
بسم الله الرحمن الرحیم

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سرفصل درس مصوب وزارت عتف
اهداف کلی درس:
آشنایی با کانسارهای مواد معدنی غیرفلزی و کاربرد تکنیک‌های مختلف در اکتشاف آن‌ها
سرفصل درس:
- مروری بر کانسارهای غیرفلزی، شکل کانسارهای غیرفلزی و ژنز آن‌ها
- مروری کلی بر کارایی روش‌های دورسنجی، ژئوفیزیک اکتشافی، ژئوشیمی اکتشافی، حفریات اکتشافی (گمانه، ترانشه، چال و چاهک)، نمونه گیری، کانی شناسی، تجزیه شیمیایی، مدل سازی ذخایر و GIS در اکتشاف مواد معدنی غیرفلزی.
- طبقه بندی کانسارهای غیرفلزی و شرح هر یک از کانسارهای غیرفلزی و ارائه و تحلیل روش‌های اکتشافی معمول در مورد هر یک از کانسارهای غیرفلزی زیر:
الف- سنگ‌ها و خاک‌ها:
۱- شن و ماسه، خاک رس و مواد راه سازی، مواد اولیه آجر، رس‌های مصرفی در صنایع سرامیک، نسوزهای بوکسیتی، سیلیمانیتی، دیستن، کرومیت و مگنزیتی، دولومیتی.
۲- ماسه‌های صنعتی، مواد خام صنایع سیمان، کانسارهای گچ و انیدرید، سنگ‌های نما و تزیینی.
ب- کانی‌های صنعتی:
۱- سنگ‌های قیمتی و جواهرات
۲- کانسارهای فلدسپات
۳- کانسارهای فسفات
۴- کانسارهای ورمیکولیت و زئولیت
ج- کانسارهای نمک
د- کانسارهای زغال سنگ و سنگ‌های بیتومن دار زغال سنگ، شرایط تشکیل، پتروگرافی.
○ دانشجو موظف است در قالب مباحث نظری آموزش داده شده طبق نظر استاد مربوط، یک پروژه مستقل ارائه نماید.
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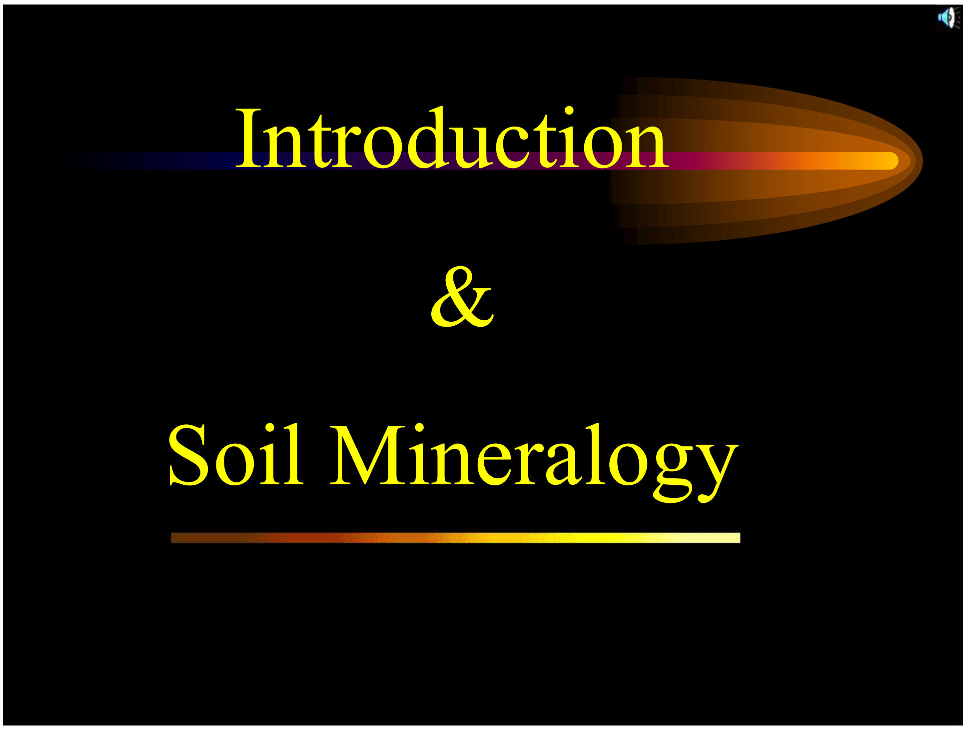
Introduction
&
Soil Mineralogy

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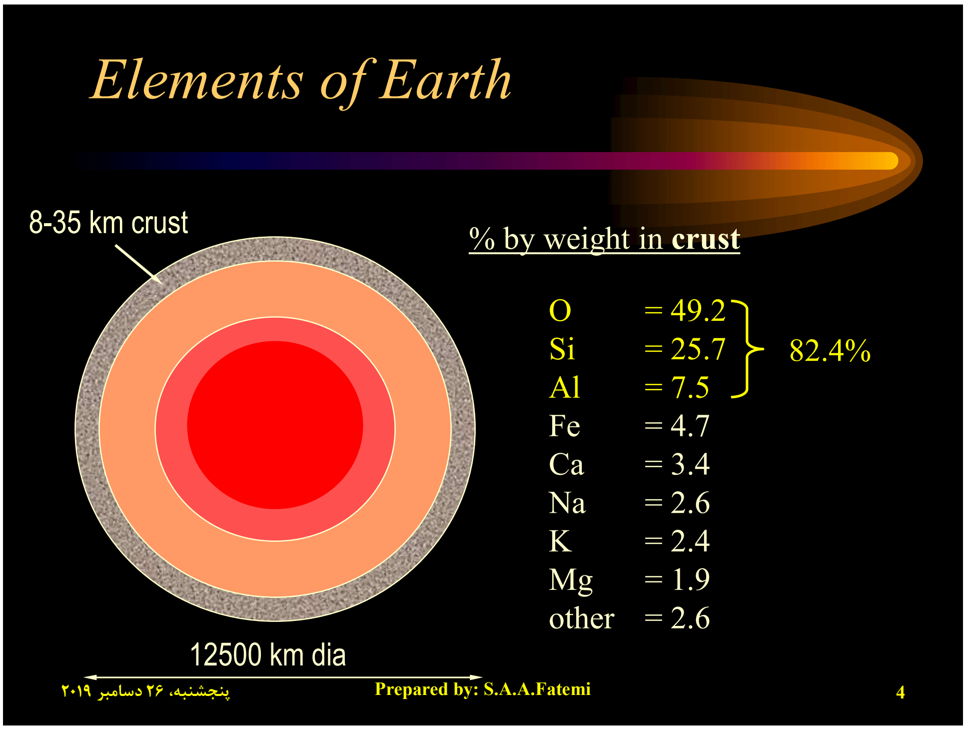
Elements of Earth
8-35 km crust
12500 km dia
% by weight in crust
O = 49.2
Si = 25.7
Al = 7.5
82.4%
Fe = 4.7
Ca = 3.4
Na = 2.6
K = 2.4
Mg = 1.9
other = 2.6
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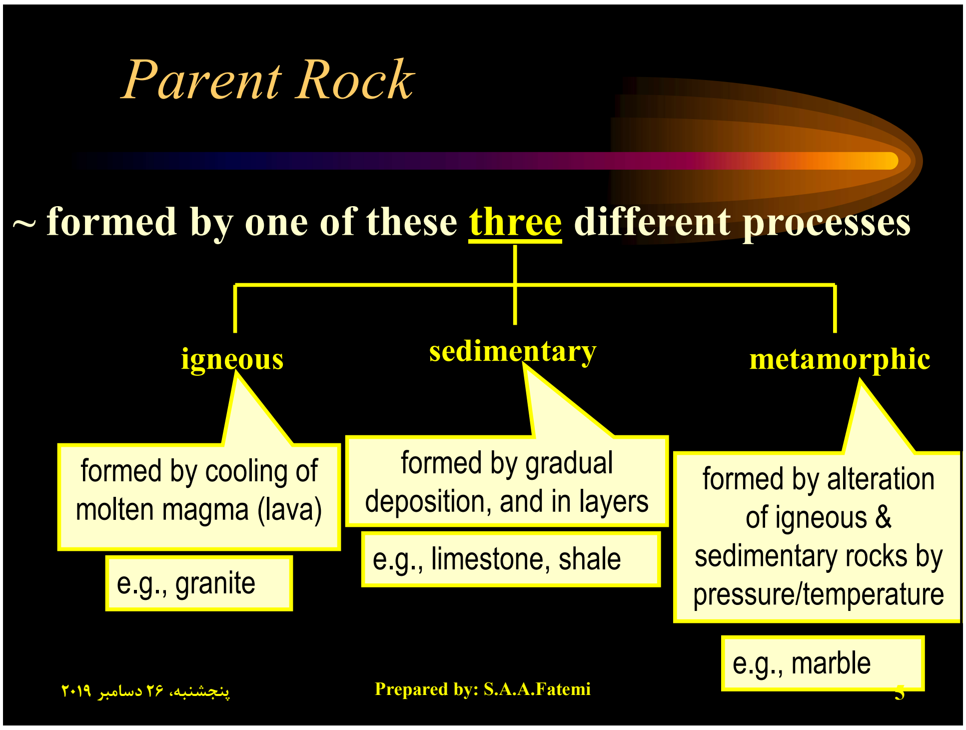
Parent Rock
~ formed by one of these three different processes
igneous
sedimentary
metamorphic
formed by cooling of molten magma (lava)
e.g., granite
formed by gradual deposition, and in layers
e.g., limestone, shale
formed by alteration of igneous & sedimentary rocks by pressure/temperature
e.g., marble
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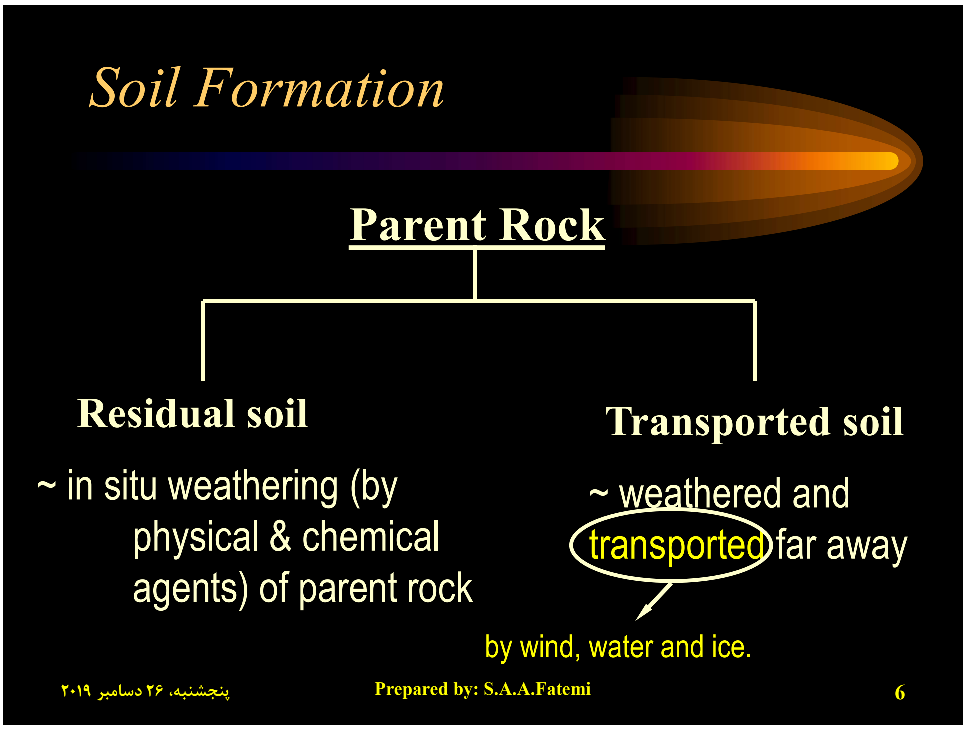
Soil Formation
Parent Rock
Residual soil
~ in situ weathering (by physical & chemical agents) of parent rock
Transported soil
~ weathered and transported far away
by wind, water and ice.
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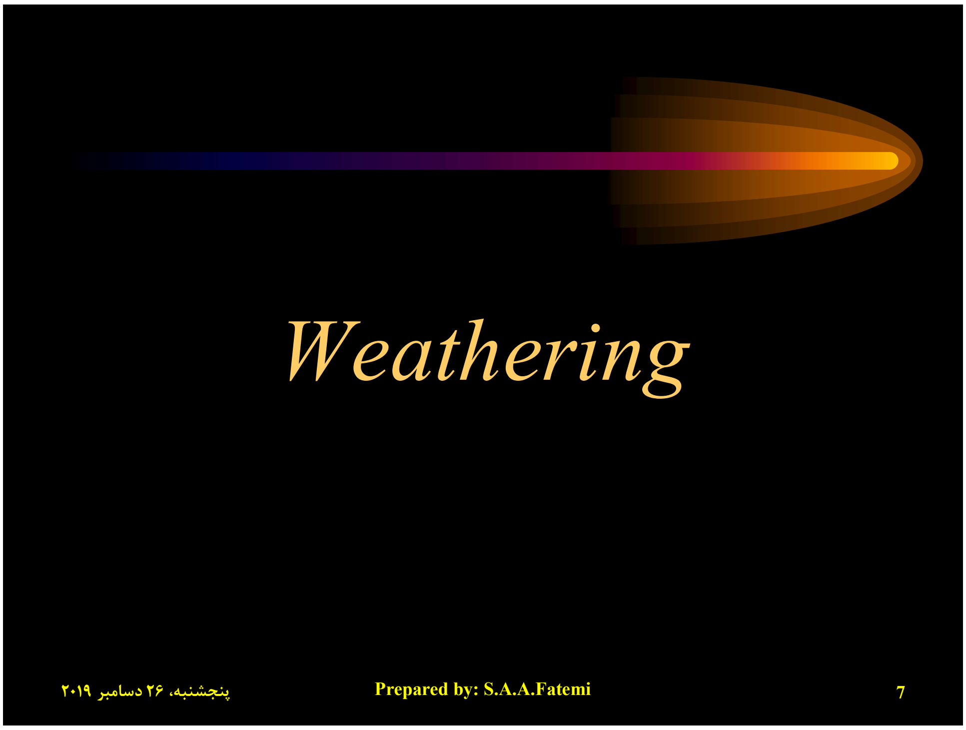
Weathering
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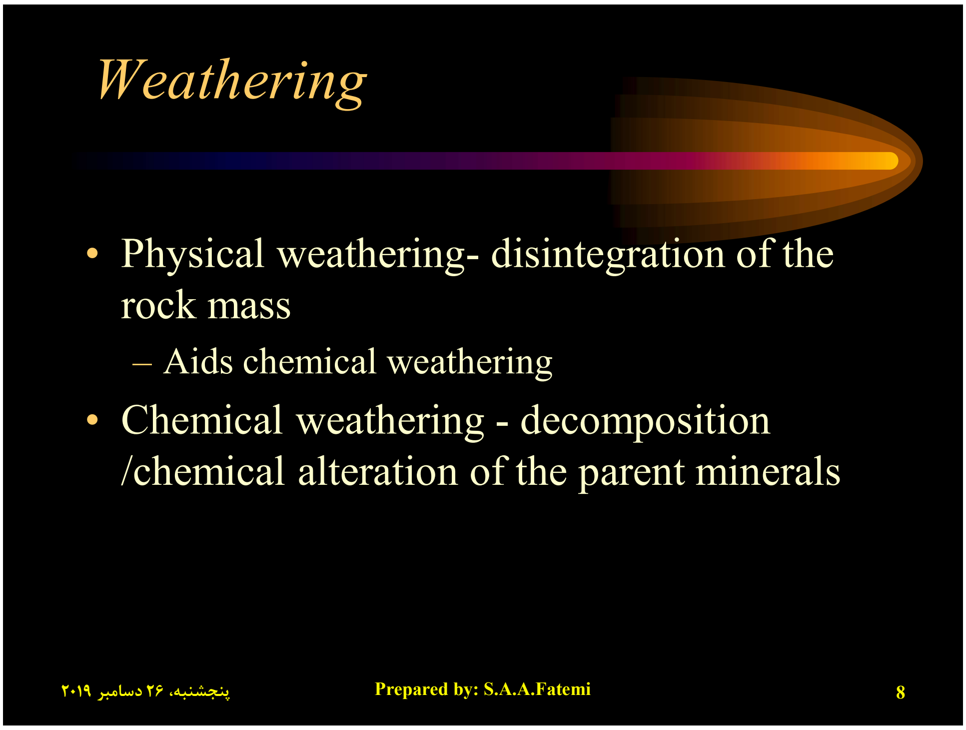
Weathering
• Physical weathering- disintegration of the rock mass
– Aids chemical weathering
• Chemical weathering - decomposition /chemical alteration of the parent minerals
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Physical Weathering

1- Unloading and Exfoliation
- Release of overburden pressure due to uplift/erosion
- Rocks tends to expand
- Stresses develop
- Stress release occurs through development of joints
- Slabs detach …. “exfoliation”

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Physical Weathering

2- Crystal Growth/Frost Action
- Arid regions …. Formation of salt crystals
- In cold regions … frost action

3- Colloid Plucking
- Colloids shrink/contract upon drying
- Exert tension on rocks with which they are in contact
- Sufficient tension to cause removal of flakes

4- Organic Activity
- Growing plants
- Burrowing animals and earthworms

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Chemical Weathering

1- Hydration and Hydrolysis

– Hydration.. Surface adsorption of water through electromagnetic bond between crystalline particles and water molecules

– Hydrolysis …. Process whereby H^+ ions from water enters crystal lattice and replaces existing cations

Chemical Weathering

2- Chelation

– Organic compounds from humus complex metal ions (M^+) and remove them

3- Oxidation

– Causes red color in many soils (Ferric Ions)

– Oxygen dissolved in water converts lower valence Fe, Mn compounds to iron and manganese hydroxides e.g. Pyrite (FeS_2) to limonite (Fe_2O_3)

Chemical Weathering

4- Carbonation

- CO_2 from atmosphere unite with water to form carbonic acid
- Carbonic acid reacts with various earth materials to form carbonates (Iron Carbonates, Ca Carbonates)

5- Cation Exchange

- When solutions are in contact with solids, ions from solution may take place of atoms in the crystal lattice and vice versa
- E.g. use of zeolites for water softening, Zeolites adsorb Ca and liberates Na

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Effects of Climate, Topography, Parent Material, Time & Biotic Factors

- Wet climate and good drainage; both accelerate weathering
- For a given amount of rainfall, rate of chemical weathering is higher in warmer climates
- Depth of water table influences weathering by determining the depth to which air is available
- Type of rainfall: short, intense rainfall promotes erosion; light, prolonged rainfall aids in leaching

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Effects of Climate, Topography, Parent Material, Time & Biotic Factors

- Topograpghy: important factor in determining rates of erosion, rates of soil accumulation
- Steep topography: encourages mechanical weathering
- Vegetation affects rate of erosion
- Organic compound aid weathering

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Residual Soil

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Residual Soil

- Soil formed by in-situ weathering
- Depth of profile varies depending on climate, parent material, drainage conditions, water table
- Soil Profile (Pedology)
- 3 Horizons
  - Horizon A(Eluvial), Horizon B (Illuvial) and Horizon C (Parent Material)

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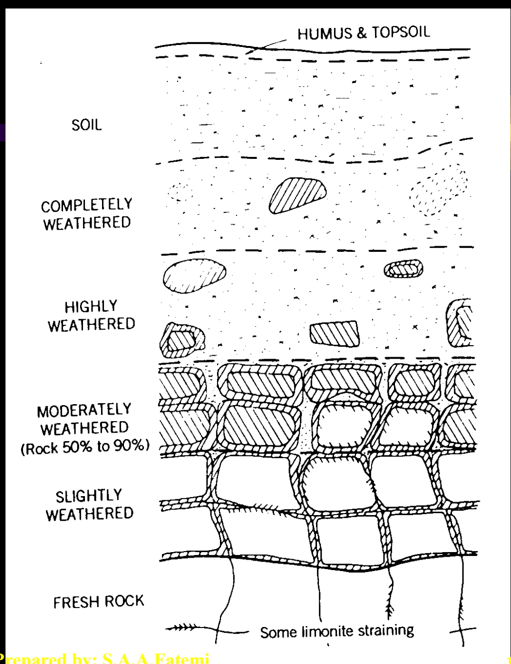
Residual Soils



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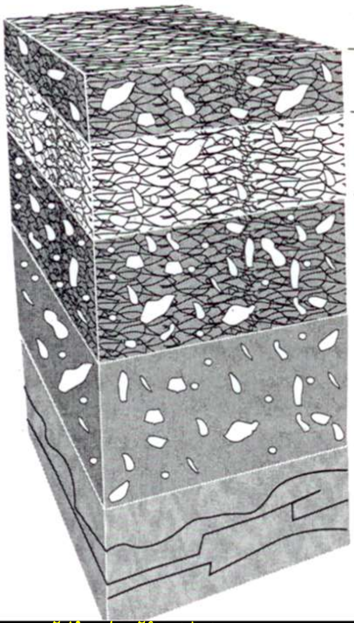

Horizon			
O	01	decomposing vegetative debris	
	02	decomposed plant and animal debris	
A	A1 A2 A3	accumulation of humified o.m. loss of clays, iron, and aluminum transitional to B (A horizon is "zone of illuviation")	solum (true soil)
B	B1 B&A B2 B3	transitional between B and A1 qualifies as B by > 50% of volume transitional to A, C, or R transitional to B, C, or R (B horizon is "zone of illuviation")	
C		parent material, may be like or unlike material from which solum was formed little affected by pedogenic processes	
R		consolidated bedrock (R horizon contains layered bedrock)	

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Transported Soils

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Transported Soils

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

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Aeolian Deposits

- Wind transported soil deposits
- Wind Erosion – common in desert environment
- No clays – no cohesion, but higher wind speeds
- Sand Dunes, sand drifts, sand shadows

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Aeolian Deposits

- Loess or loessal soil: uniform (0.01-0.05mm) wind-blown sediment, loosely deposited, some cohesion due to calcareous or clay binder, vertical cleavage (planes of weakness) due to vertical tree roots, unstable when saturated

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Great Sand Dunes; Colorado

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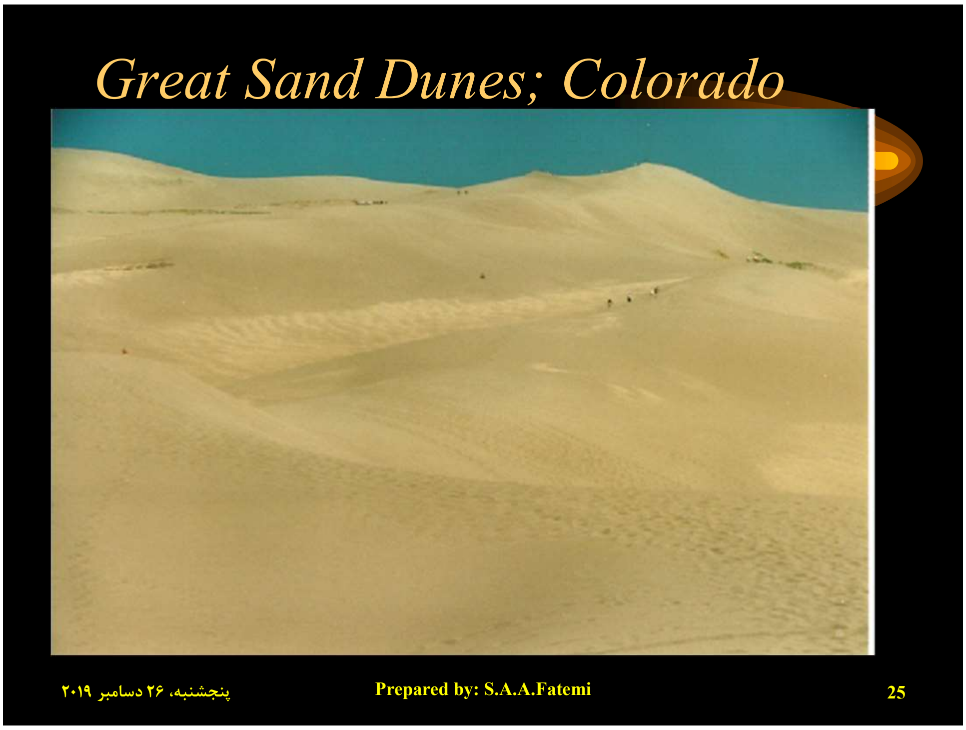
Great Sand Dunes; Colorado
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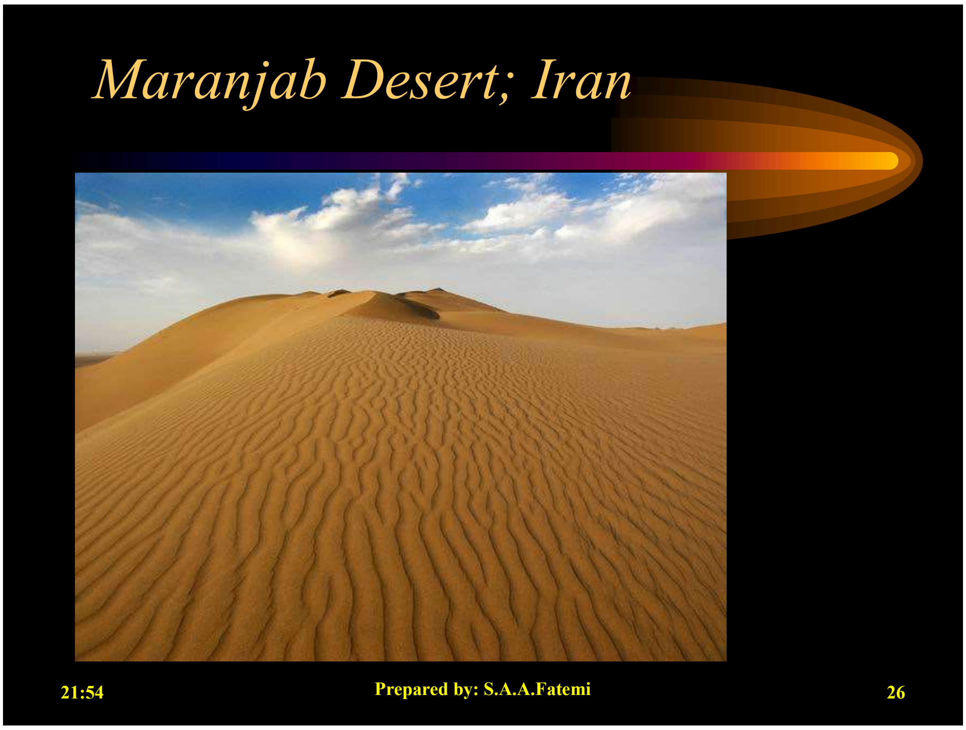
Maranjab Desert; Iran
21:54
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Alluvial Deposits

- Transported and deposited by rivers/streams
- Water picks up soil particles when the flow velocity is higher, deposits sediment load when the velocity decreases (when river enters flatter terrain and widens)
- *Alluvial fans* – coarse particles dropped out to form triangular shaped deposits
- *Deltaic deposits* – more or less triangular shaped areas of alluvial deposits in the vicinity of river mouths known as deltas
- *Point bars*- deposits formed on the inside of a bend
- *Natural levees* - long ridges parallel to river banks formed during flooding

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Alluvial Fan; Death Valley, CA

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Alluvial Fan

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Glacial Deposits

- Transported and deposited by glaciers
- Mountain glaciers
- Continental glaciers – "Great Ice Age" Sheets of ice expand and advance over land when climatic conditions permitted
- Glacial till = heterogeneous mixture of particles of all sizes, unstratified deposit
- Land form resulting from the process .. *Ground moraine or till plain*
- Lateral moraine, middle moraines, end moraines

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Glacial Deposits

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Glacial Deposits

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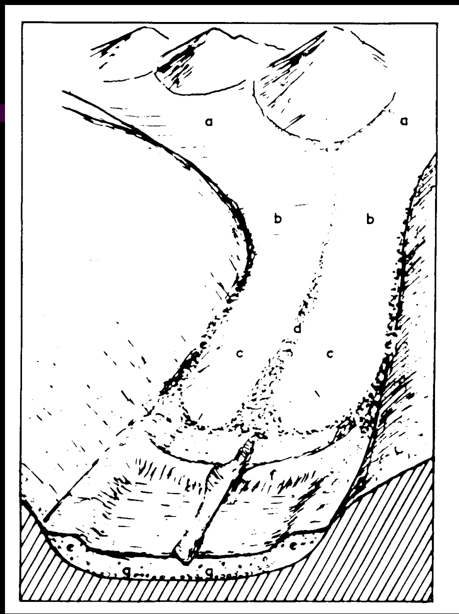
Glacial Deposits

a. Accumulation
b. Debris on glacier
c. Melting area
d. Middle moraine
e. Lateral moraine
f. End moraine
g. Bottom moraine



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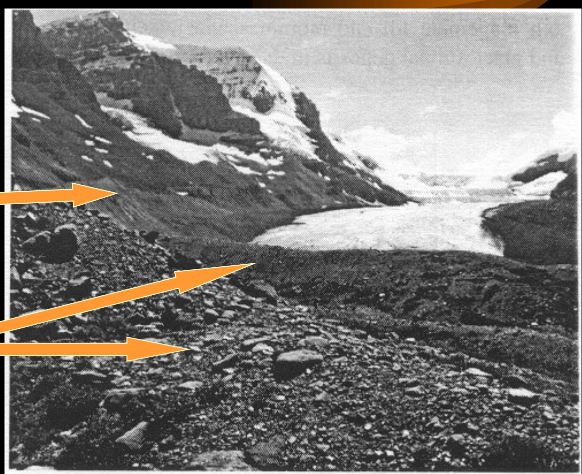
Glacial Deposits



Lateral moraines

Terminal moraine

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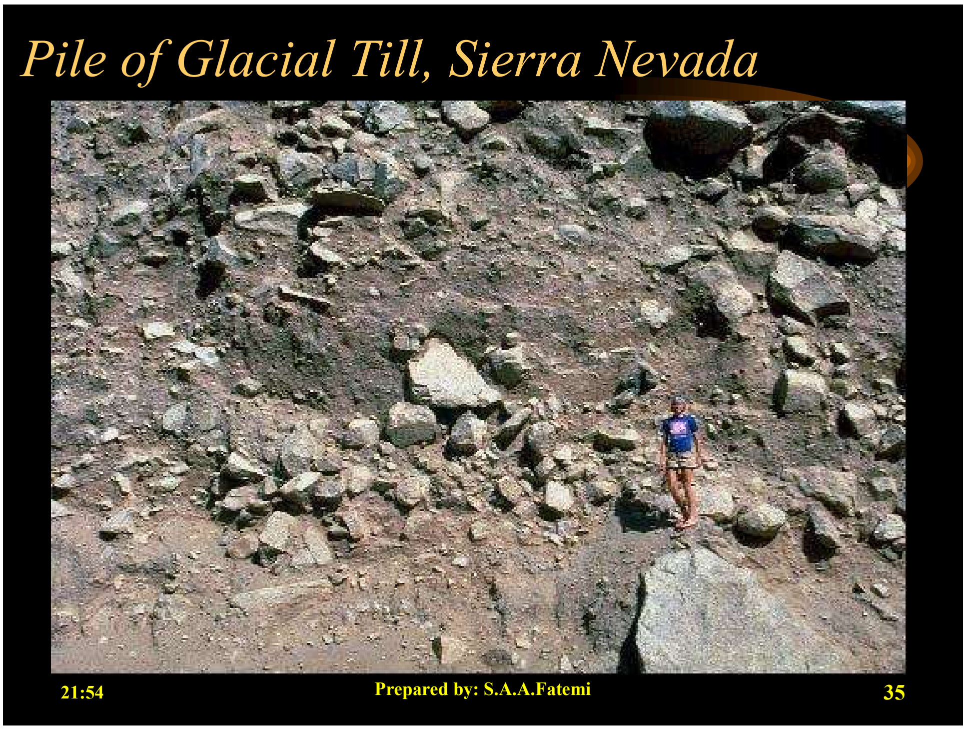
Pile of Glacial Till, Sierra Nevada
21:54
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Lateral Moraine
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Other Types of Soil Deposits

- *Lacustrine* – lake bed deposited
- Marine deposits
- *Caliche* – Layers of soil cemented together by carbonates deposited as a result of evaporation; found in semi arid climates
- *Varved clay* - alternating layers of medium gray inorganic silt and darker silty clay. Thickness of individual layers rarely exceed 10mm. Formed in freshwater environment by melt water from glaciers

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Post Depositional Changes

- Desiccation
  - Drying of fine-grained soil ususally accompanied by shrinkage and cracking
  - Cause of apparent overconsolidation
- Weathering
  - New soil forming processes after exposure to atmosphere
  - Uplifted marine clays Cation exchange Na^+ replaced by K^+

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Post Depositional Changes

- Consolidation
  - Densification of soil due to overburden, lowering of water table etc.
  - Strength increases; compressibility & permeability decreases
- Jointing and Fissuring
  - Usually associated with unloading and/or drying

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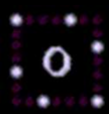
Atomic Structure



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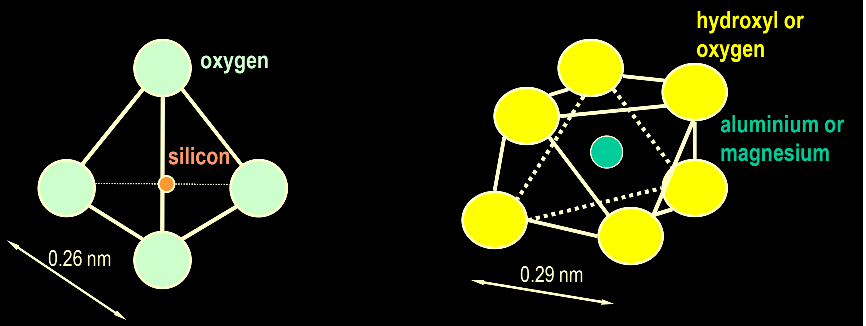
Basic Structural Units

Clay minerals are made of two distinct structural units.



Silicon tetrahedron **Aluminium Octahedron**

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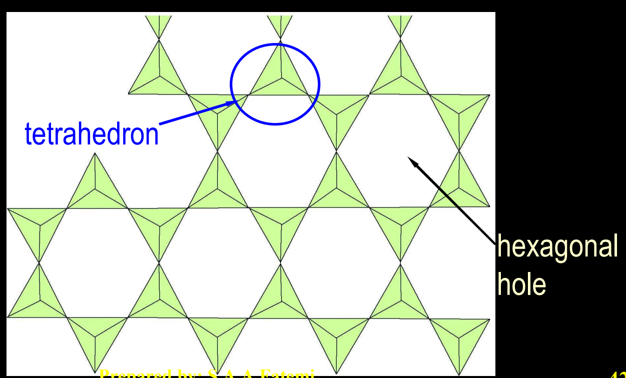
Tetrahedral Sheet

Several tetrahedrons joined together form a tetrahedral sheet.



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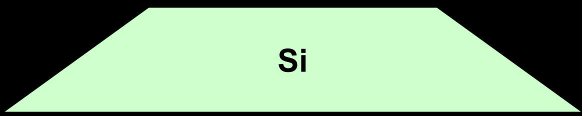
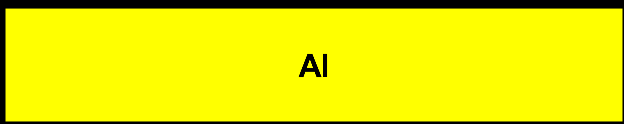
Tetrahedral & Octahedral Sheets

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



and alumina **octahedral sheet** by:



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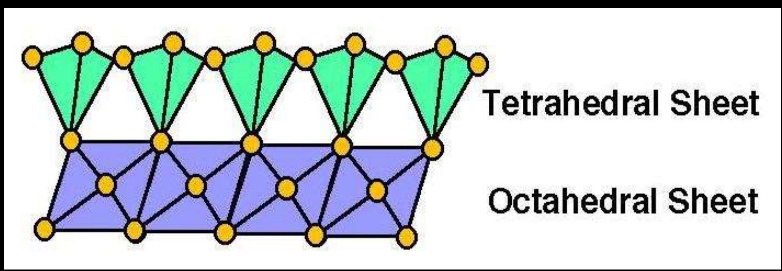
Different Clay Minerals

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

<u>1:1 Clay Mineral</u> (e.g., kaolinite, halloysite):



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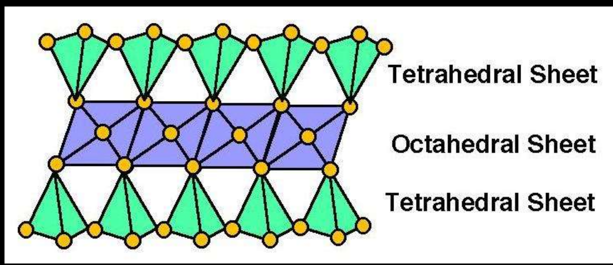
Different Clay Minerals

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

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



Clay Mineral Groups

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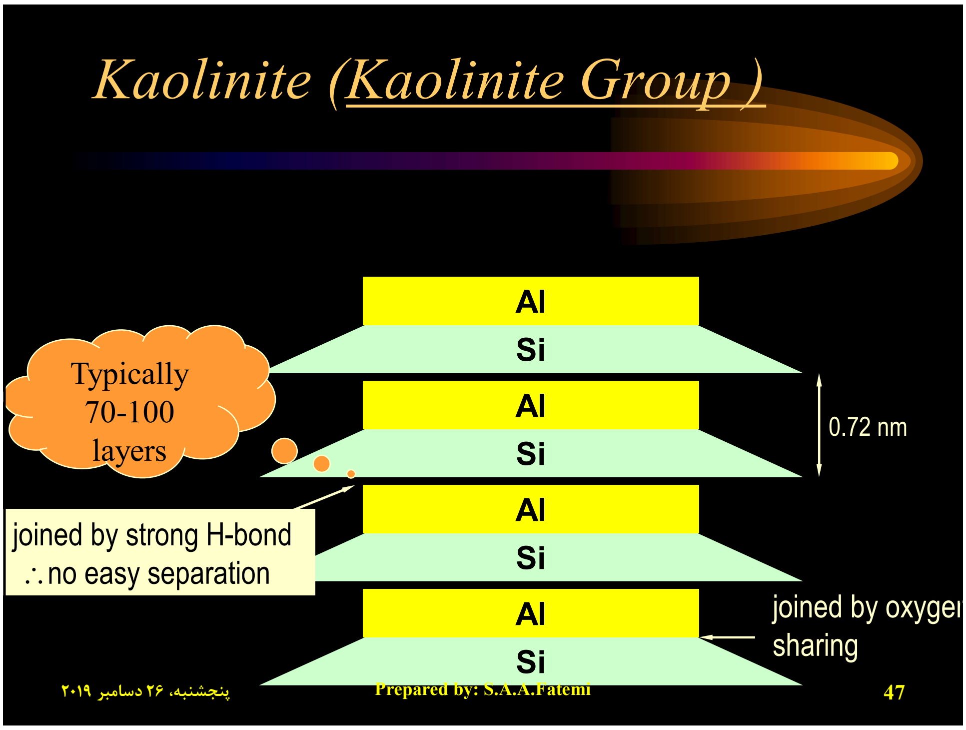
- Kaolinite Group
  - Kaolinite, Serpentine, Halloysite
- Smectite Group
  - Montmorillonite, Saponite
- Illite Group
  - Muscovite, Illite, Vermiculite
- Chlorite Group



Kaolinite (Kaolinite Group)
Al
Si
Al
Si
Al
Si
Al
Si
Typically 70-100 layers
0.72 nm
joined by strong H-bond
∴ no easy separation
joined by oxygen sharing
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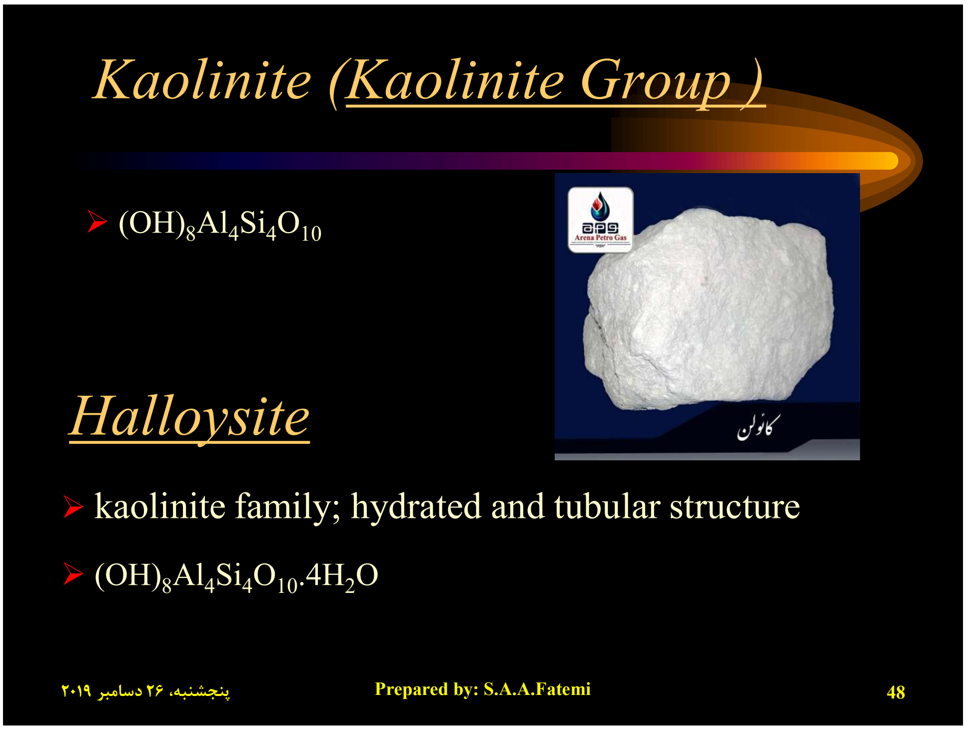

Kaolinite (Kaolinite Group)
➢ $(OH)_8Al_4Si_4O_{10}$
کائولن
Halloysite
➢ kaolinite family; hydrated and tubular structure
➢ $(OH)_8Al_4Si_4O_{10}.4H_2O$
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Kaolinites

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- Conditions that favor its formation:
  - When silica is less abundant (cf. to alumina) hence 1:1 structure
  - Low pH, leaching
  - Found in areas where precipitation is high and drainage is good
- Primary constituent in china clay; used by ceramics industry; also by paper, paint and pharmaceutical industries
- Interlayer bonding through H-bonds

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Kaolin mine, Bulgaria

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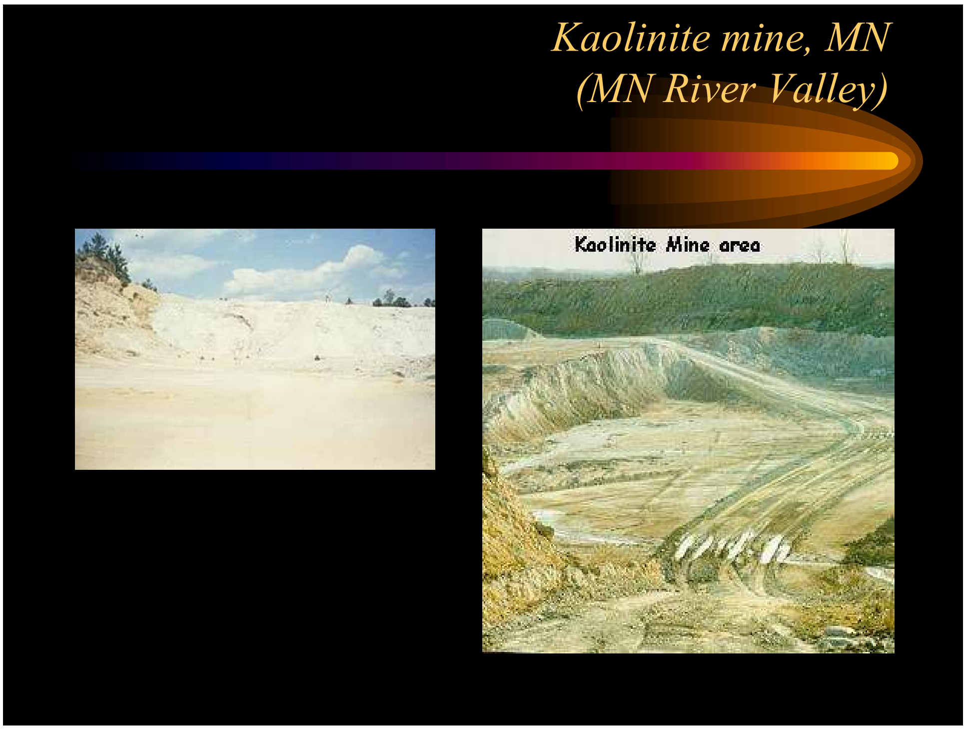
Kaolinite mine, MN
(MN River Valley)
Kaolinite Mine area

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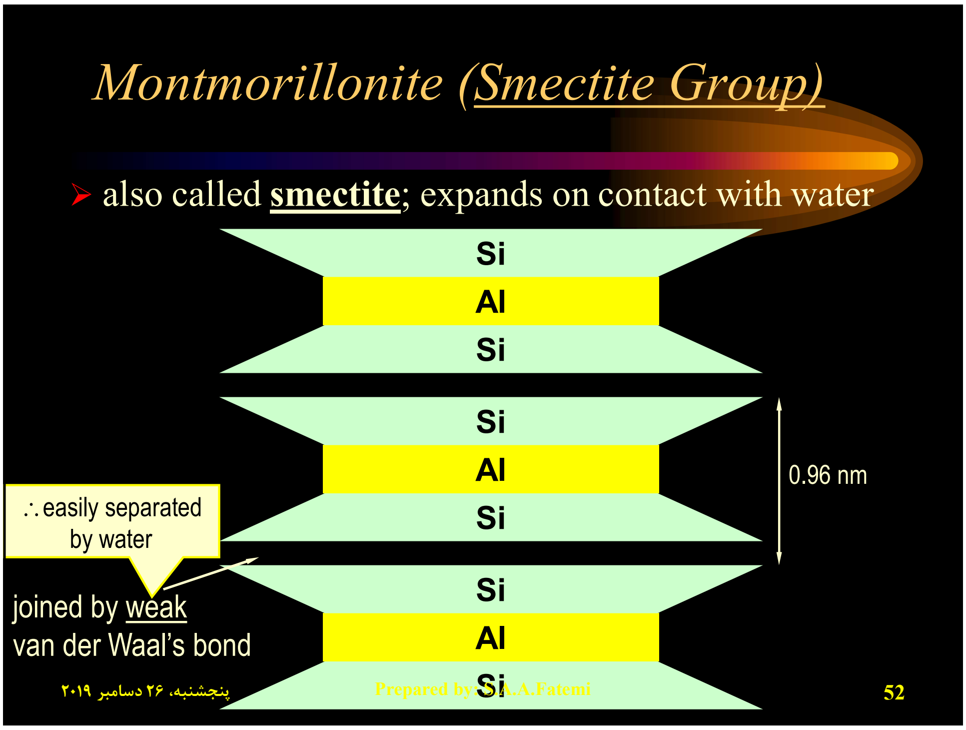
Montmorillonite (Smectite Group)
also called smectite; expands on contact with water
Si
Al
Si
Si
Al
Si
Si
Al
Si
0.96 nm
∴ easily separated by water
joined by weak van der Waal's bond
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Montmorillonite (Smectite Group)

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

swells on contact with water

high affinity to water

Bentonite

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

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Smectites

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- Conditions that favor its formation:
  - When silica is abundant (compared to alumina) hence 2:1 structure
  - High pH, High electrolyte content, More Mg^{2+} and Ca^{2+} than K^+ and Na^+; poor leaching
  - Found in areas where evaporation exceeds precipitation (arid and semi-arid climates)
- Bentonite; clay deposit primarily composed of Montmorillonite; Formed by weathering of volcanic ash; Used in drilling mud, slurry trench wall construction, sealing boreholes etc.

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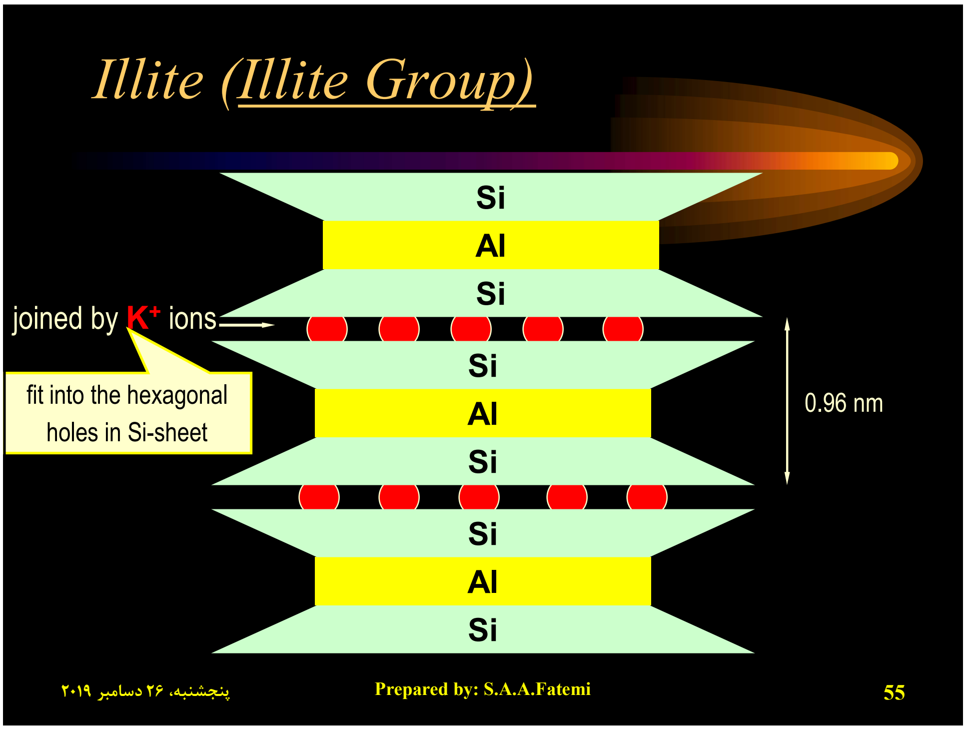

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Others…

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

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Identifying Clay Minerals

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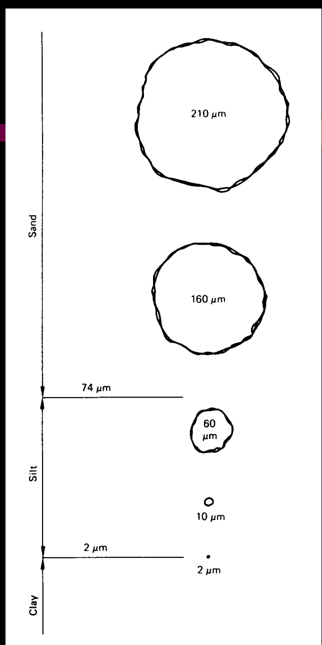
Clay Formation

- Clay particles < 2 μm
- Compared to Sands and Silts, clay size particles have undergone a lot more "chemical weathering"!



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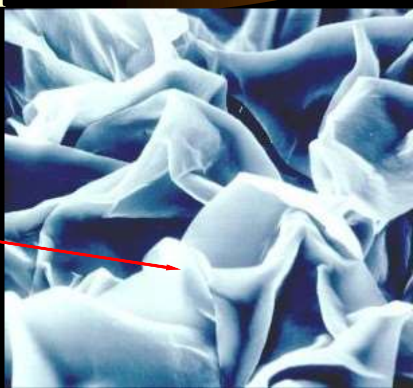
Clay vs. Sand/Silt

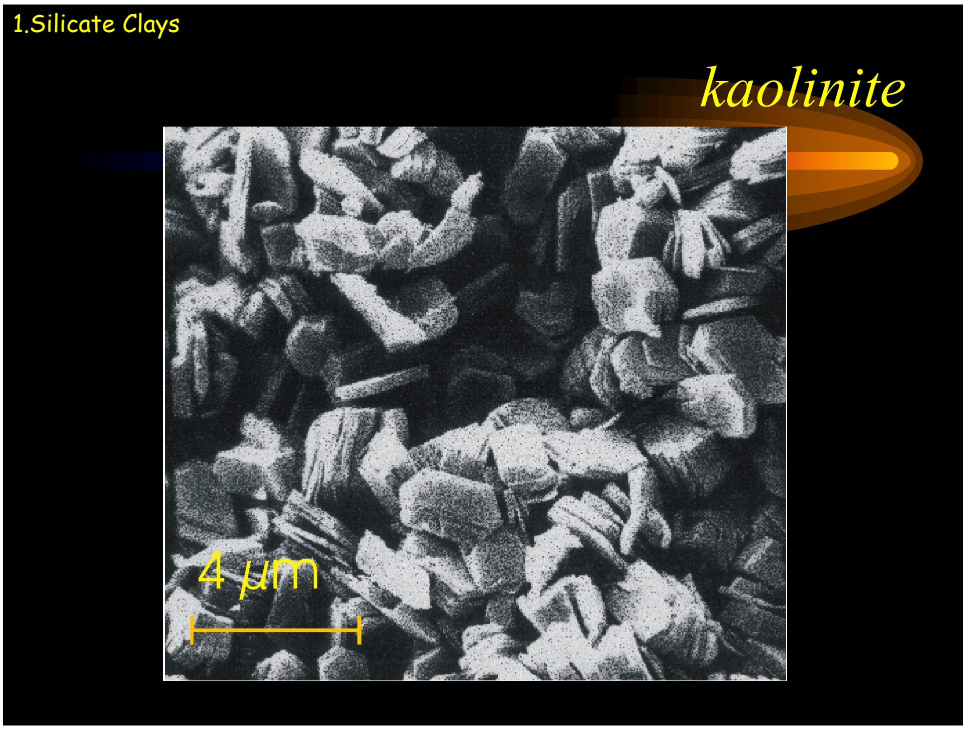
- Clay particles are generally more platy in shape (sand more equi-dimensional)
- Clay particles carry surface charge
- Amount of surface charge depends on type of clay minerals
- Surface charges that exist on clay particles have major influence on their behavior (for e.g. plasticity)

Scanning Electron Microscope

- common technique to <u>see</u> clay particles
- qualitative

plate-like structure




1.Silicate Clays
kaolinite
4 µm

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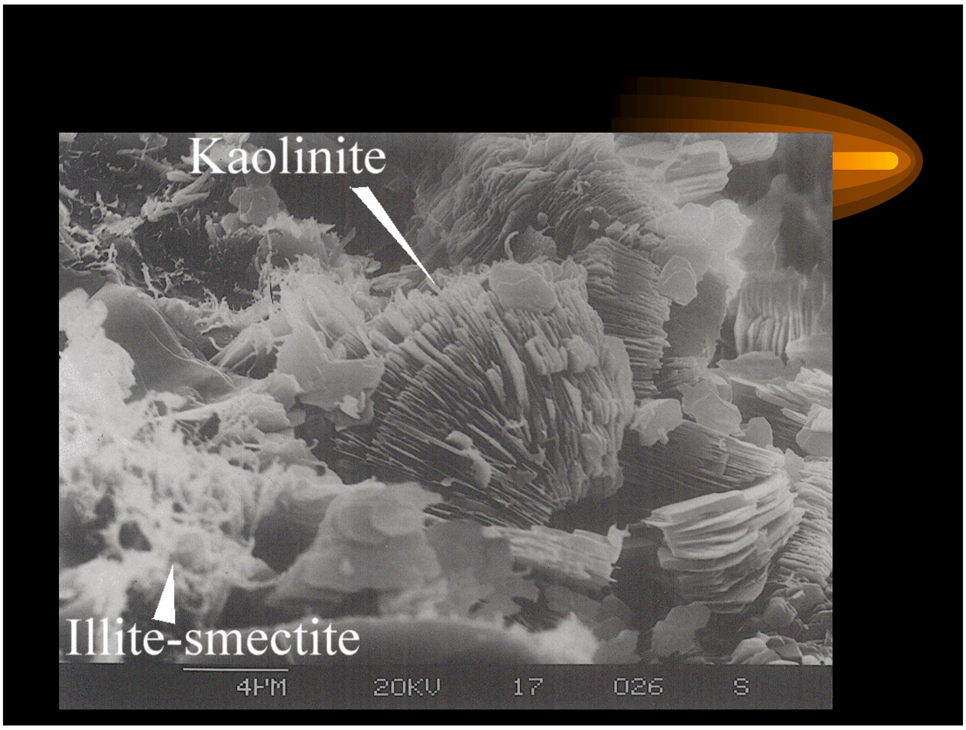
Kaolinite
Illite-smectite
4µM 20KV 17 026 S

62

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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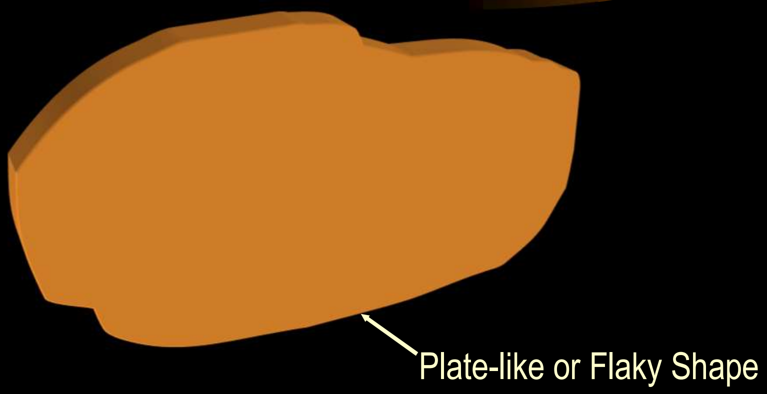
A Clay Particle



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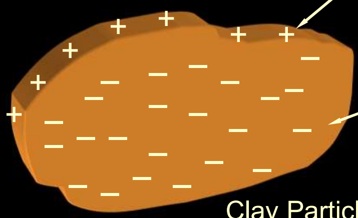
Isomorphous Substitution

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



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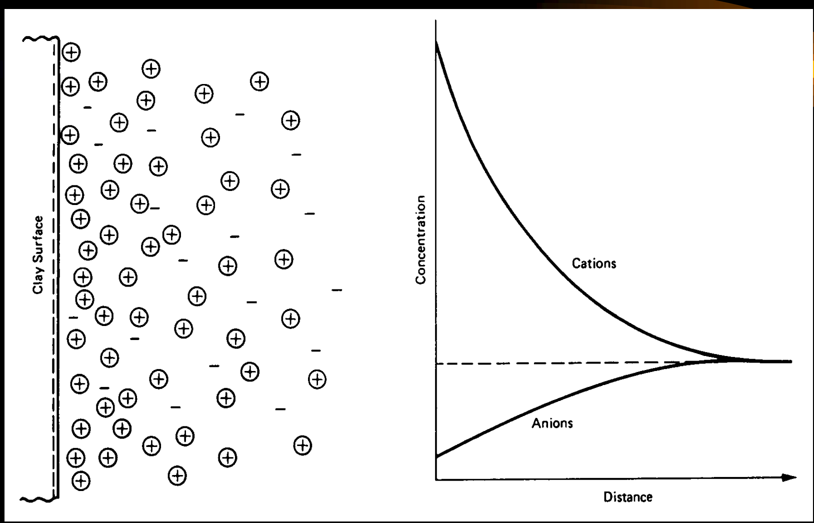
Ion Distributions in Clay-Water Systems



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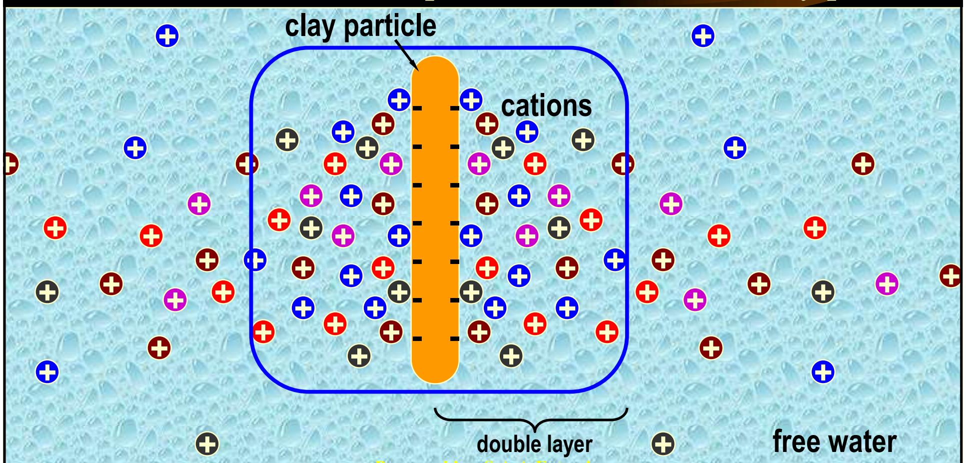
Cation Concentration in Water

- cation concentration drops with distance from clay particle



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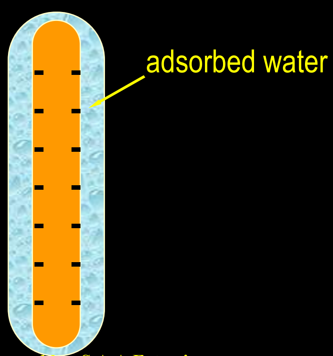
Adsorbed Water

- 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



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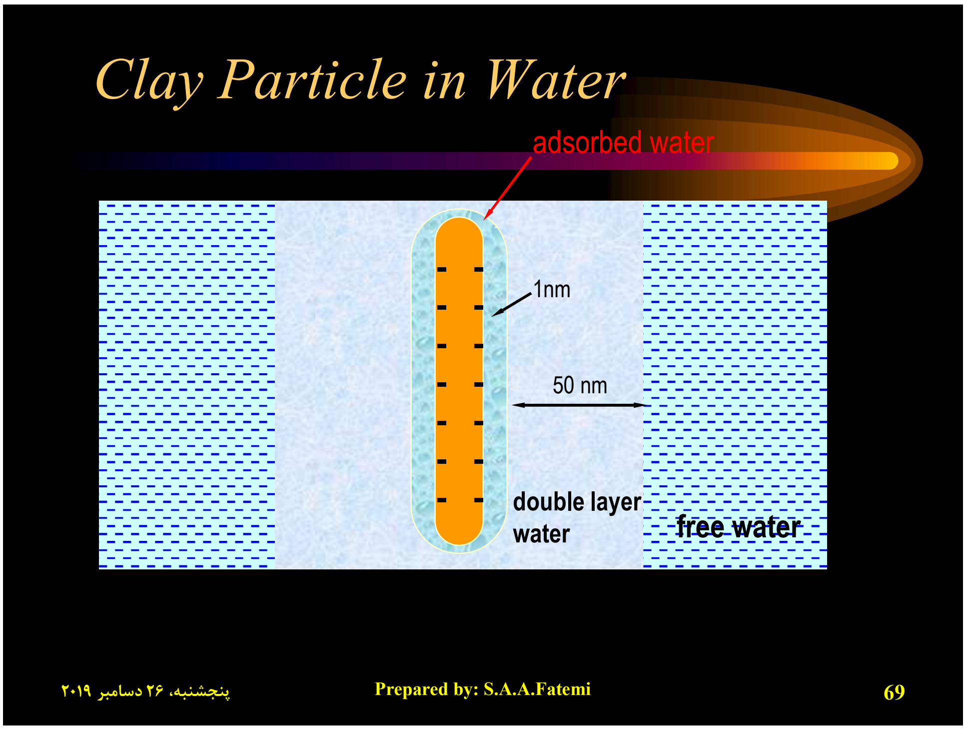
Clay Particle in Water
adsorbed water
1nm
50 nm
double layer water
free water
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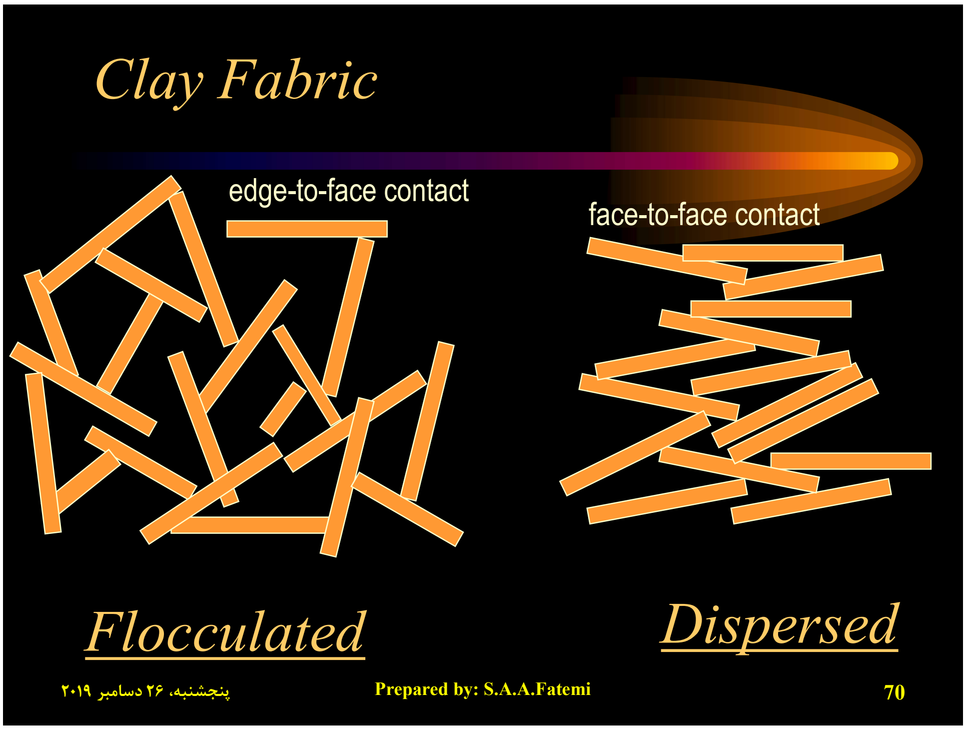
Clay Fabric
edge-to-face contact
face-to-face contact
Flocculated
Dispersed
پنجشنبه، ۲۶ دسامبر ۲۰۱۹
Prepared by: S.A.A.Fatemi
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Summary - Clays

- 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.

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