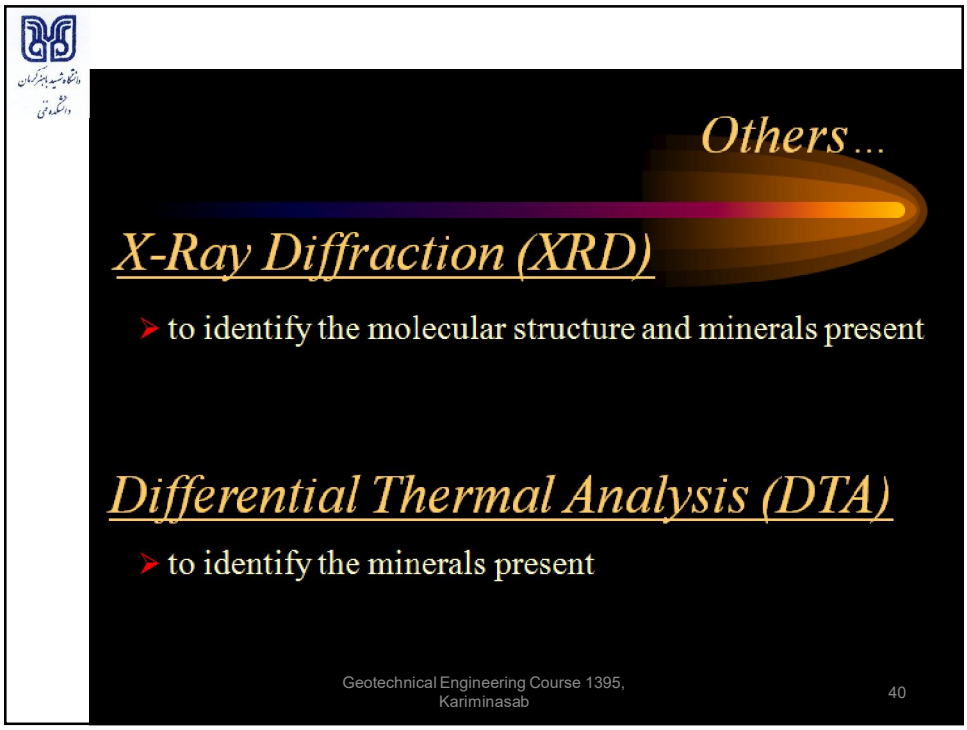
Others ...
X-Ray Diffraction (XRD)
to identify the molecular structure and minerals present
Differential Thermal Analysis (DTA)
to identify the minerals present
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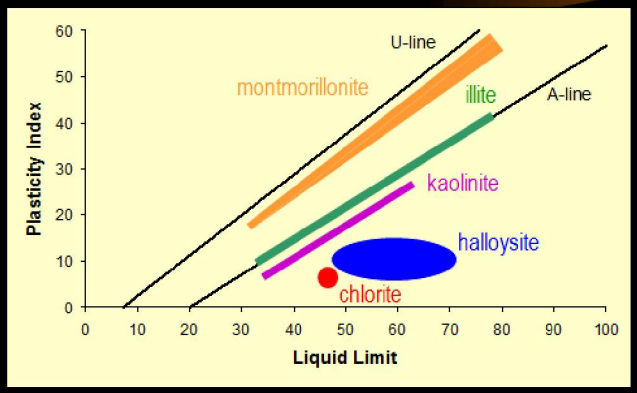
Casagrande's PI-LL Chart



Specific Surface

- surface area per unit mass (m^2/g)
- smaller the grain, higher the specific surface

e.g., soil grain with specific gravity of 2.7



10 mm cube



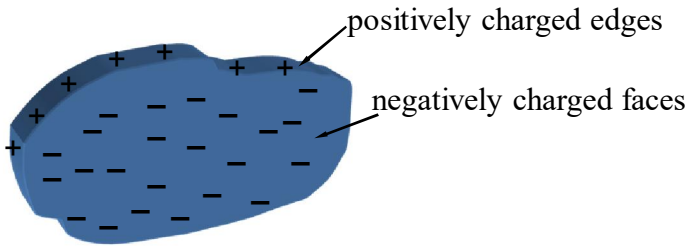
1 mm cube

spec. surface = 222.2 mm^2/g

spec. surface = 2222.2 mm^2/g

Isomorphous Substitution

- substitution of Si^{4+} and Al^{3+} by other lower valence (e.g., Mg^{2+}) cations
- results in charge imbalance (net negative)



Clay Particle with Net negative Charge

Definition

Specific surface = surface / volume

Specific surface = surface / mass ⟶ Preferred

$$\frac{\text{Surface related force}}{\text{Gravational force}}$$

Surface related forces: van der Waals forces, capillary forces, etc.

Example:

$1\times1\times1\,\text{cm}$ cube, $\rho = 2.65\,\text{g/cm}^3$

$$S_s = \frac{6\cdot 1\,\text{cm}^2}{1\,\text{cm}^3\cdot 2.65\,\text{g/cm}^3} = 2.3\cdot 10^{-4}\cdot \text{m}^2/\text{g}$$

$1\times1\times1\,\mu\text{m}$ cube, $\rho = 2.65\,\text{g/cm}^3$

$$S_s = \frac{6\cdot 1\,\mu\text{m}^2}{1\,\mu\text{m}^3\cdot 2.65\,\text{g/cm}^3} = 2.3\cdot \text{m}^2/\text{g}$$

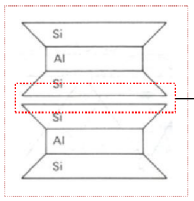
S_s is inversely proportional to the particle size

3.2 Typical Values

Montmorillonite

50-120 m^2/gm (external surface)

700-840 m^2/gm (including the interlayer surface)



Interlayer surface

Illite



65-100 m^2/gm

Kaolinite

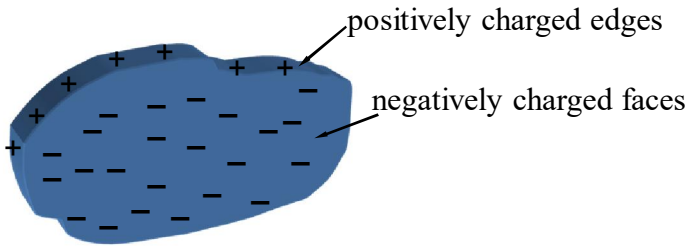


10-20 m^2/gm

Interaction of Water and Clay Minerals

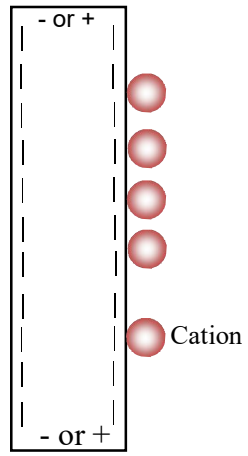
Isomorphous Substitution

- substitution of Si^{4+} and Al^{3+} by other lower valence (e.g., Mg^{2+}) cations
- results in charge imbalance (net negative)



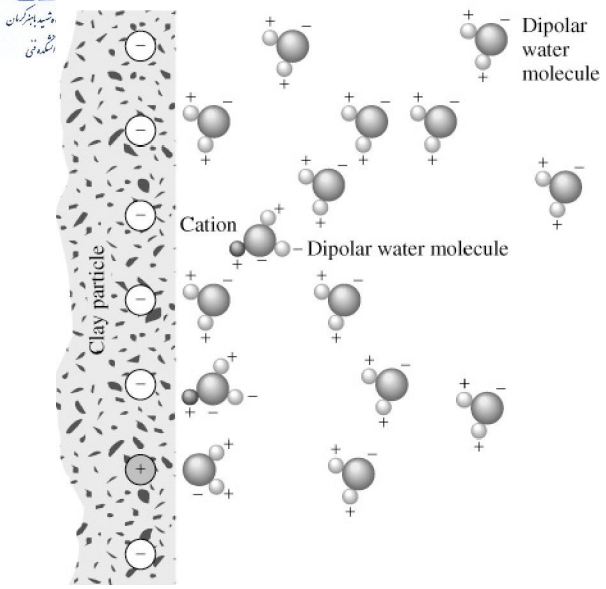
Clay Particle with Net negative Charge

"Charged" Clay Particles



Dry condition

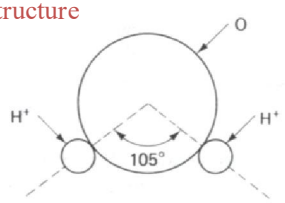
- External or interlayer surfaces are negatively charged in general.
- The edges can be positively or negatively charged.
- Different cations balance charge deficiencies.



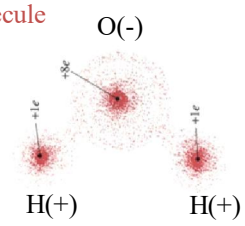
Attraction of dipolar molecules in diffuse double layer

4.4 Polar Water Molecules

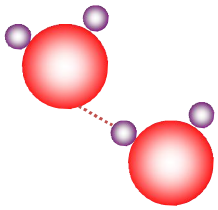
Structure



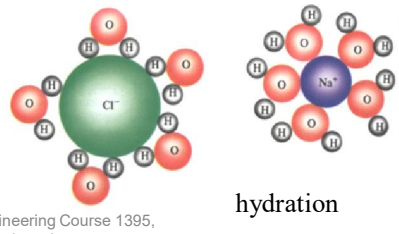
Polar molecule



Hydrogen bond

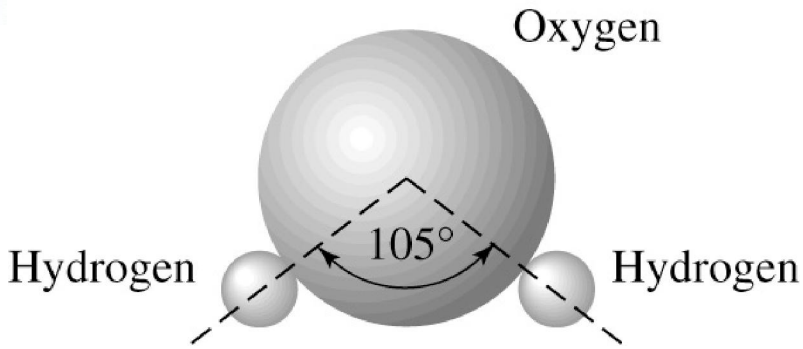


Salts in aqueous solution



hydration

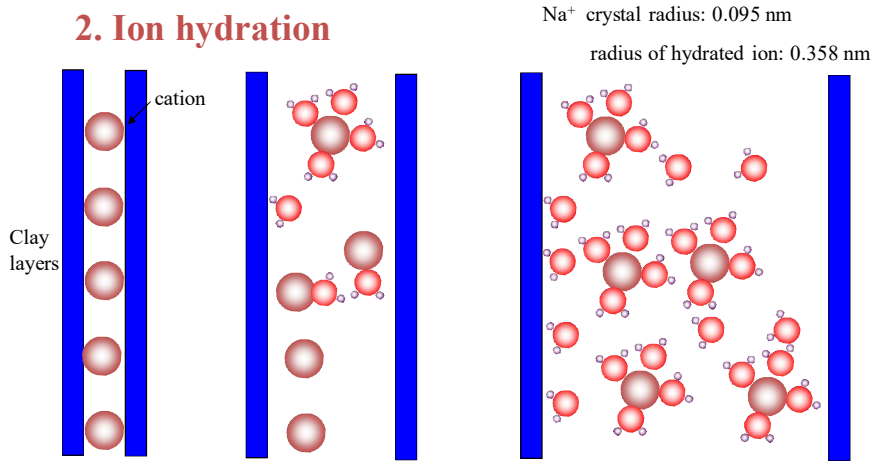
50



Dipolar character of water

Clay-Water Interaction

2. Ion hydration

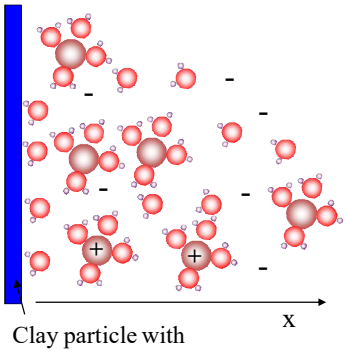


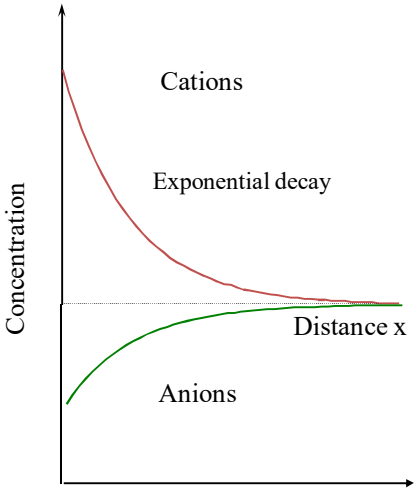
Dry condition (Interlayer)

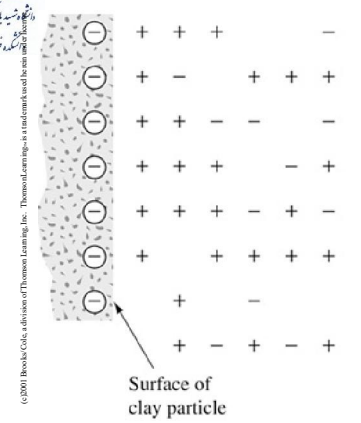
The water molecules wedge into the interlayer after adding water

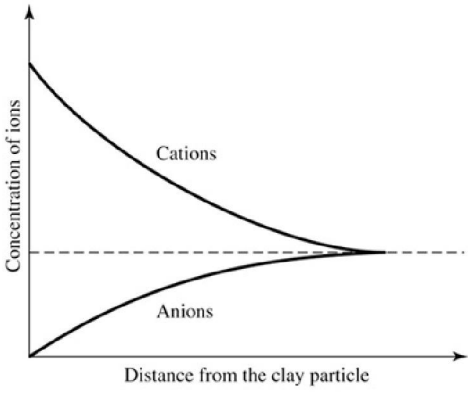
The cations are fully hydrated, which results in repulsive forces and expanding clay layers (hydration energy).

Diffuse Double Layer









Diffuse double layer

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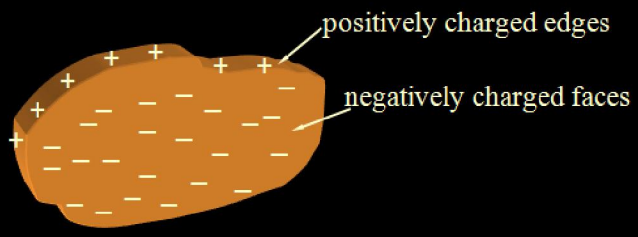


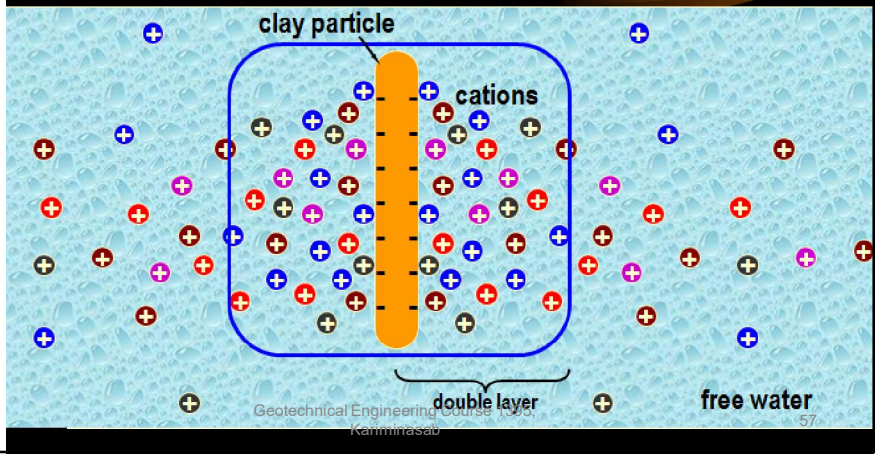
Clay Particle with Net negative Charge

A Comparison

Mineral	Specific surface (m^2/g)	C.E.C (meq/100g)
Kaolinite	10-20	3-10
Illite	80-100	20-30
Montmorillonite	800	80-120
Chlorite	80	20-30

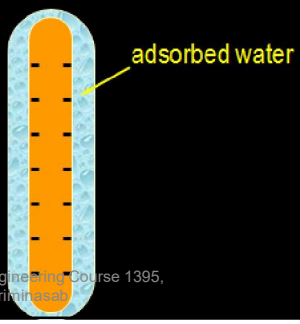
Cation Concentration in Water

- cation concentration drops with distance from clay particle

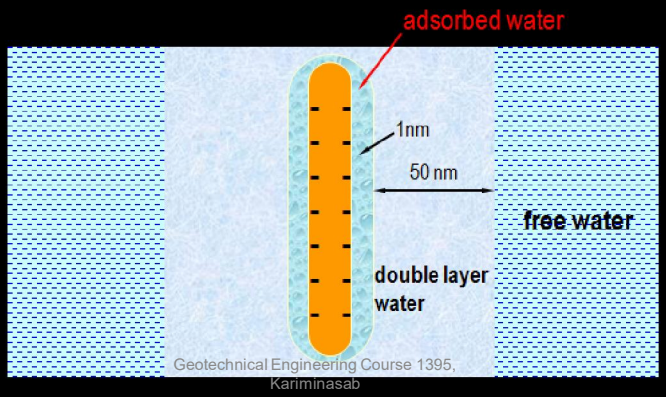


Adsorbed Water

- A thin layer of water tightly held to particle; like a skin
- 1-4 molecules of water (1 nm) thick
- more viscous than free water



Clay Particle in Water



Summary - Clays

- Clay particles are like plates or needles. They are negatively charged.
- Clays are plastic; Silts, sands and gravels are non-plastic.
- Clays exhibit high dry strength and slow dilatancy.

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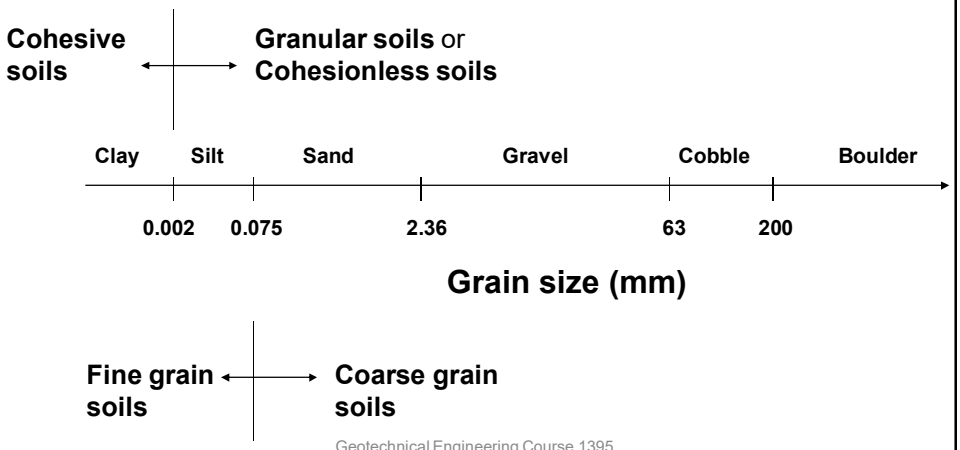
Summary - Montmorillonite

- Montmorillonites have very high specific surface, cation exchange capacity, and affinity to water. They form reactive clays.
- Montmorillonites have very high liquid limit (100+), plasticity index and activity (1-7).
- Bentonite (a form of Montmorillonite) is frequently used as drilling mud.

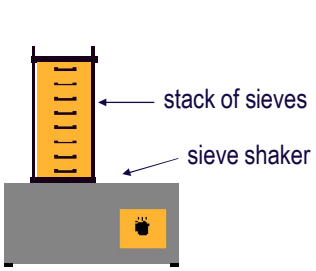
Major Soil Groups



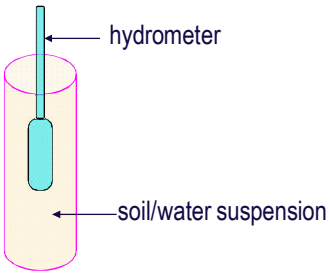
Grain Size Distribution

Determination of GSD:

- In coarse grain soils ..... By sieve analysis
- In fine grain soils ..... By hydrometer analysis



Sieve Analysis



Hydrometer Analysis