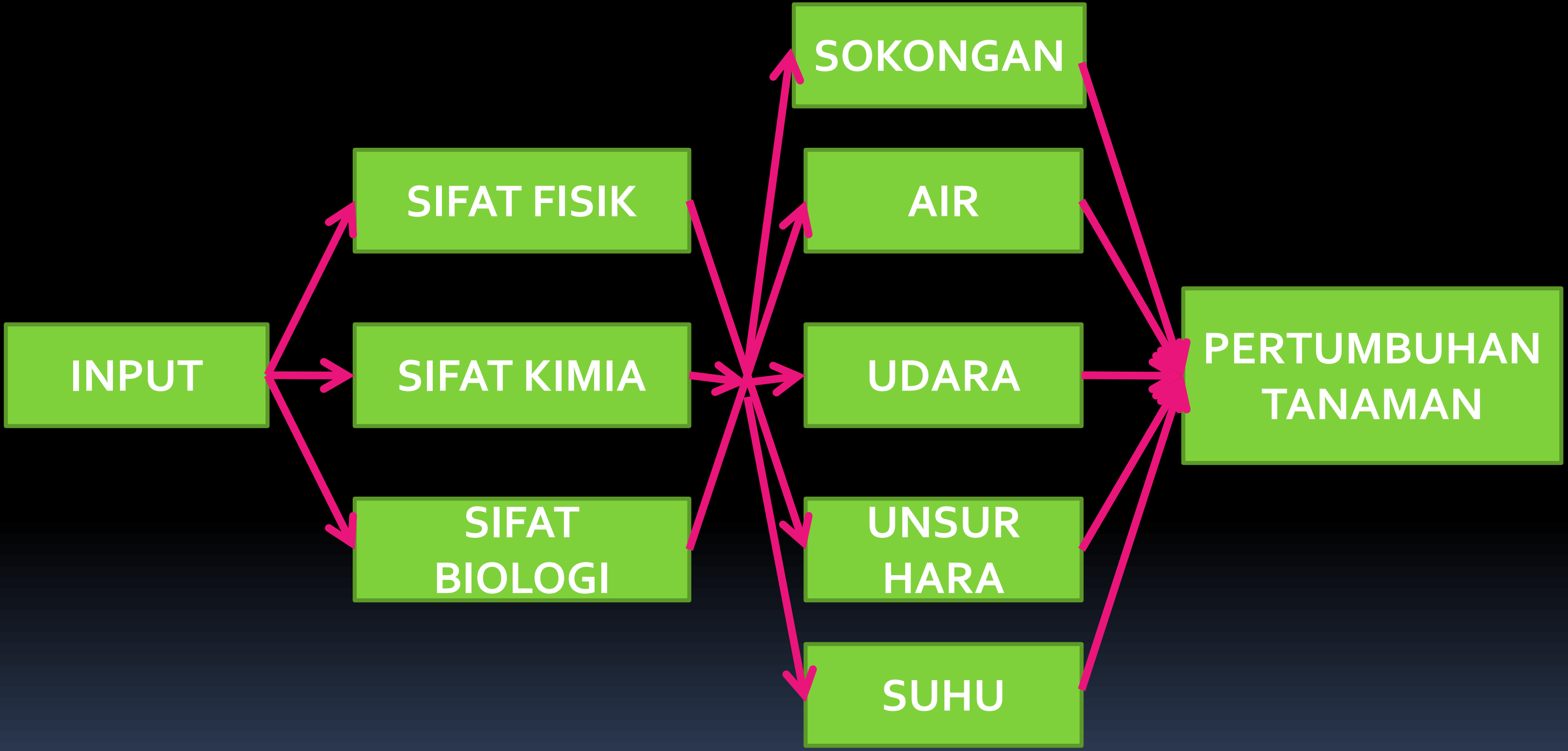
2. KOLOID TANAH DAN KESUBURAN TANAH



INPUT

SIFAT FISIK

SIFAT KIMIA

SIFAT BIOLOGI

SOKONGAN

AIR

UDARA

UNSUR HARA

SUHU

PERTUMBUHAN TANAMAN

2. KOLOID TANAH DAN KESUBURAN TANAH

2.1. Pendahuluan

a. Pengertian Koloid

Koloid adalah partikel berukuran kurang dari 1 mikron sampai berukuran mendekati ukuran molekul dan menunjukkan sifat-sifat koloidal (Gerak Brown dan efek tyndal).

b. Koloid dalam tanah

Koloid dalam tanah secara garis besar dapat dibagi 2:

> Koloid anorganik: mineral liat tanah

> Koloid organik: senyawa humik *(Humic substance)*

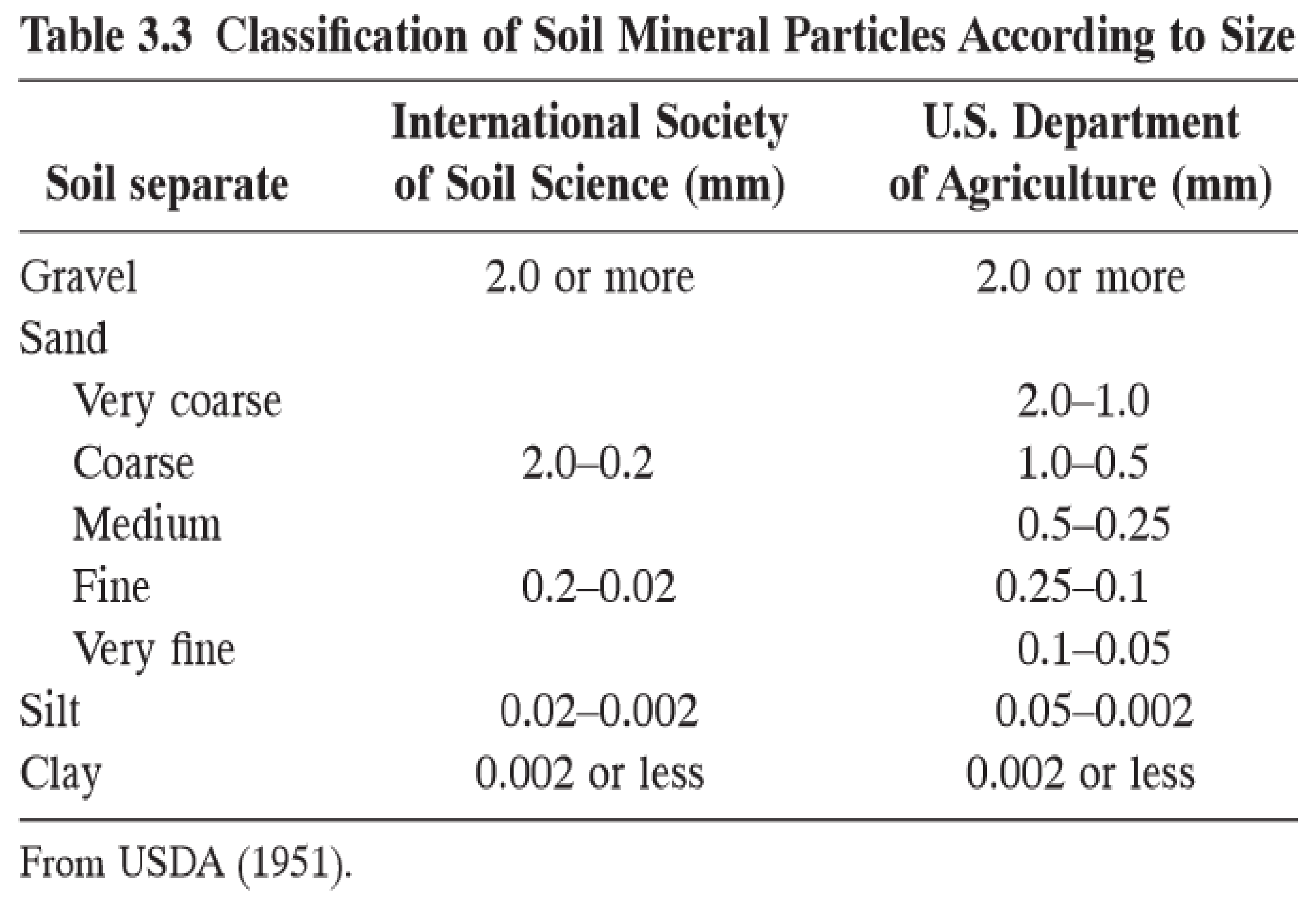


Table 3.3 Classification of Soil Mineral Particles According to Size

Soil separate	International Society of Soil Science (mm)	U.S. Department of Agriculture (mm)
Gravel	2.0 or more	2.0 or more
Sand		
Very coarse		2.0–1.0
Coarse	2.0–0.2	1.0–0.5
Medium		0.5–0.25
Fine	0.2–0.02	0.25–0.1
Very fine		0.1–0.05
Silt	0.02–0.002	0.05–0.002
Clay	0.002 or less	0.002 or less

From USDA (1951).

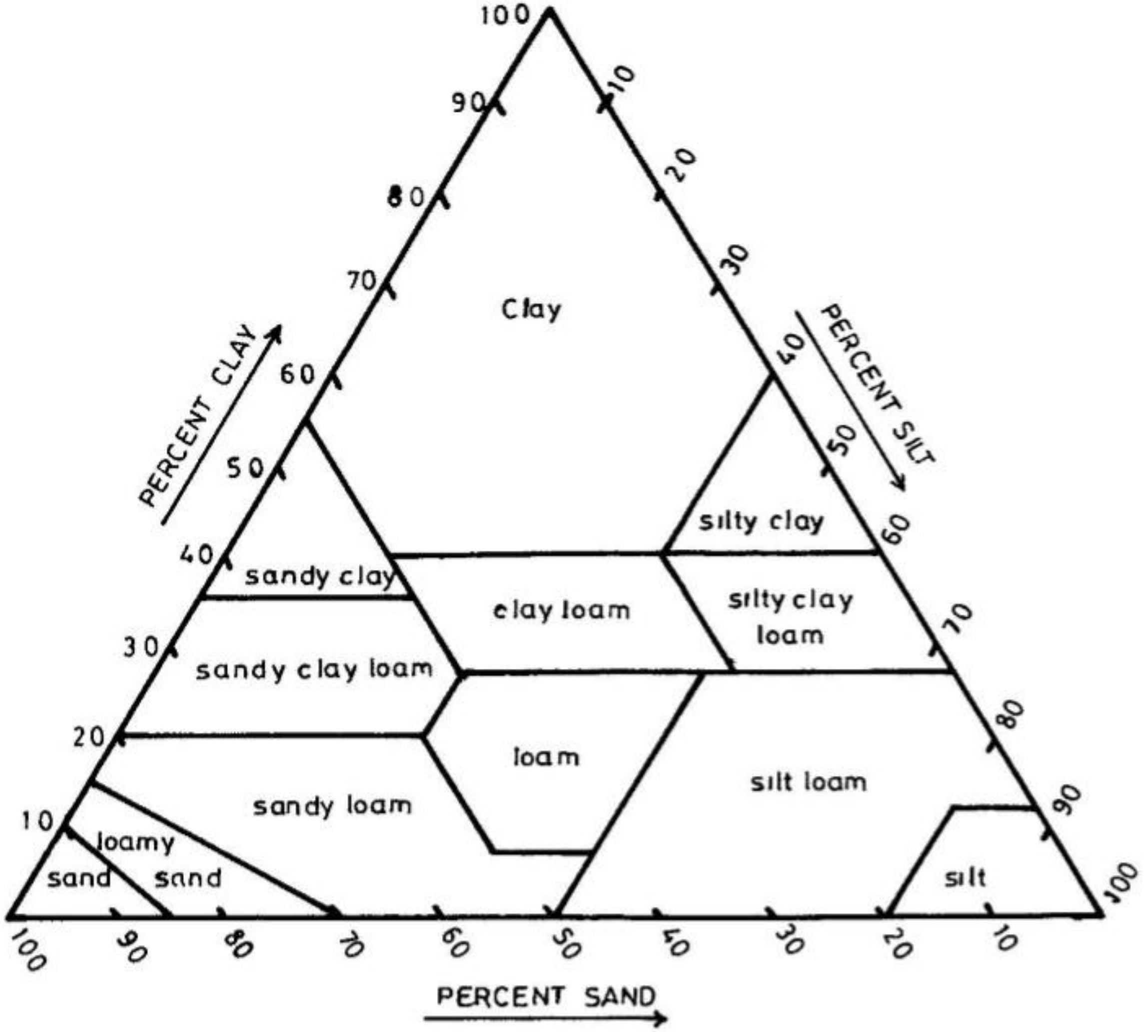


Figure 3.4. Chart showing the percentages of clay (below 0.002 mm), silt (0.002 to 0.05 mm), and sand (0.05 to 2.0 mm) in the basic soil textural classes. (From USDA, 1951.)

KOLOID

- is: partikel berukuran < 1 µm sampai mendekati ukuran molekul yang menunjukkan sifat2 koloidal.
- Sifat koloidal: menunjukkan gerak brown dan efek tindal

Koloid Tanah:

Is: partikel tanah yang menunjukkan sifat-sifat koloidal. Why? Karena liat yg mrp partikel tanah yg ukurannya <2 µm termasuk koloid.

Koloid tanah terdiri dari koloid anorganik (mineral liat) dan organik (senyawa humik/humic compound/humic substance)

❑ Apa Kepentingan koloid tanah?

Koloid tanah menentukan sifat fisik, kimia bahkan biologi tanah. Sifat fisik dan kimia apa saja yang dipengaruhi koloid tanah

Manfaat Koloid Tanah

1. Di bidang Pertanian

Berperanan dalam kesuburan tanah, shg berpengaruh thd pertumbuhan tanaman.

2. Di Bidang Konservasi Tanah dan Air

Koloid tanah menentukan sifat fisika tanah, shg berpengaruh terhadap infiltrasi, permeabilitas. Dg dmk, berpengaruh thd run off dan erosi.

3. Teknik sipil (Bangunan, jalan, dll)

Mineralogi tanah/koloid tanah karena berpengaruh terhadap sifat fisik tanah, sehingga mempengaruhi kekokohan bangunan, jalan, dll.

B. Klasifikasi Mineral

1. Bdsk Genesisnya

Mineral digolongkan ke dalam: mineral primer dan sekunder.

Mineral Primer:

adalah mineral yg terjadi langsung dr magma dan membentuk diri menjadi batuan t3 sbg kerak bumi.

Mineral Sekunder

adalah mineral yang terjadi dr mineral primer yang tlh mengalami pelapukan atau pelarutan dan mengkristal kembali

2. Bdsk Warnanya

Mineral digolongkan ke dalam **mineral terang** dan **gelap.**

Mineral terang adalah mineral yg tdk berwarna or berwarna putih spt kuarsa.

Mineral Gelap adalah mineral yg berwarna hitam, hijau, coklat, biru, dsb.

3. Bdsk Bobot Jenisnya

Digolongkan ke dalam mineral berat dan mineral ringan. Mineral berat memiliki BJ > 2,9 g/cm^3 sedangkan mineral ringan memiliki BJ < 2,9 g/cm^3

4. Bdsk Kedudukan sbg Penyusun Batuan

Mineral digoloongkan ke dalam mineral utama, tambahan dan mineral pengiring.

Minerl utama: menyusun sebagian besar dari batuan. Mineral tambahan hanya menyusun sebagian kecil dari batuan. Minerl pengiring: mineral yg kadang-kadang ada, ttp terkadang tidak ada dalam suatu batuan.

5. Bdsk sifat dan susunan kimianya (Berzelius dan Mason, 1959):

Terdapat 8 kelas mineral sbb:

1. Unsur tunggal, spt emas (Au), Intan (C) , dll
2. Senyawa sulfida, spt AgS, dll
3. Senyawa oksida dan hidroksida, spt hematit (Fe_2O_3), Limonit ($Fe_2O_3.$ n H_2O), dll.
4. Senyawa Halogen, spt KCl, NaCl, dll.
5. Senyawa karbonat, nitrat, dll: spt $CaCO_3$, $NaNO_3$, dll
6. Senyawa sulfat, Chromat, Molibdat, spt gips ($CaSO_4$. $2H_2O$), dll
7. Senyawa Fosfat, arsenat, vanadat, spt apatit, dll.
8. Senyawa silikat, spt kuarsa, Felsdspar, amfibol, mika dan mineral liat.

> Mineral yg banyak ditemukan dipermukaan bumi adalah silikat yakni hampir 80% kerak bumi tersusun mineral gol. silikat.

> Mineral gol silikat dibedakan atas:

- Neso silikat
- Sorro silikat
- Cyclo silikat
- Ino silikat I (Piroksen)
- Ino silikat II (Amphibol)
- Phylosilikat
- Tektosilikat

> Golongan Phylosilikat terdiri dari:

- 1. Gol. Serpentin
- 2. Gol. mineral liat: Kaolinit, Montmorilonit, dll.
- 3. Gol Mika: Muskovit, Phlogopit, Biotit, Lepidolit, Margarit
- 4. Gol. Khlorit.

Mineral yang terdapat di dalam tanah:

> Komposisi tanah terediri dari: padatan, air, dan udara

> Padatan: terdiri dari komponen anorganik dan organik

> Anorganik : pasir, debu dan liat. Mineral liat dibedakan atas:

1. Kristalin:
   a. Oksida dan hidroksida: Fe, Al, Mn, Si, Ti
   b. Silikat: Neso-, Sorro-, Siklo-, Ino- dan Phyllosilikat
   c. Garam agak larut: karbonat, sulfat, sulfida

2. Non kristalin:
   a. Hidrous oksida dari Al dan Si
   b. Alumino silikat: Alofan, Imogolit dan gelas volkan.

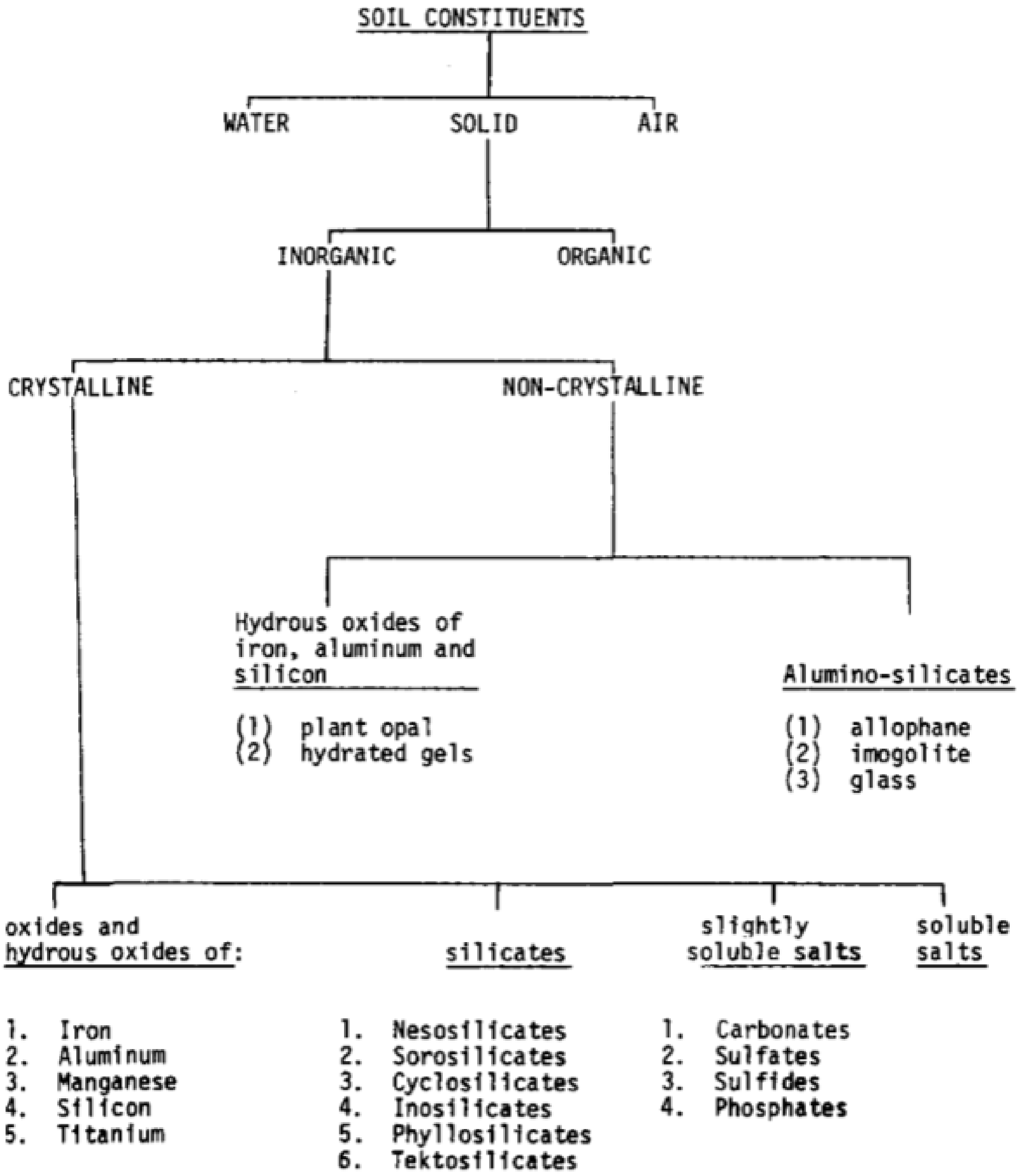


Figure 2.3. Minerals commonly found in soils.

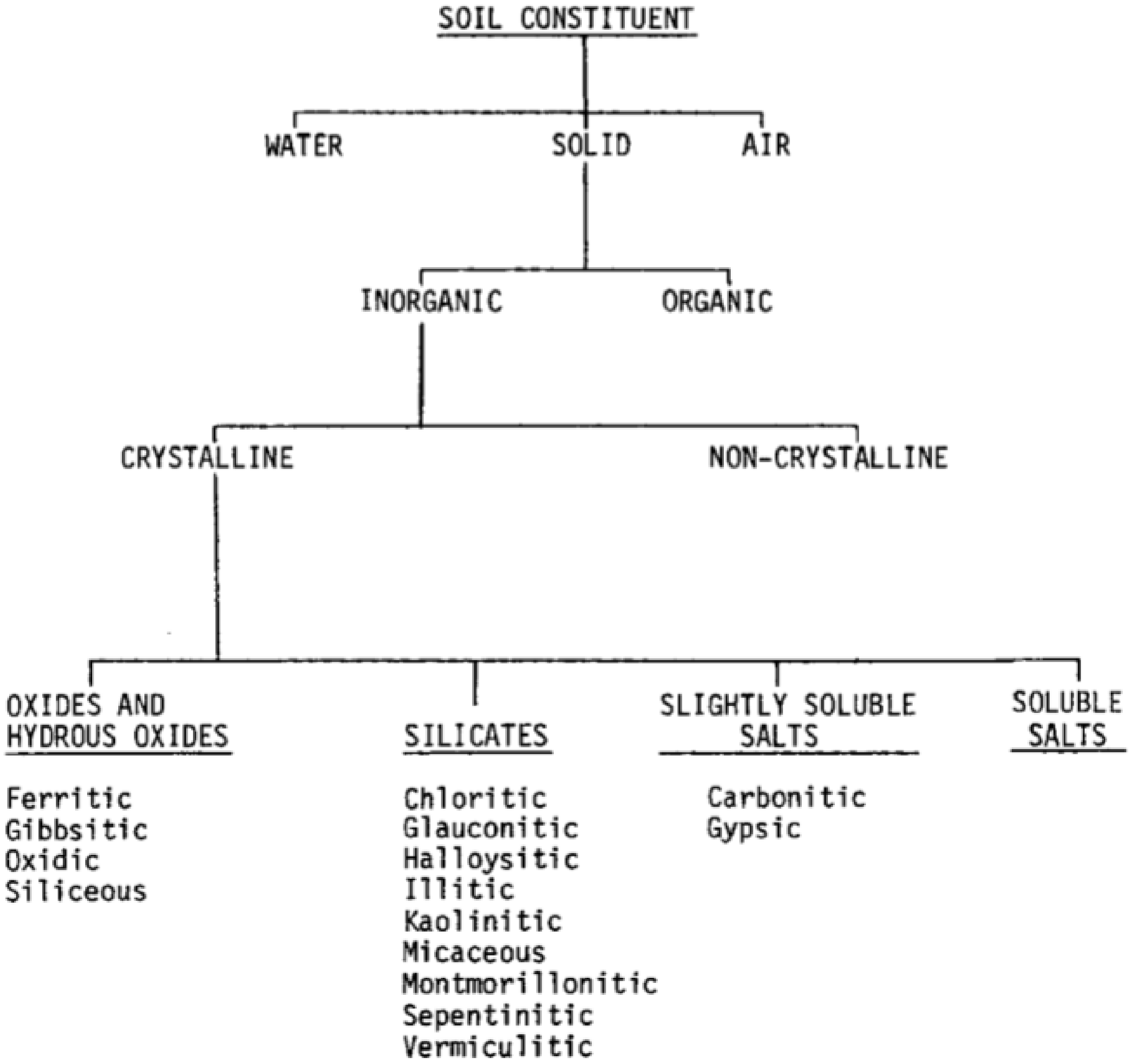


Figure 2.4. Classification of mineralogy according to *Soil Taxonomy.*

- Pengelompokkan tsb berkaitan erat dengan sifat dan ciri tanah
- Tanah kaya mineral primer berarti tanah belum mengalami pelapukan lanjut. Dmk sebaliknya.
- Tanah kaya mineral gelap, berarti tanah ini mudah mengalami pelapukan, dmk sebaliknya.
- Mineral kelas silikat mrp mineral yg dominan di dalam batuan dan tanah.
- Ada hubungan jenis mineral dominan dengan iklim
- Ada hubungan jenis mineral dominan dengan ordo tanah

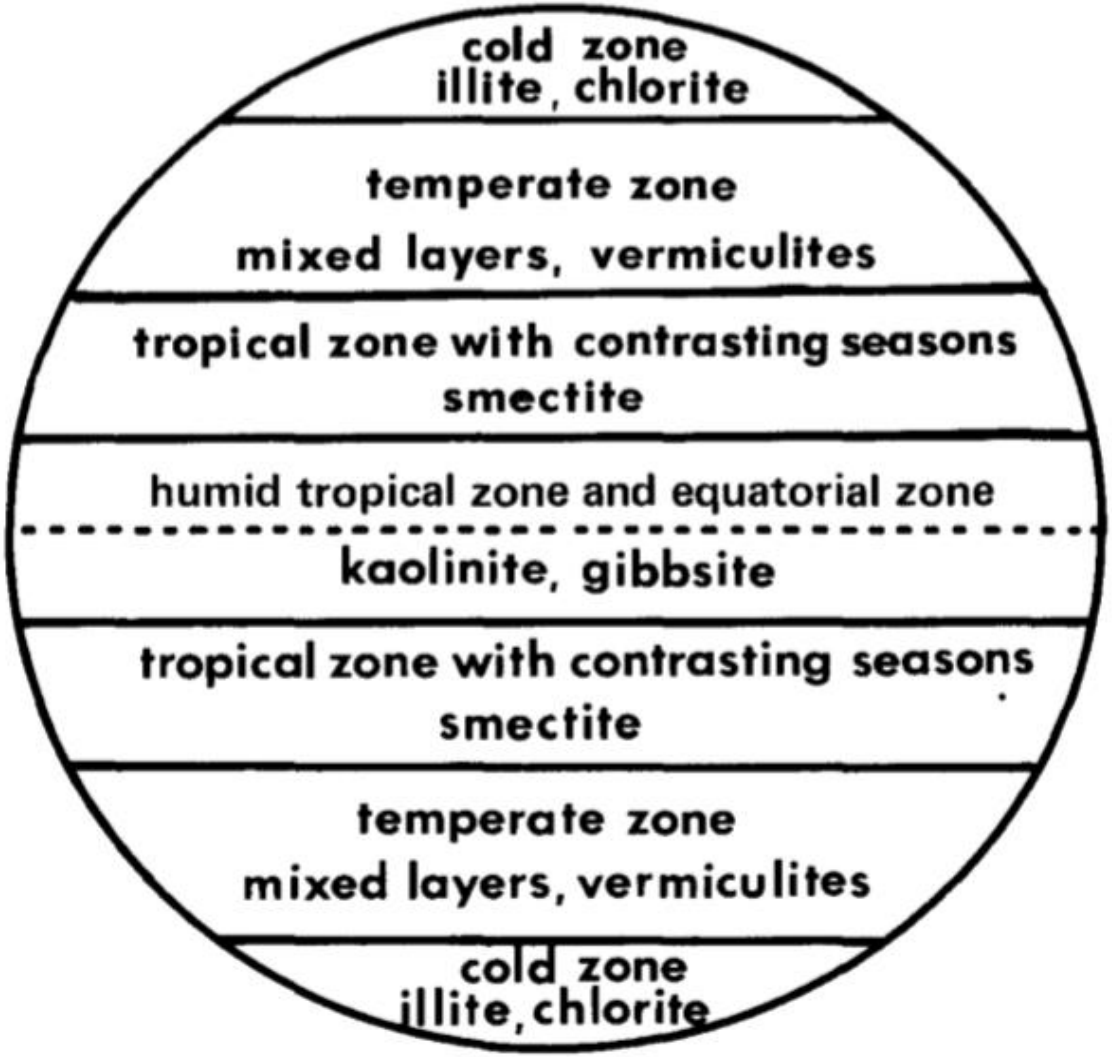


Figure 2.1. The effect of climate on clay mineral occurrence. Millot (1979).

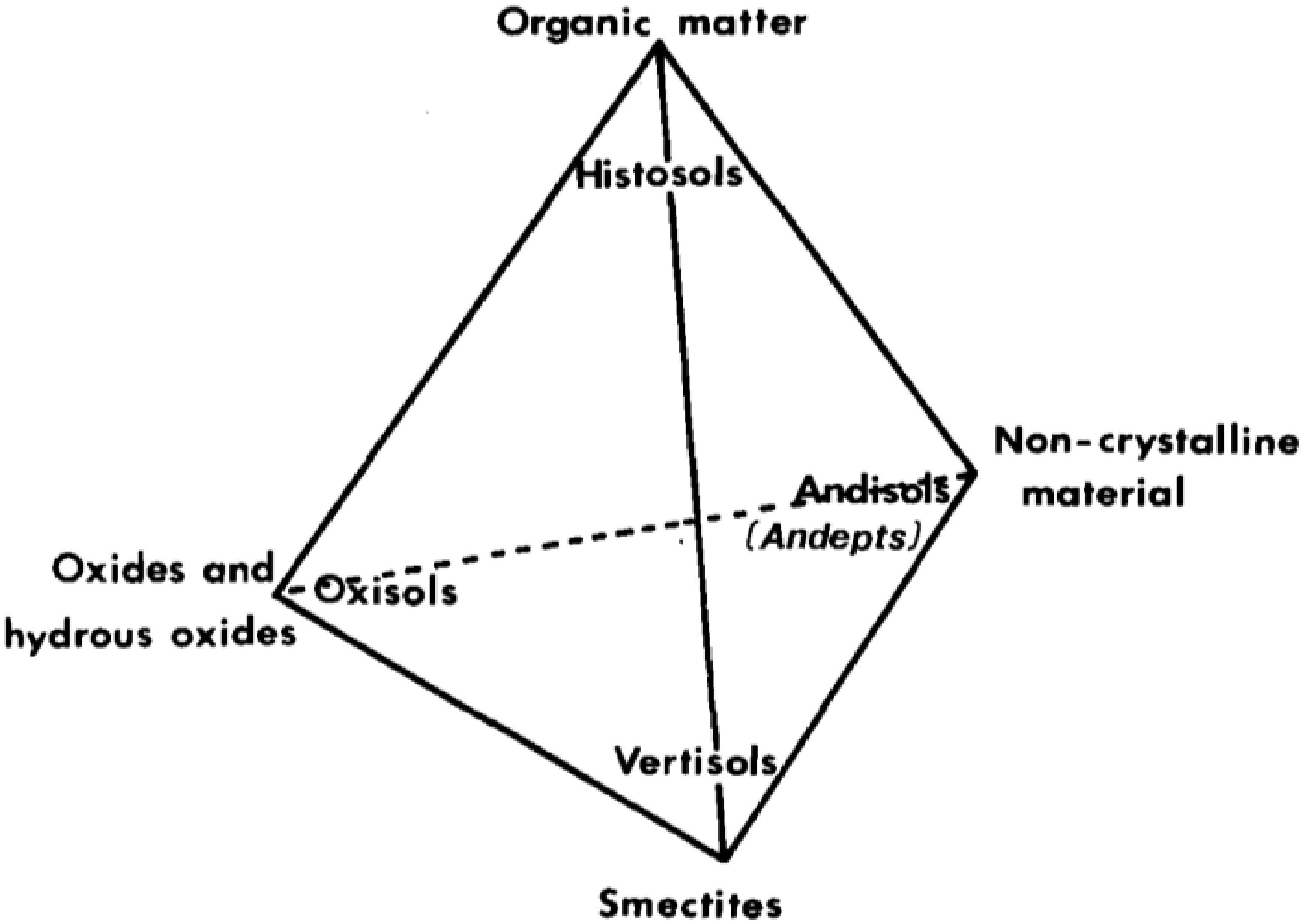


Figure 2.5. Relationship between soil composition and soil classification.

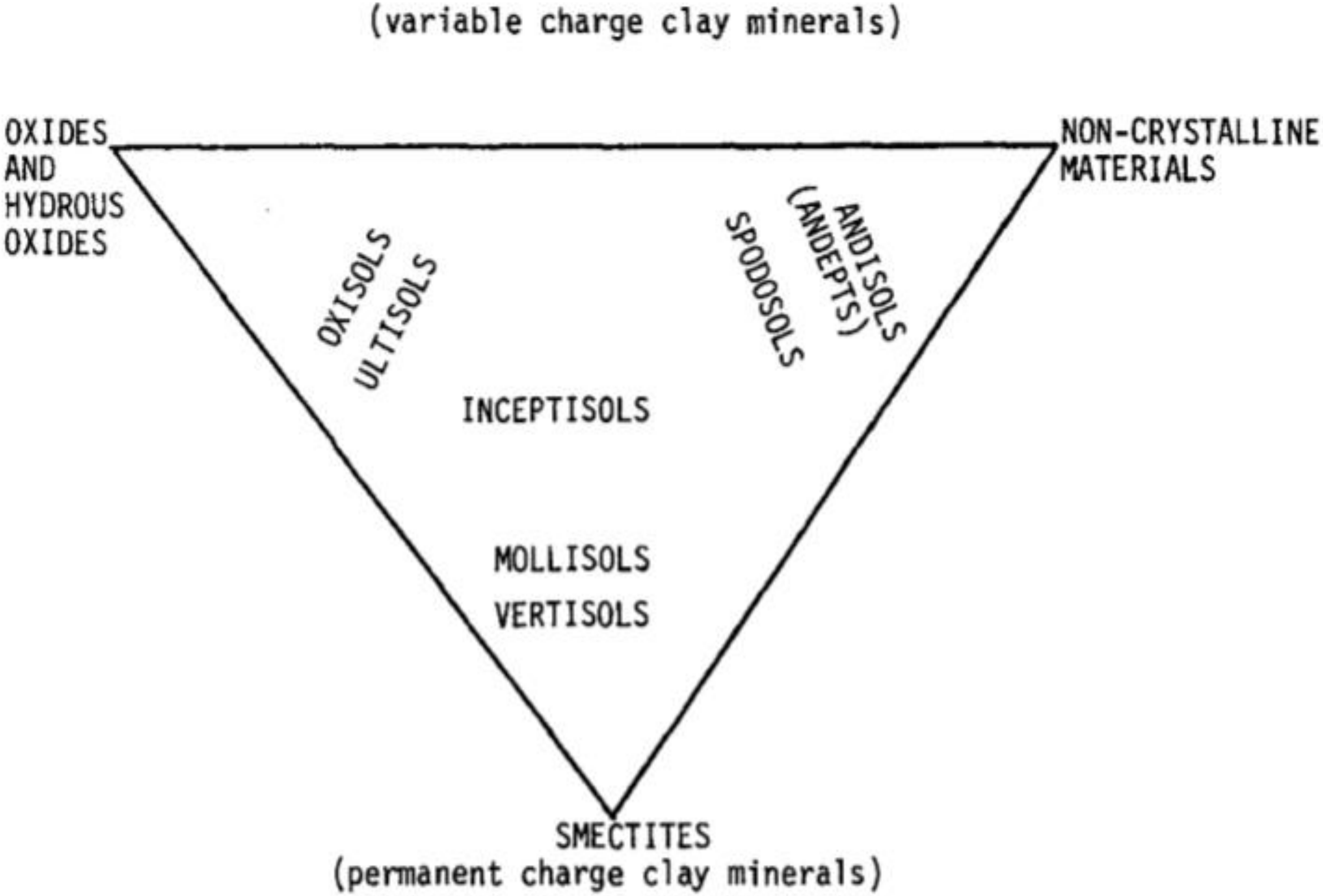
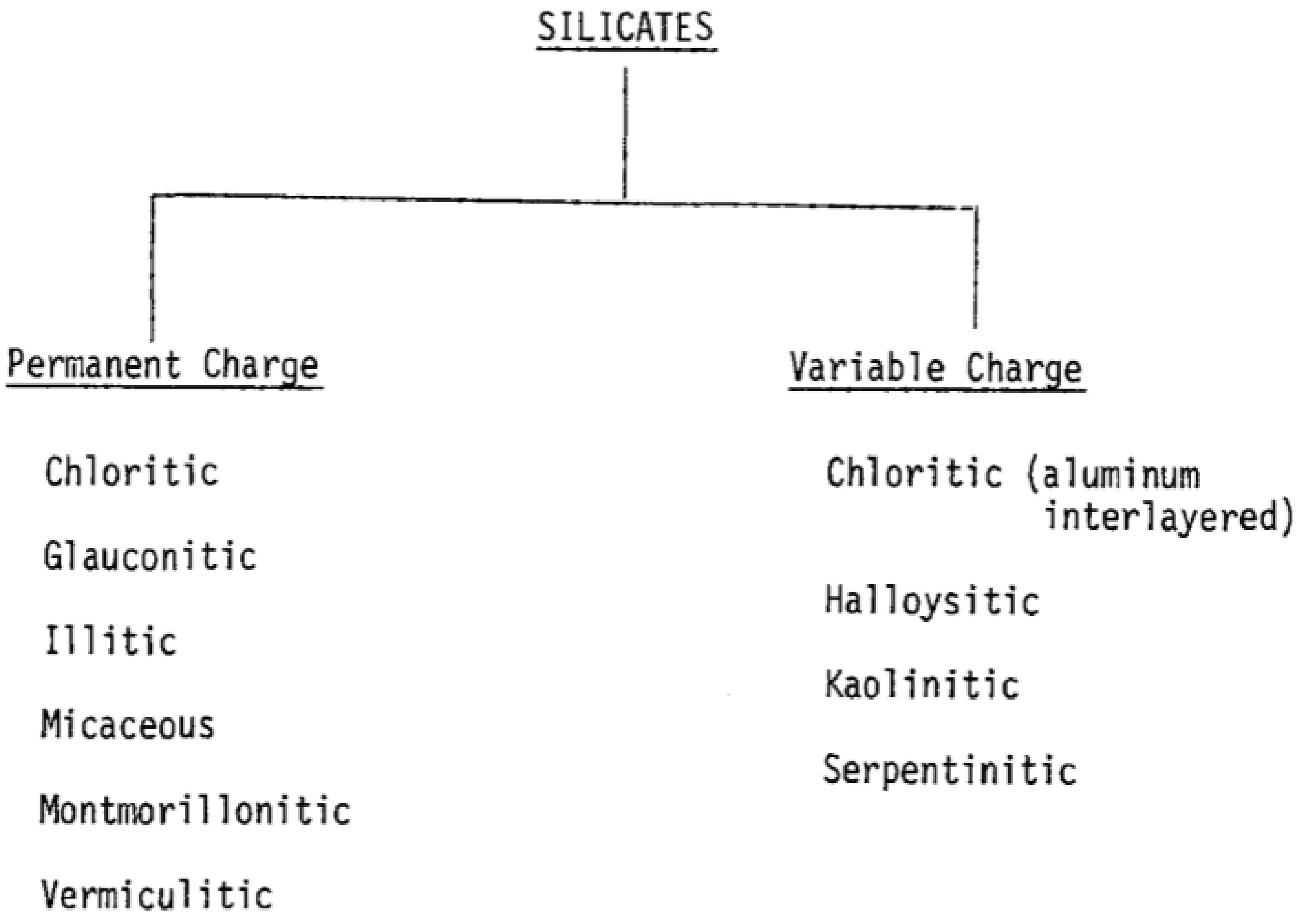


Figure 2.6. Relationship between inorganic soil constituents and soil orders.



SILICATES

Permanent Charge

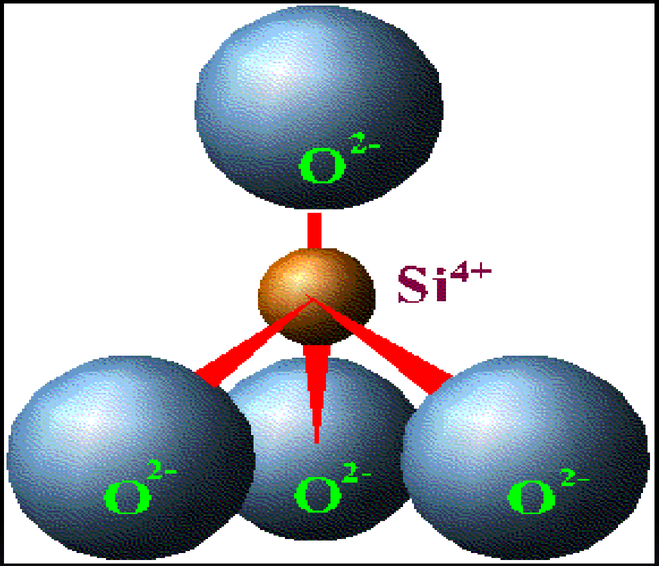
- Chloritic
- Glauconitic
- Illitic
- Micaceous
- Montmorillonitic
- Vermiculitic

Variable Charge

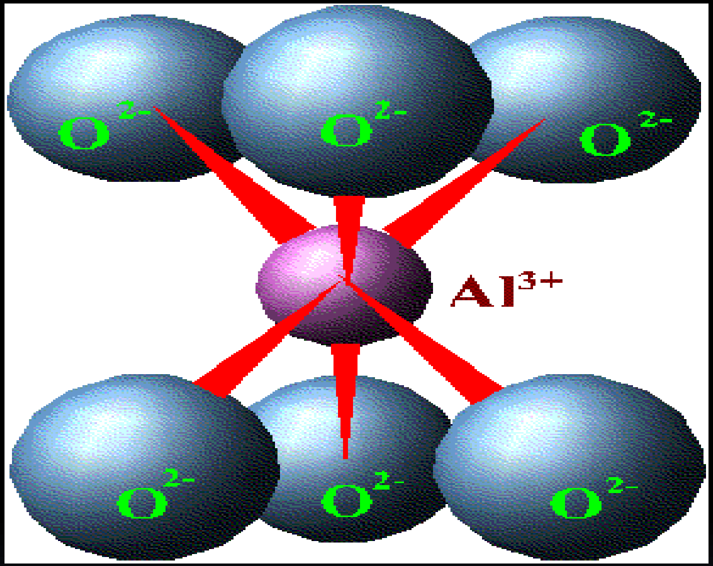
- Chloritic (aluminum interlayered)
- Halloysitic
- Kaolinitic
- Serpentinitic

Figure 2.7. Separation of the silicate mineralogy classes into permanent and variable charge types.

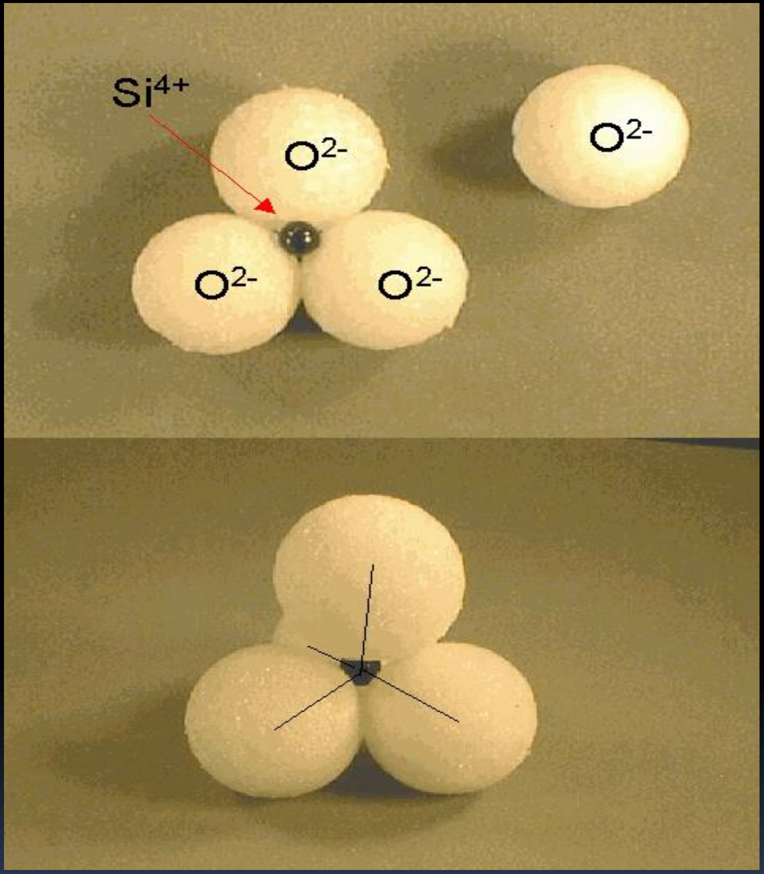
STRUKTUR DASAR MINERL LIAT FILOSILIKAT



Si -Tetrahedra



Al-Oktahedra


Si4+
O2-
O2-
O2-
O2-

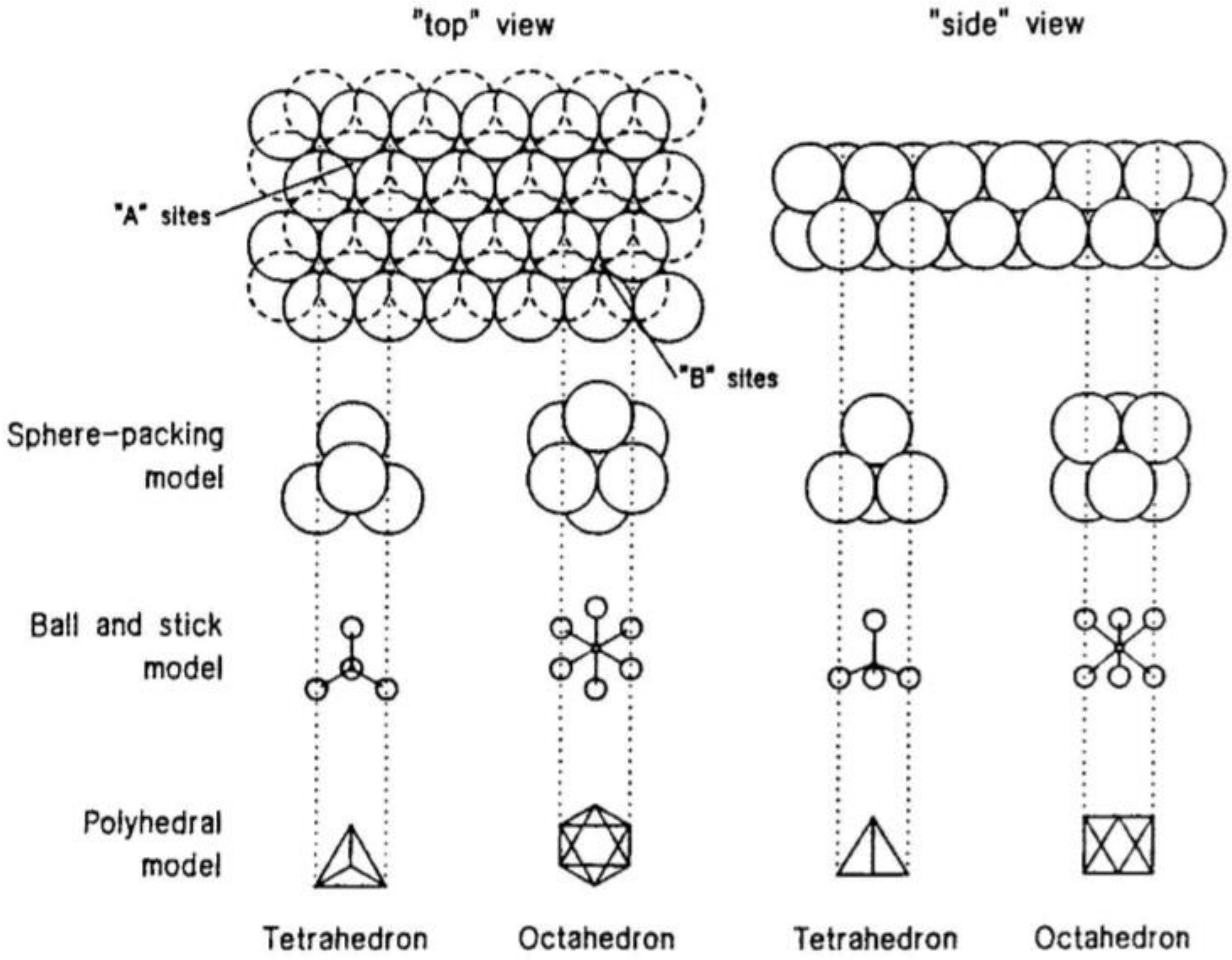
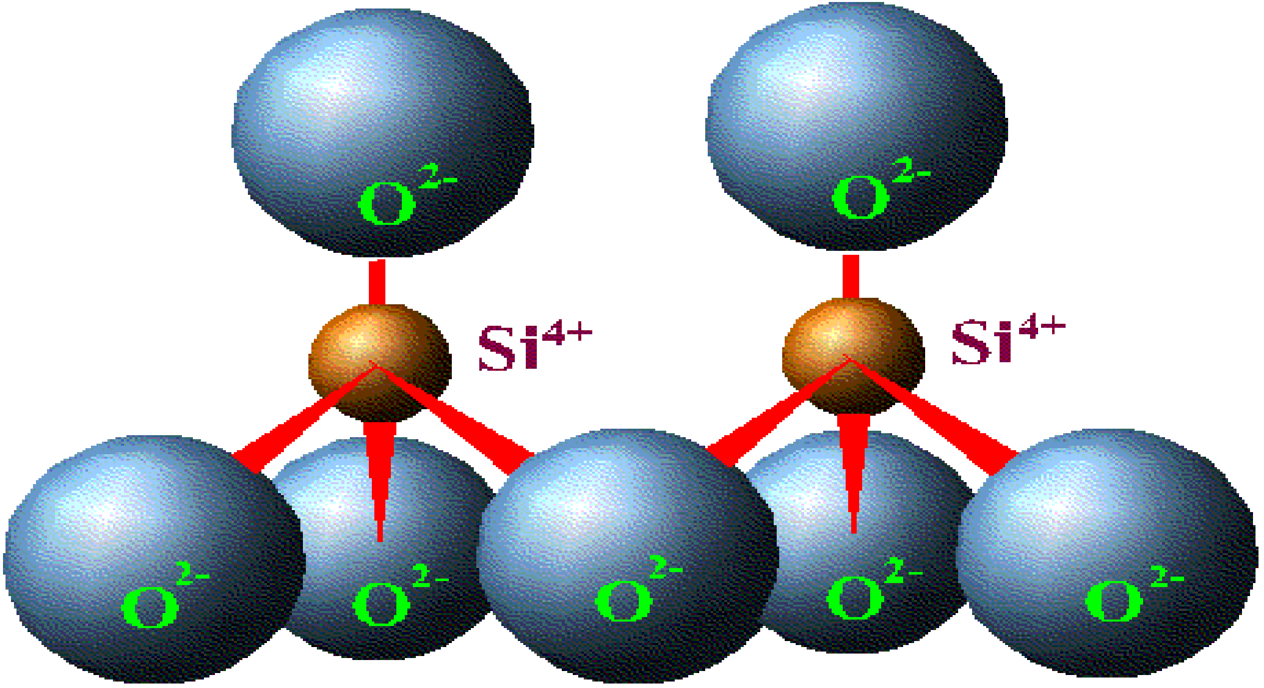
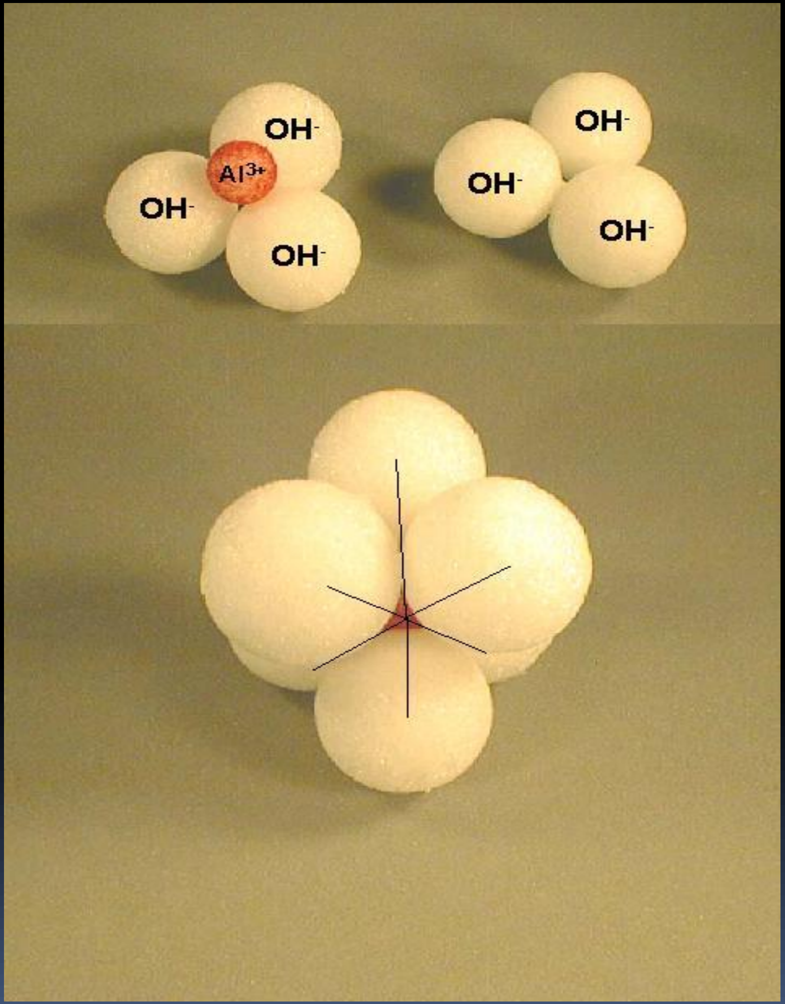
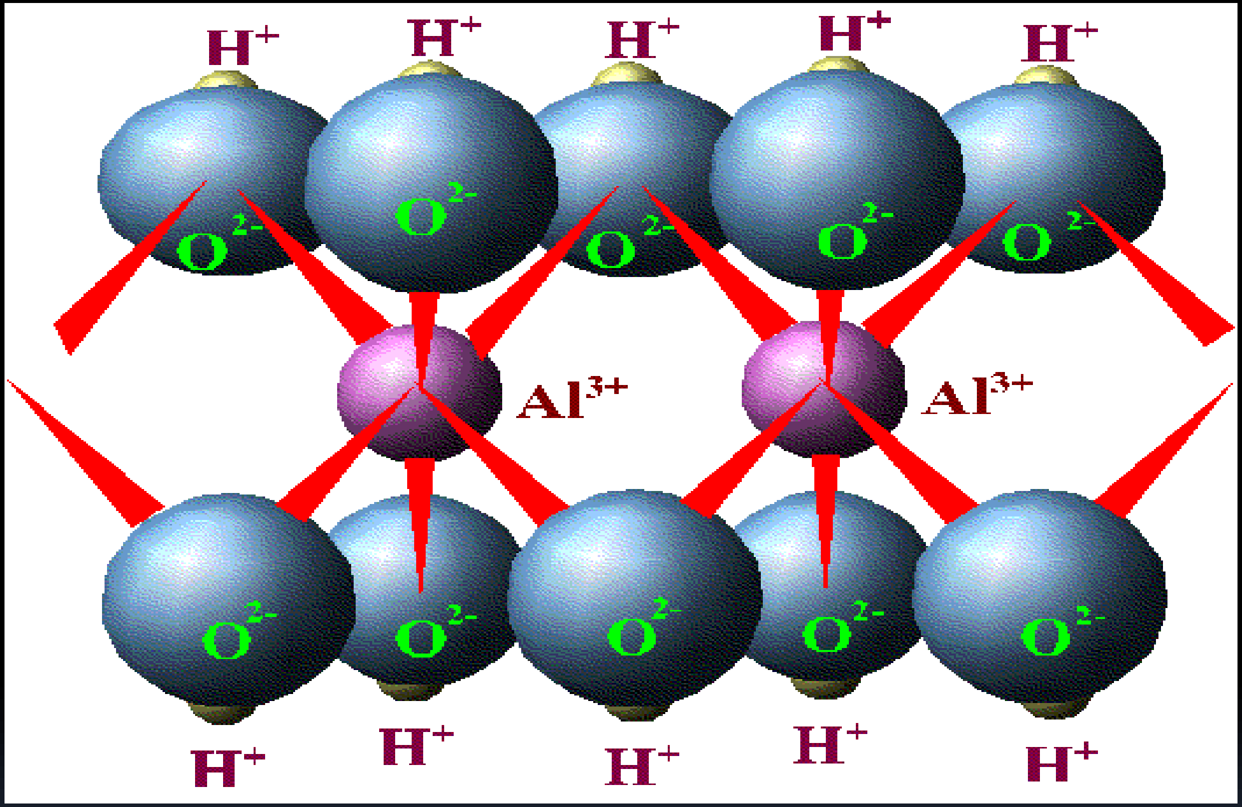


Figure 4.1. Octahedra and tetrahedra as a consequence of two planes of close-packaged spheres and three ways of representing octahedra and tetrahedra. (Adapted from Schulze, 1989.)

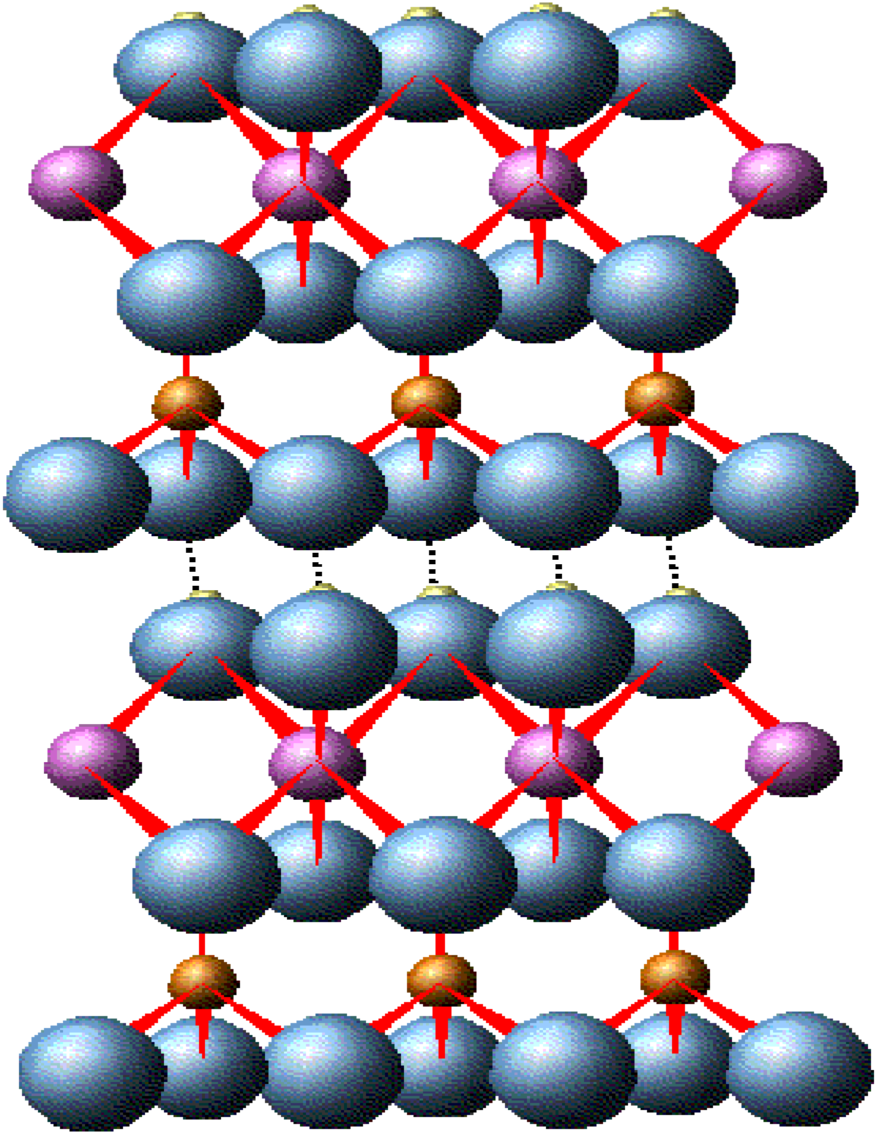


Pertautan antara Struktur Si-tetrahedra dengan Si-tetrahedra lainnya membentuk lembar Si-tetrahedra


OH-
Al3+
OH-
OH-
OH-
OH-
OH-



Pertautan antara Struktur Al-oktahedra dengan Al-oktahedra lainnya membentuk lembar Al-oktahedra



Struktur
mineral liat
Tipe 1:1
Tdr dr 1 lembar
Si-tetrahedra
dan 1 lembar
Al-oktahedra

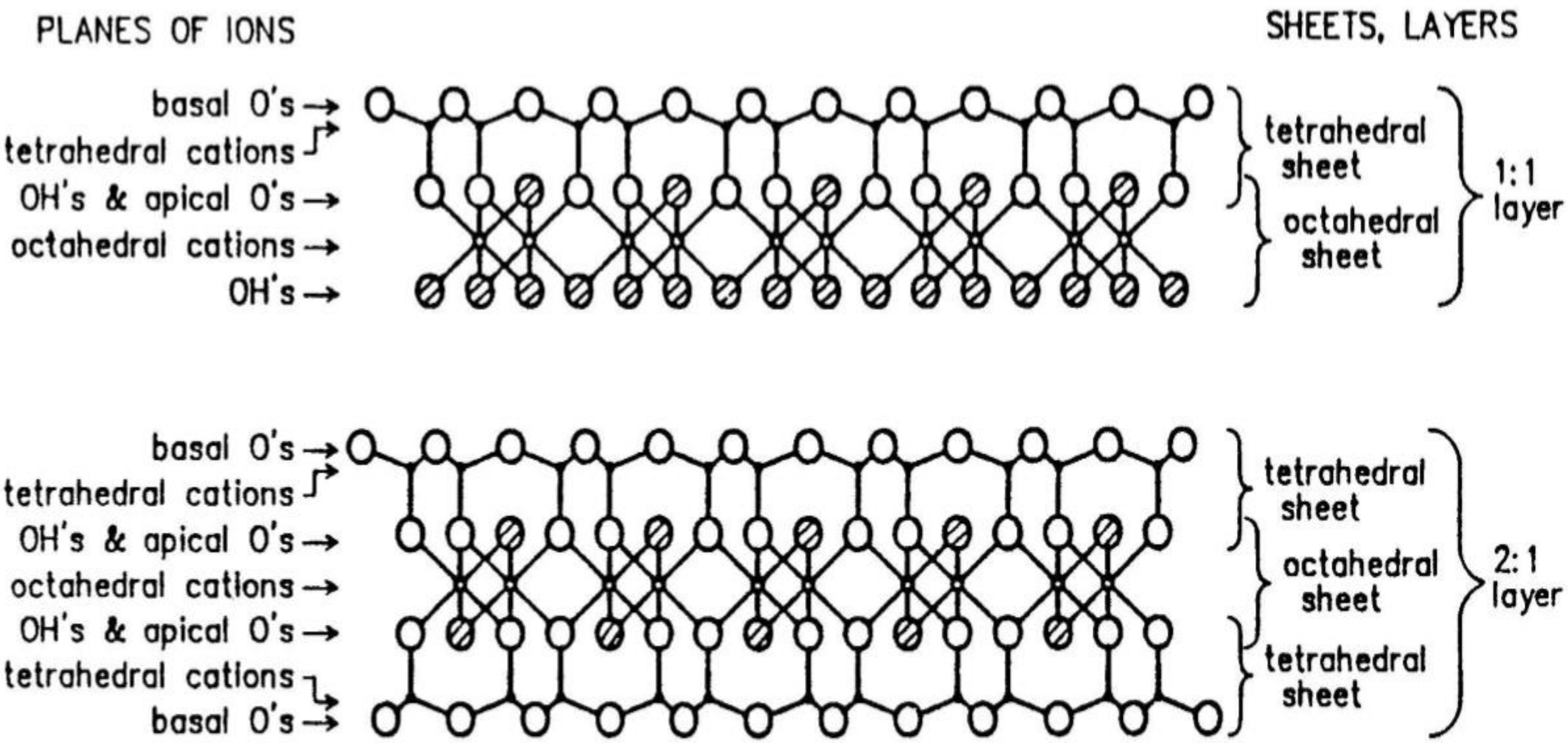
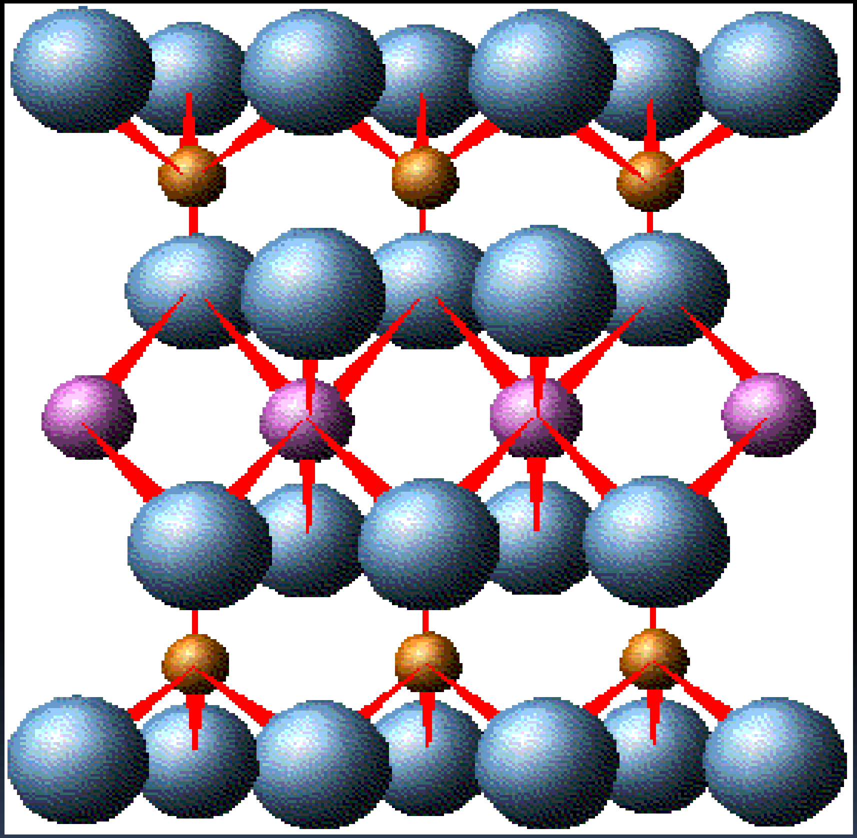


Figure 4.2. Phyllosilicate nomenclature. (Adapted from Schulze, 1989.)



Struktur
mineral liat
Tipe 2:1
Tdr dr 2 lembar
Si-tetrahedra
dan
1 lembar Si-
tetrahedra

GENESIS MINERAL LIAT

1. Rekristalisasi

Mineral primer mengalami pelapukan, shg dihasilkan senyawa-senaywa terlarut kmd mengalami resintesis/ rekristalisasi.

2. Penggabungan bahan amorf koloidal

pembentukan alofan dan imogolit.

GENESIS MINERAL LIAT

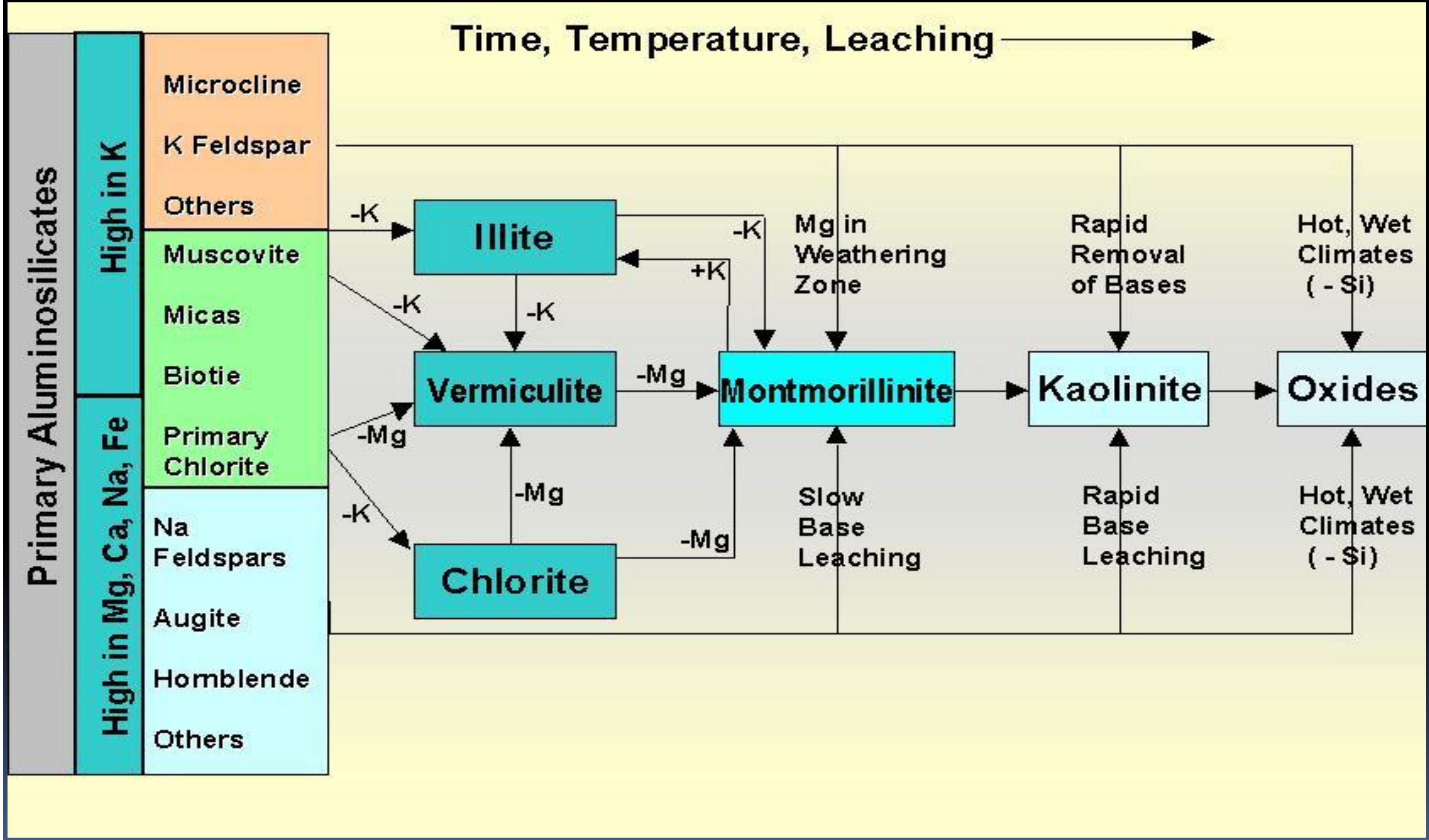
3. Transformasi/alterasi

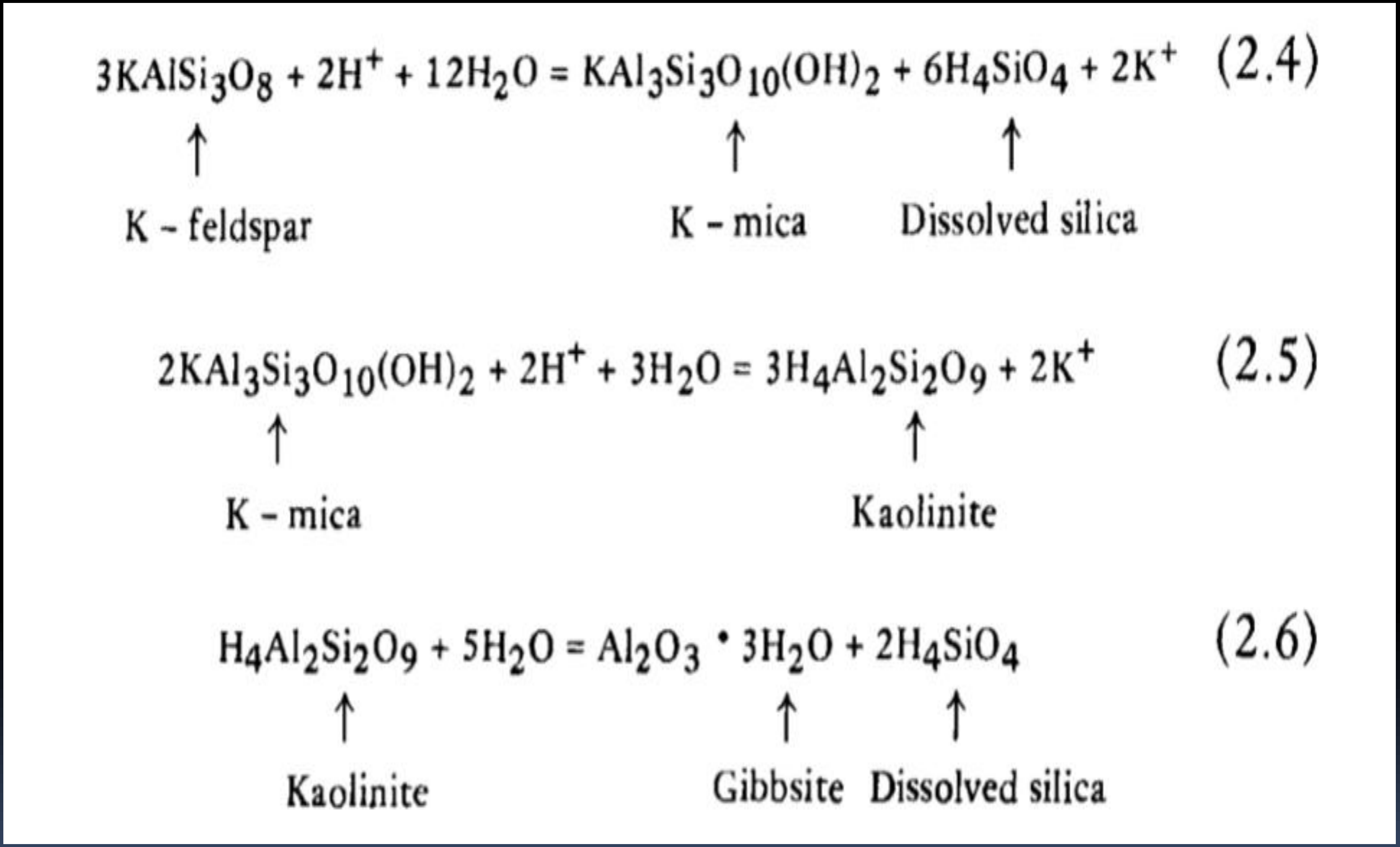
Perubahan dari bahan mineral bukan filosilikat, mengalami perombakan shg struktur asalnya berubah menjadi mineral filosilikat (struktur asalnya masih ada). Plagioklas mengalami alterasi menjadi mineral liat.

4. Transformasi lapisan

Lapisan dari suatu mineral mengalami perubahan shg menjadi mineral baru. e.g. perubahan mika menjadi vermikulit. Strk asal Al-Si terhidrat masih ada. Transformasi Montmorillonit menjadi Kaolinit.

PROSES GENESIS MINERAL LIAT

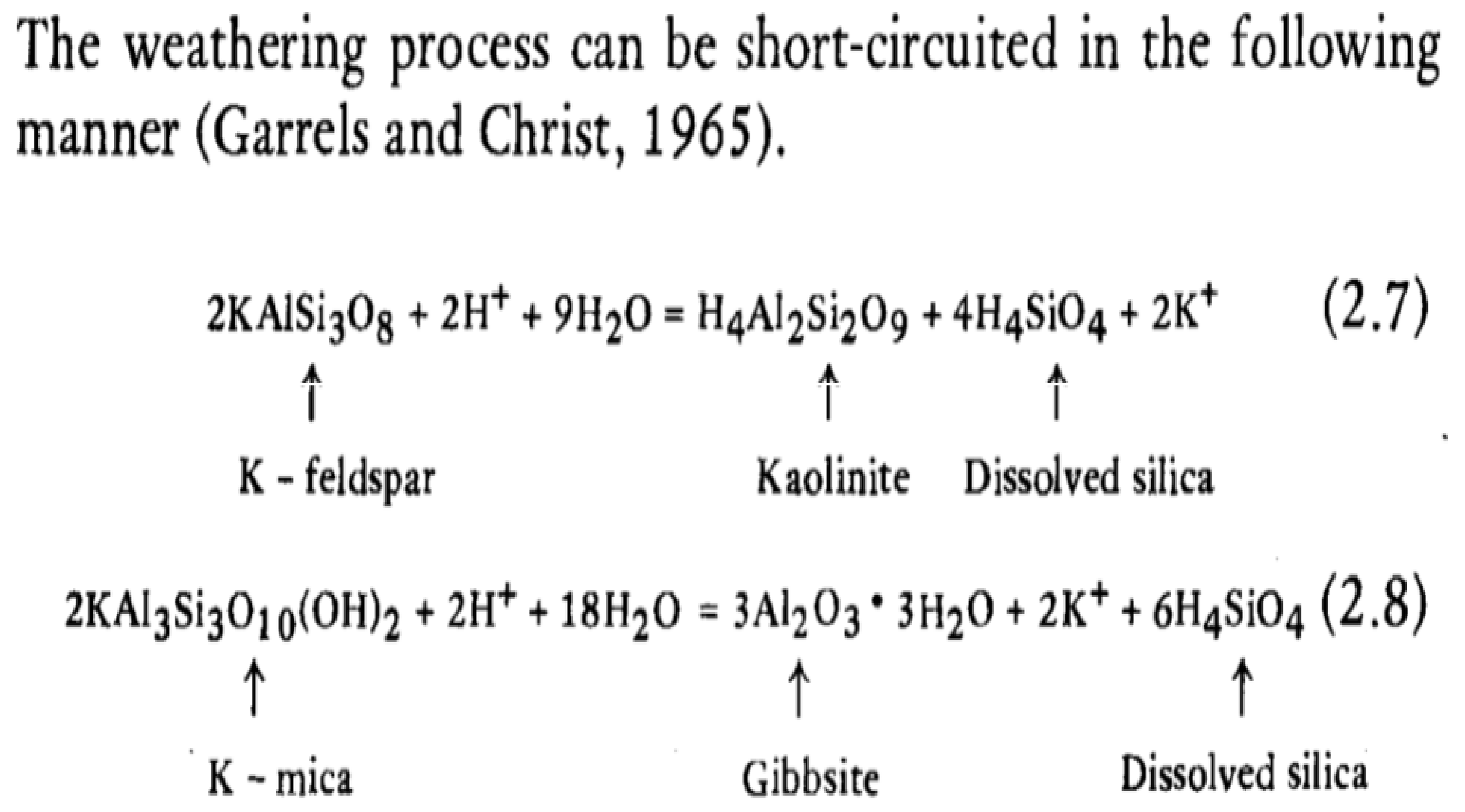




$$\underset{\substack{\uparrow\\ \text{K - feldspar}}}{3KAlSi_3O_8} + 2H^+ + 12H_2O = \underset{\substack{\uparrow\\ \text{K - mica}}}{KAl_3Si_3O_{10}(OH)_2} + \underset{\substack{\uparrow\\ \text{Dissolved silica}}}{6H_4SiO_4} + 2K^+ \tag{2.4}$$

$$\underset{\substack{\uparrow\\ \text{K - mica}}}{2KAl_3Si_3O_{10}(OH)_2} + 2H^+ + 3H_2O = \underset{\substack{\uparrow\\ \text{Kaolinite}}}{3H_4Al_2Si_2O_9} + 2K^+ \tag{2.5}$$

$$\underset{\substack{\uparrow\\ \text{Kaolinite}}}{H_4Al_2Si_2O_9} + 5H_2O = Al_2O_3 \cdot \underset{\substack{\uparrow\\ \text{Gibbsite}}}{3H_2O} + \underset{\substack{\uparrow\\ \text{Dissolved silica}}}{2H_4SiO_4} \tag{2.6}$$



The weathering process can be short-circuited in the following manner (Garrels and Christ, 1965).

$$\underset{\underset{\text{K - feldspar}}{\uparrow}}{2KAlSi_3O_8} + 2H^+ + 9H_2O = \underset{\underset{\text{Kaolinite}}{\uparrow}}{H_4Al_2Si_2O_9} + \underset{\underset{\text{Dissolved silica}}{\uparrow}}{4H_4SiO_4} + 2K^+ \qquad (2.7)$$

$$\underset{\underset{\text{K - mica}}{\uparrow}}{2KAl_3Si_3O_{10}(OH)_2} + 2H^+ + 18H_2O = \underset{\underset{\text{Gibbsite}}{\uparrow}}{3Al_2O_3 \cdot 3H_2O} + 2K^+ + \underset{\underset{\text{Dissolved silica}}{\uparrow}}{6H_4SiO_4} \qquad (2.8)$$

C. Mineral Liat Tanah

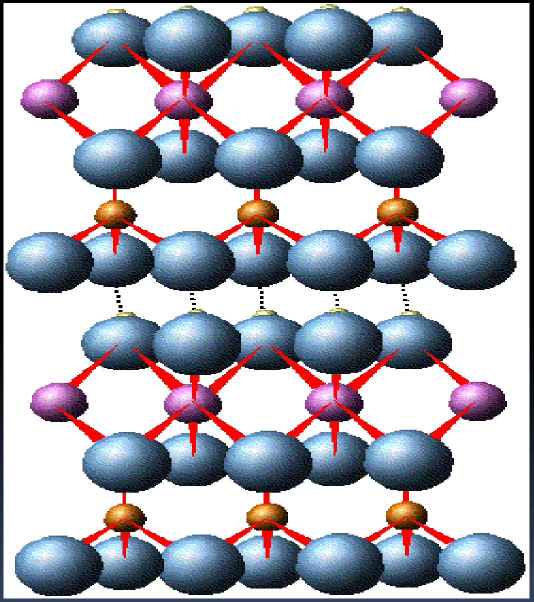
1. **Tipe Mineral Liat**

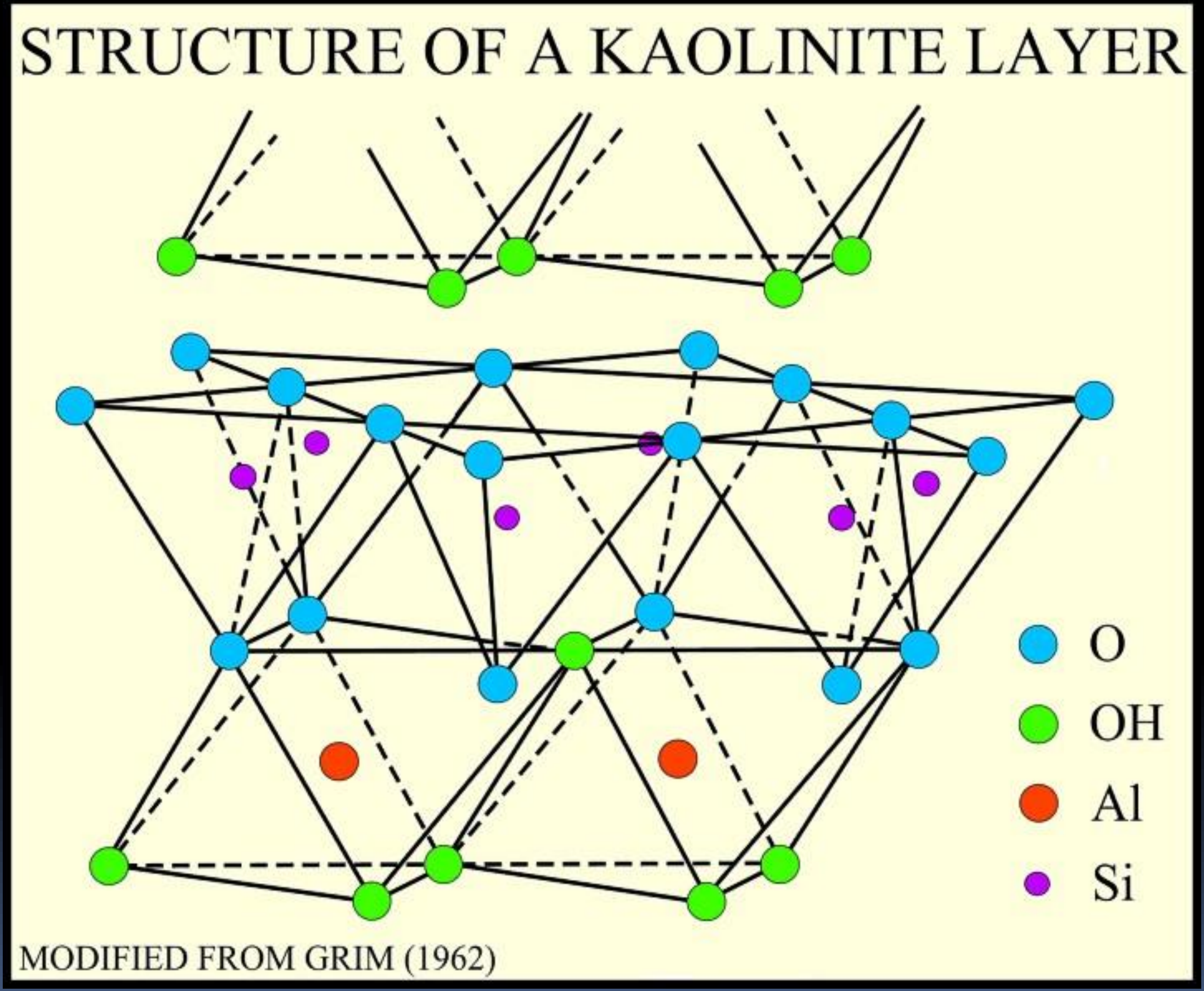
   Bdsk jml lembar silikat dan aluminat, mineral liat silikat digolongkan ke dalam tipe: 1:1, 2:1, 2:2 atau 2:1:1

2. **Struktur Kimia beberapa mineral liat tanah**

   Tipe 1:1, contohnya: Kaolinit, Haloysit

Kaolinit

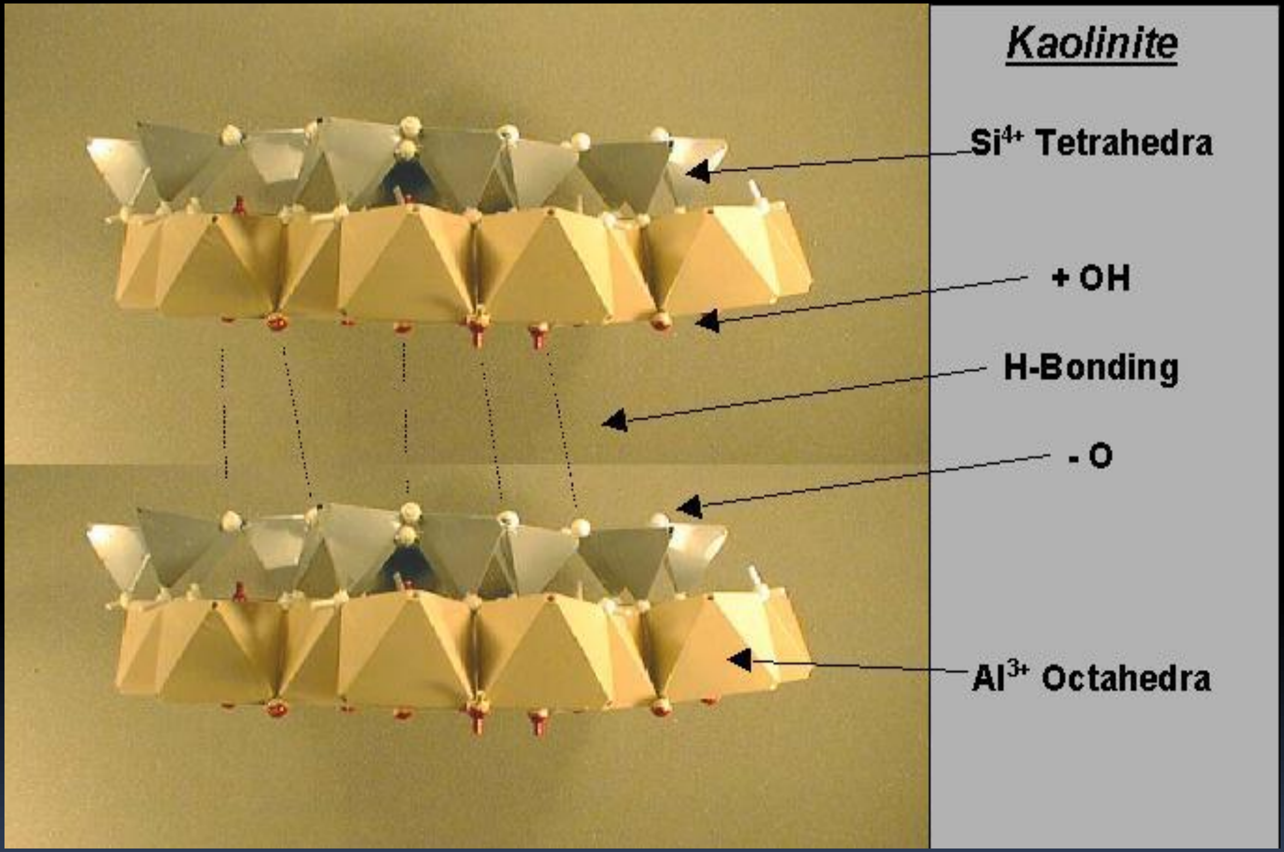




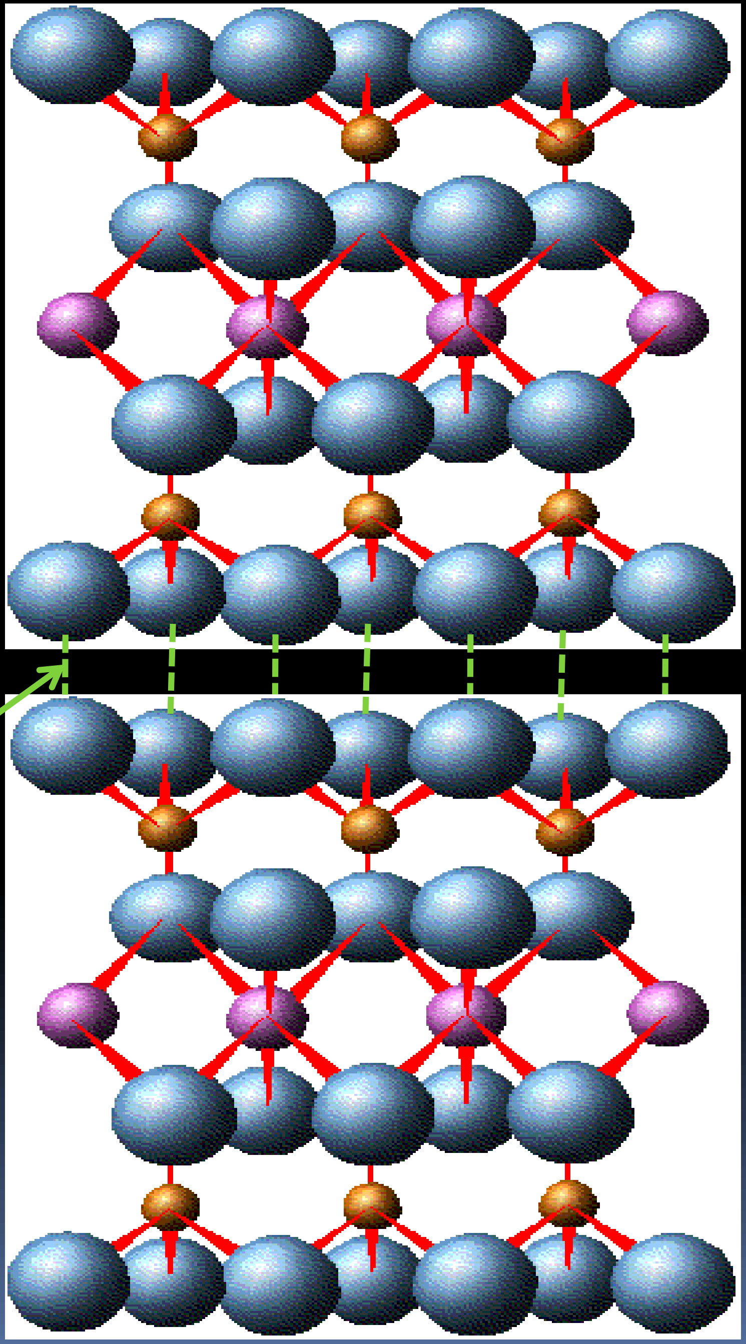
STRUCTURE OF A KAOLINITE LAYER

MODIFIED FROM GRIM (1962)

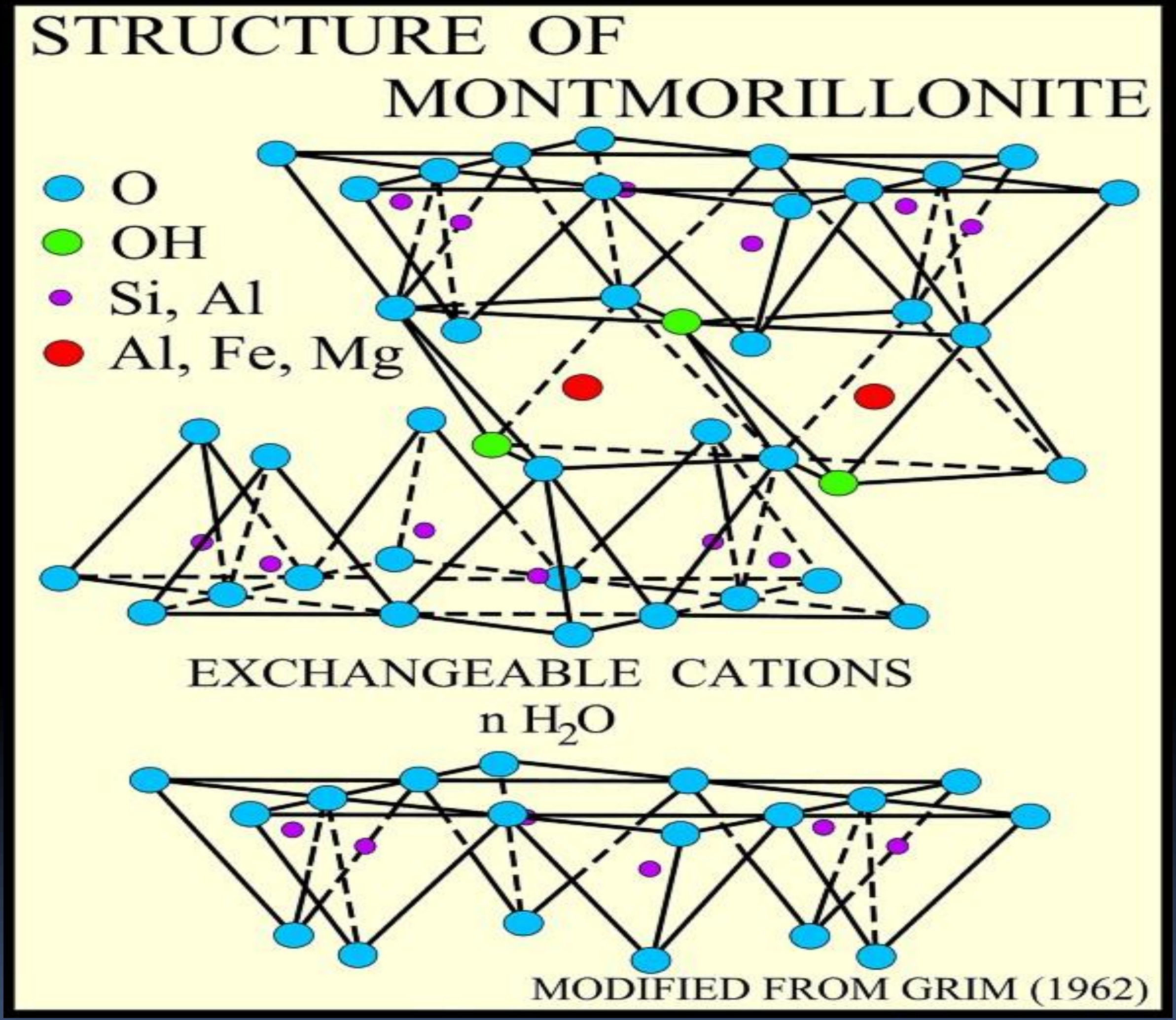
KARAKTERISTIK KOLOID LIAT

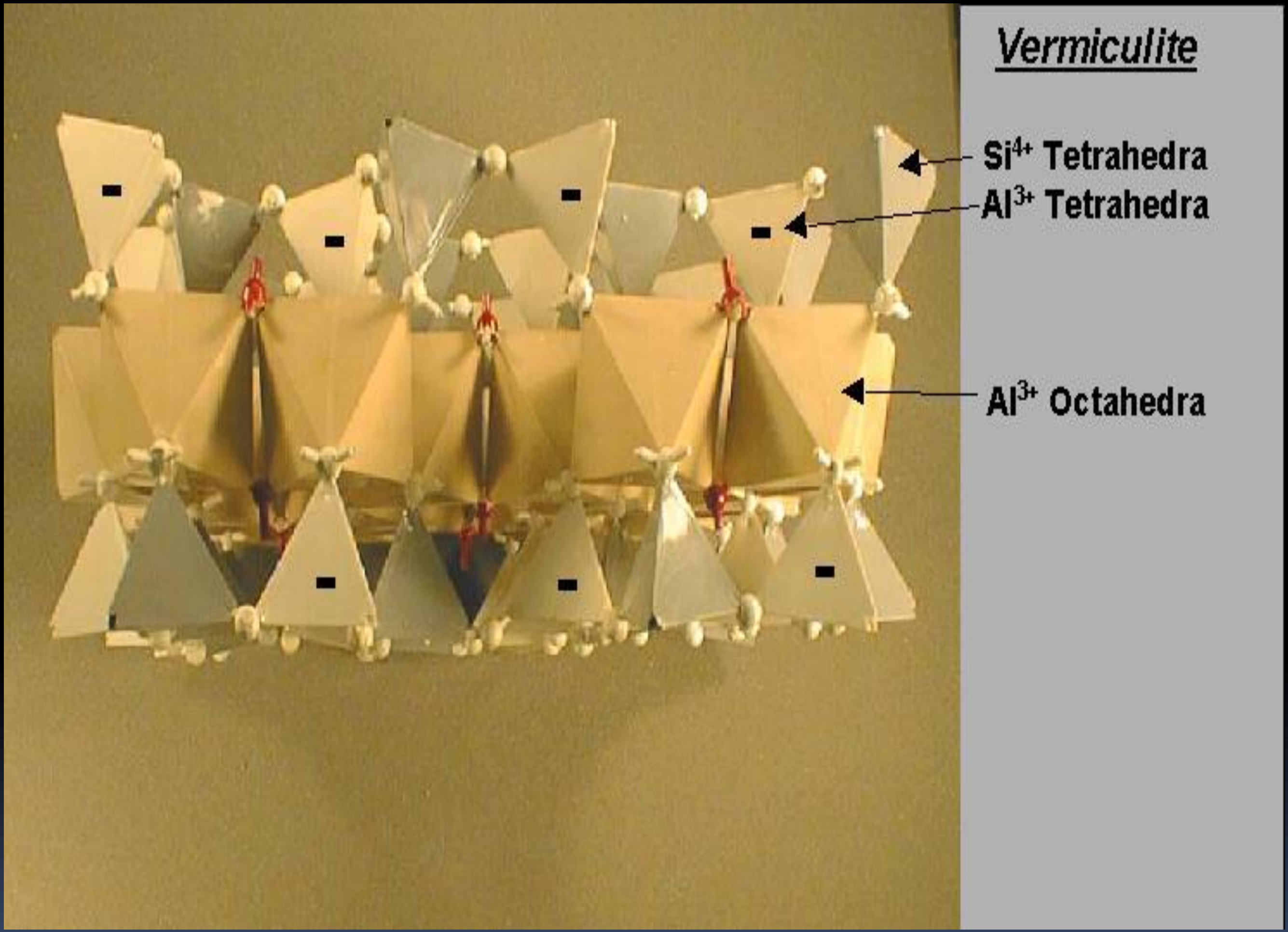


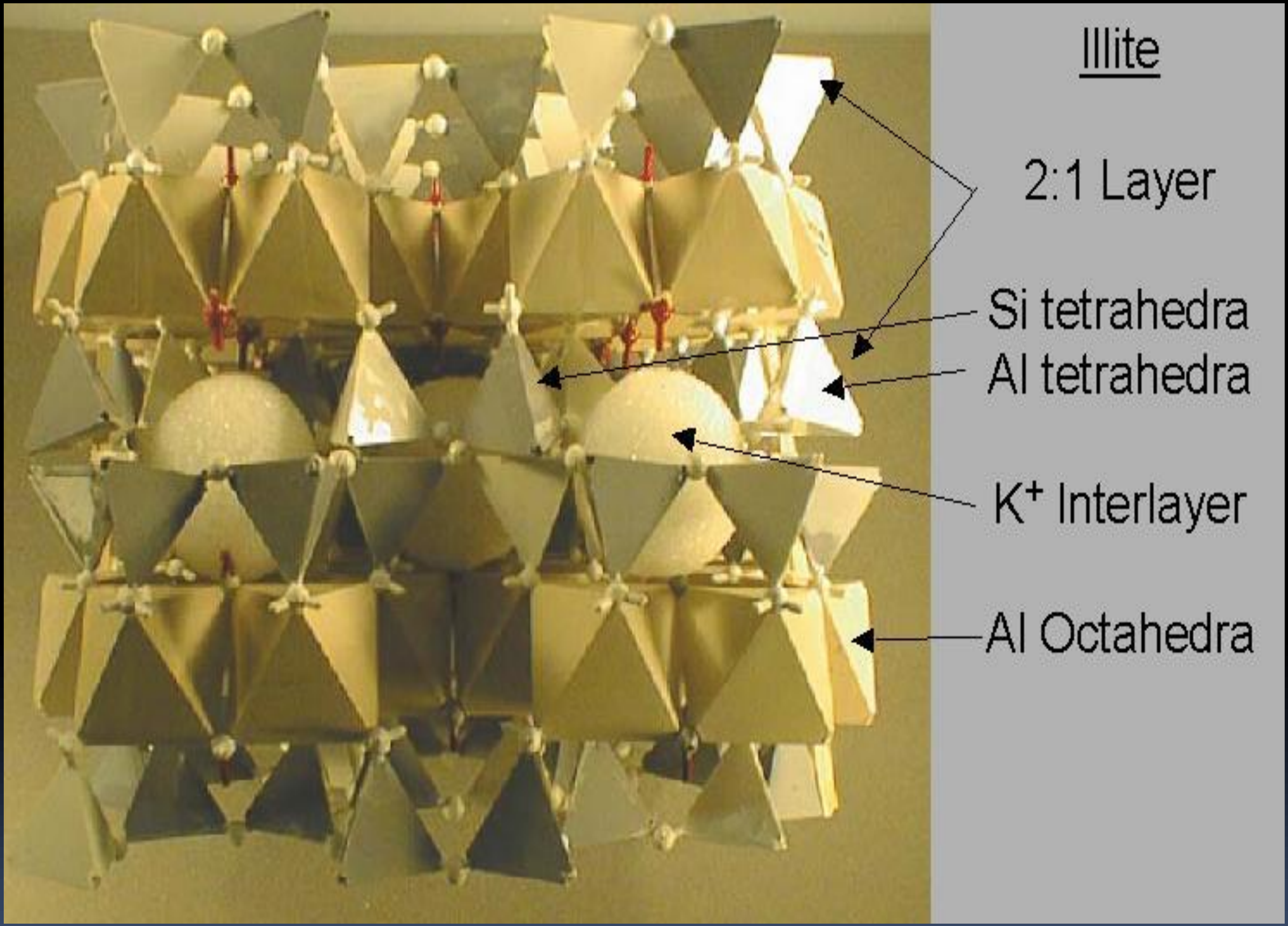
Tipe Liat 2:1
Contoh MONTMORILONIT

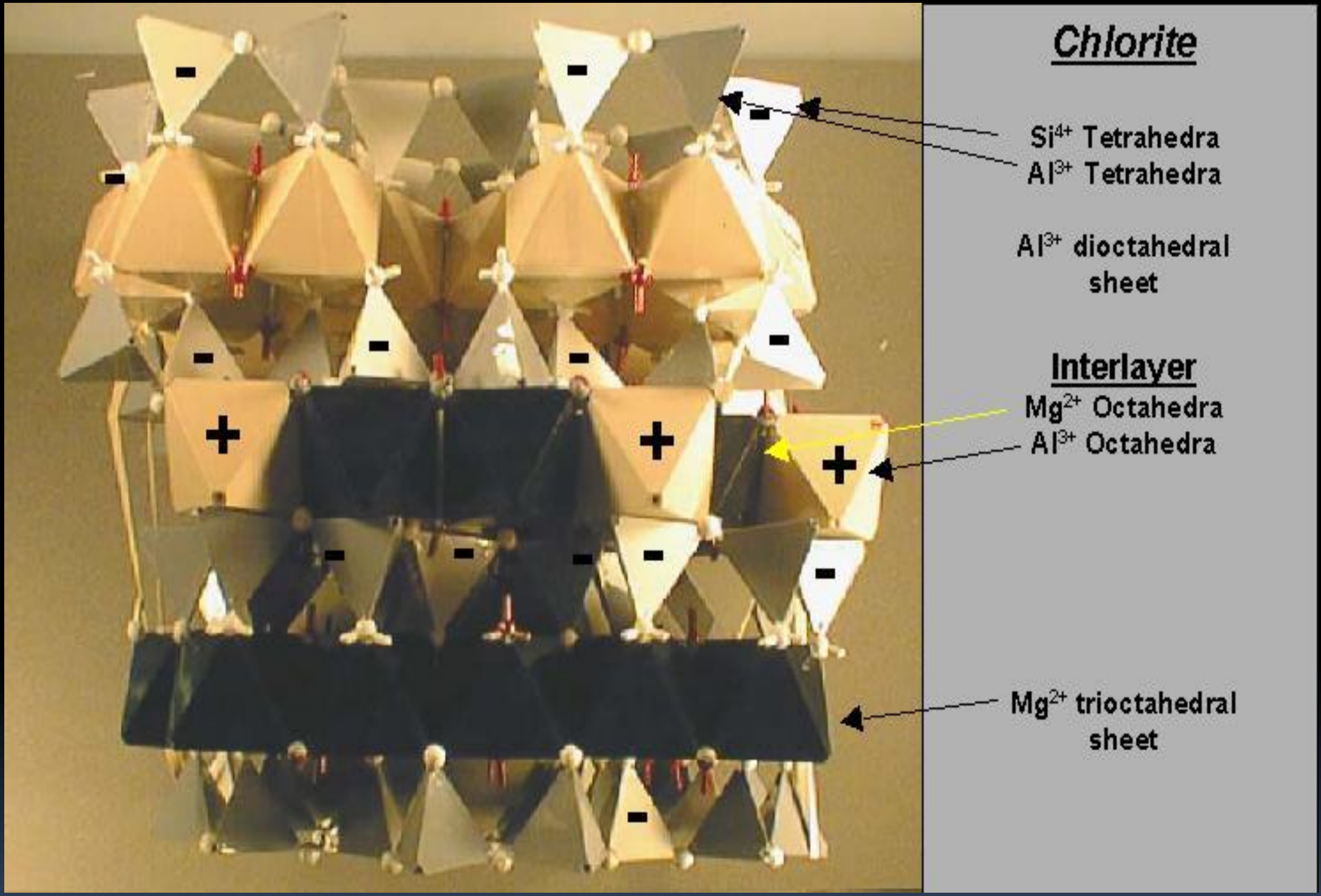


Ikatan Oksigen


STRUCTURE OF MONTMORILLONITE
● O
● OH
● Si, Al
● Al, Fe, Mg
EXCHANGEABLE CATIONS
n H_2O
MODIFIED FROM GRIM (1962)


Vermiculite
Si^{4+} Tetrahedra
Al^{3+} Tetrahedra
Al^{3+} Octahedra


Illite
2:1 Layer
Si tetrahedra
Al tetrahedra
K⁺ Interlayer
Al Octahedra



Chlorite

Si^{4+} Tetrahedra
Al^{3+} Tetrahedra

Al^{3+} dioctahedral
sheet

Interlayer
Mg^{2+} Octahedra
Al^{3+} Octahedra

Mg^{2+} trioctahedral
sheet

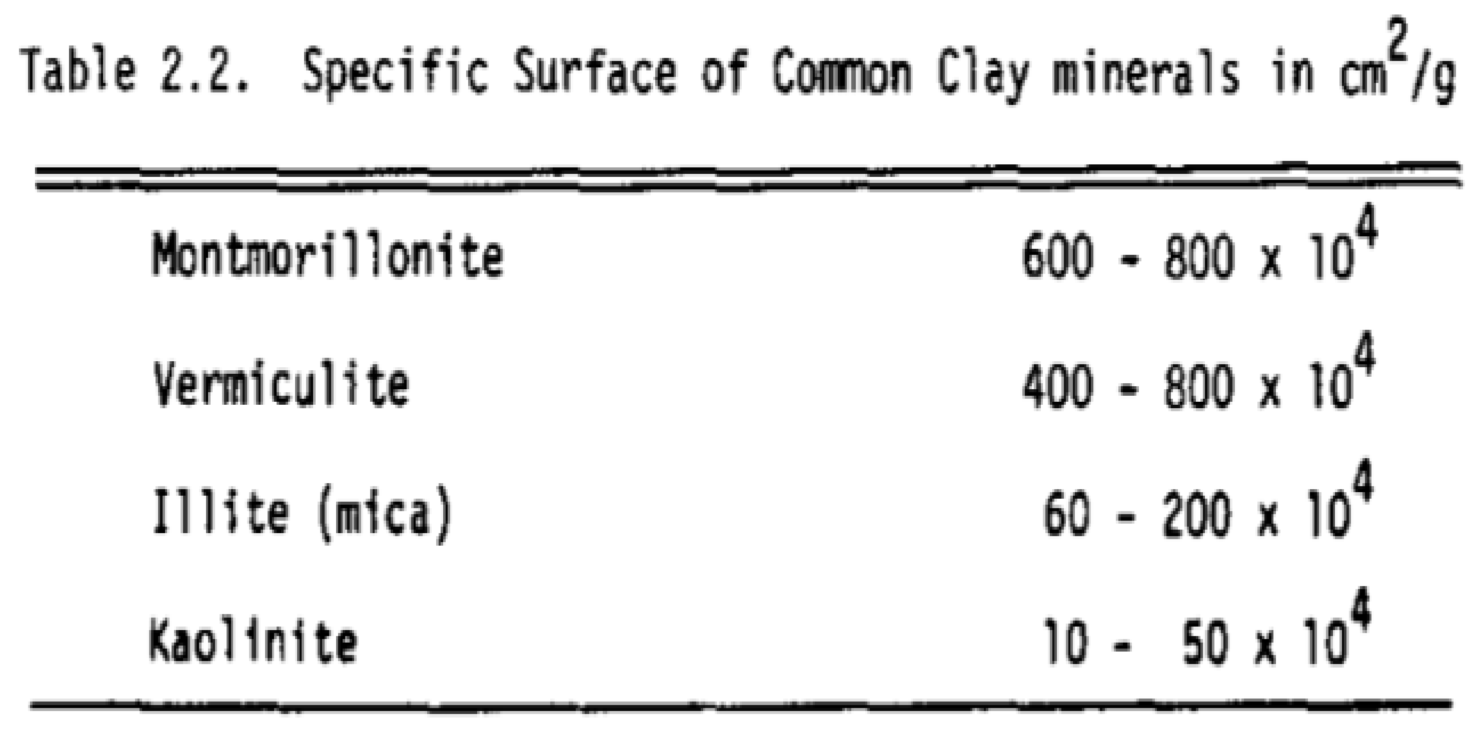


Table 2.2. Specific Surface of Common Clay minerals in cm^2/g

Montmorillonite	600 - 800 x 10^4
Vermiculite	400 - 800 x 10^4
Illite (mica)	60 - 200 x 10^4
Kaolinite	10 - 50 x 10^4

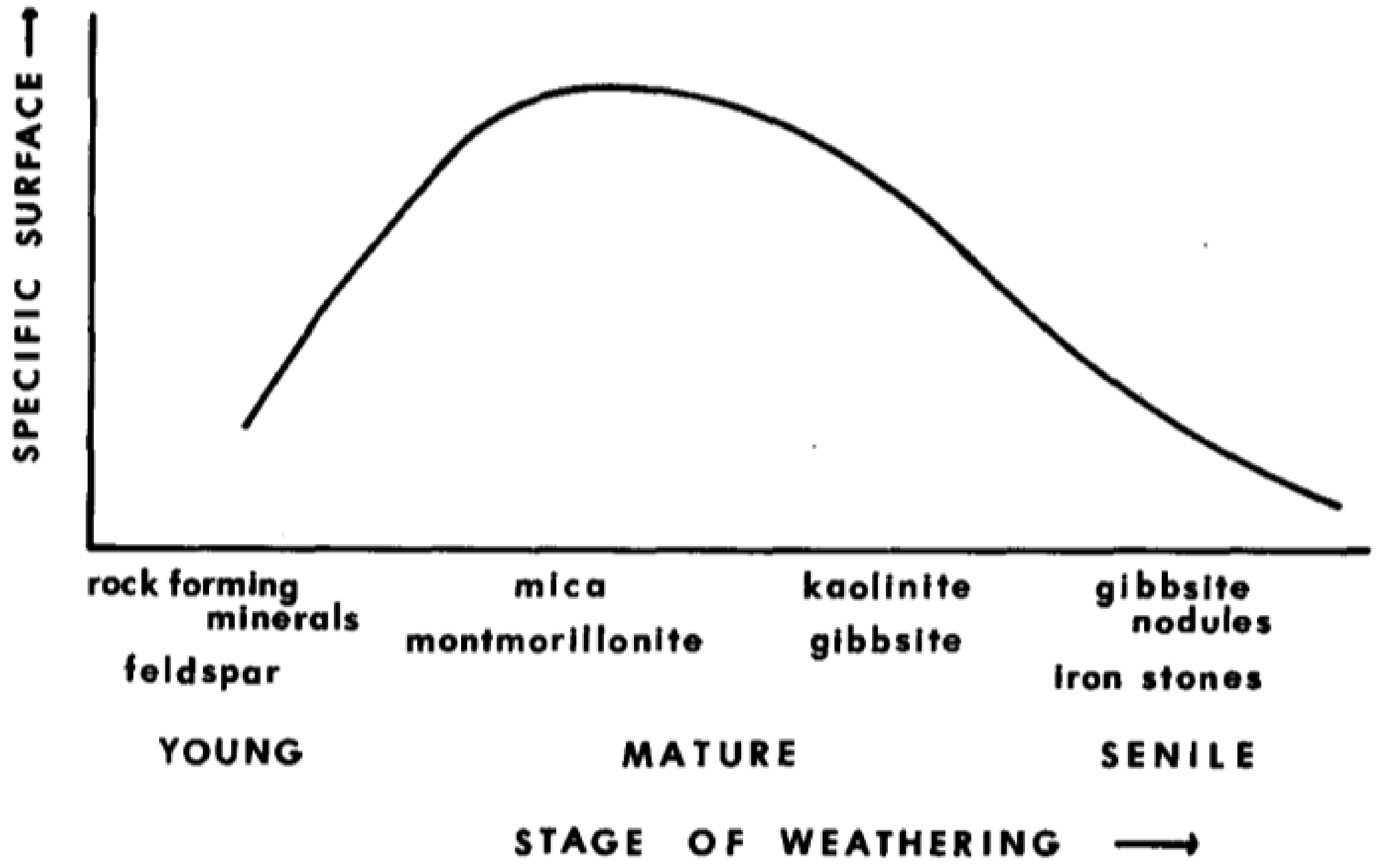


Figure 2.2. Relationship between specific surface of mineral and the stage of soil weathering.

KIMIA PERMUKAAN LIAT TANAH

1. Koloid tanah bahan paling aktif dalam tanah, mengapa?
2. Kimia permukaan (surrface chemistry) koloid tanah penting dipahami, karena disitulah tempat berlangsung berbagai reaksi fisik maupun kimia
3. Siat fisik tanah yang terkait dengan kemampuan memegang air, pembentukan agregat, dll terkait dengan kimia permukaan koloid
4. Sifat kimia tanah yang terkait dengan KTK, KTA, dll terkait dengan kimia permukaan koloid

KIMIA PERMUKAAN LIAT TANAH

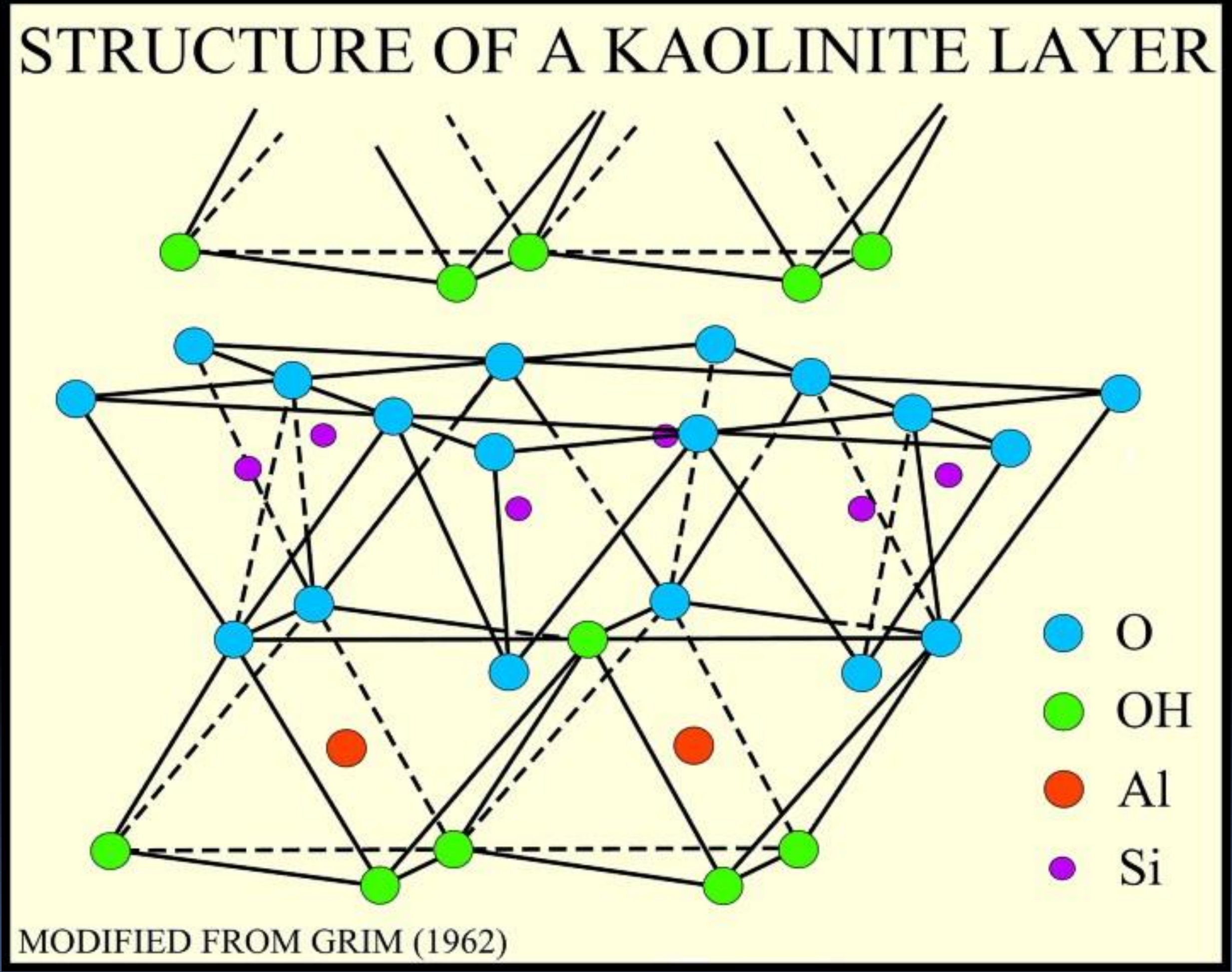
2. Permukaan liat:

a. Permukaan yg tbtk oleh rangkaian Si-O-Si dr tetrahedron silika (ikatan siloksan / permukaan siloksana). Permukaan pada liat tipe 2:1, dg muatan tbtk mll substitusi isomorfik.

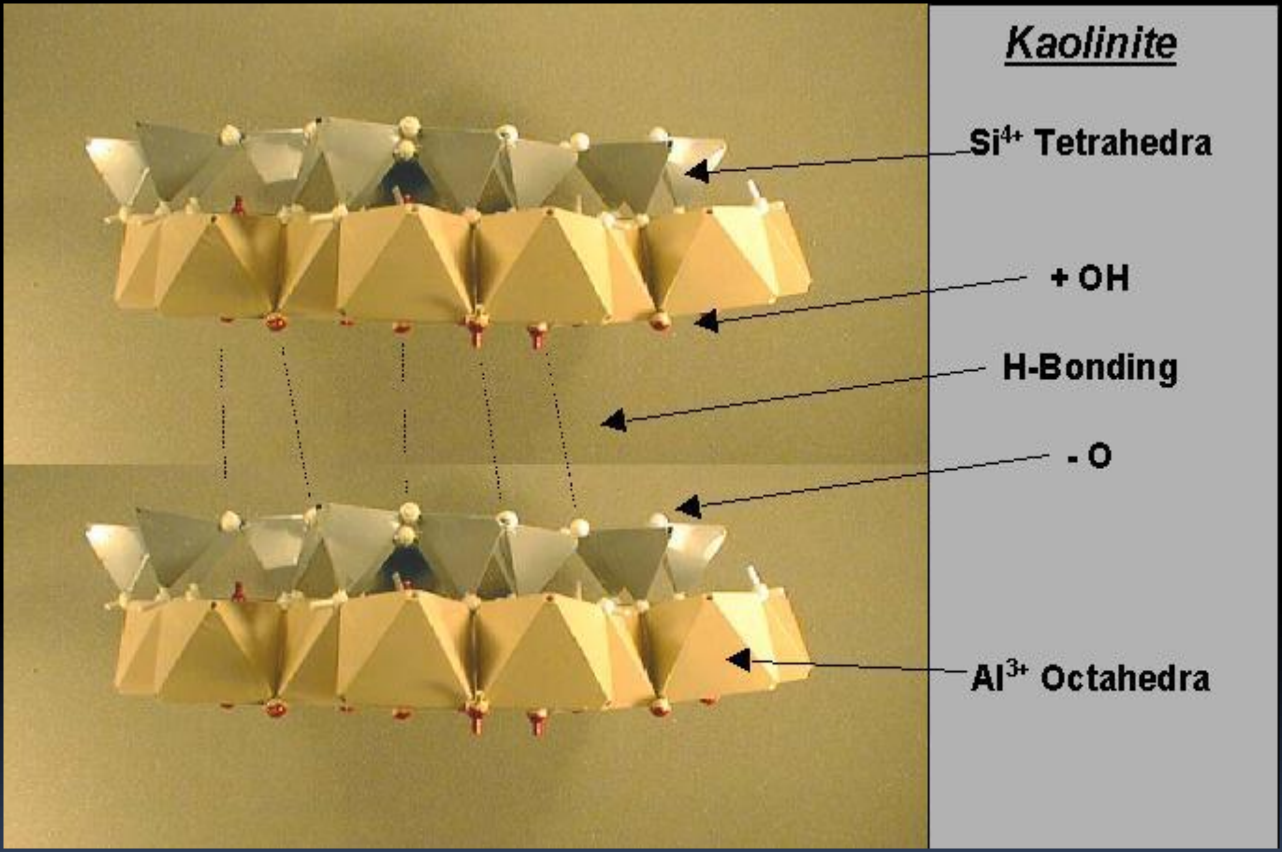
b. Permukaan yg tbtk oleh rangkaian O-Al-OH dr oktahedron Alumina. Permukaan liat ini memiliki gugus OH terbuka, tdp pd Oksida-hidroksida Al, Fe, dll, liat kaolinit (1:1). Gugus Oh tsb mrp sbr muatan negatif.

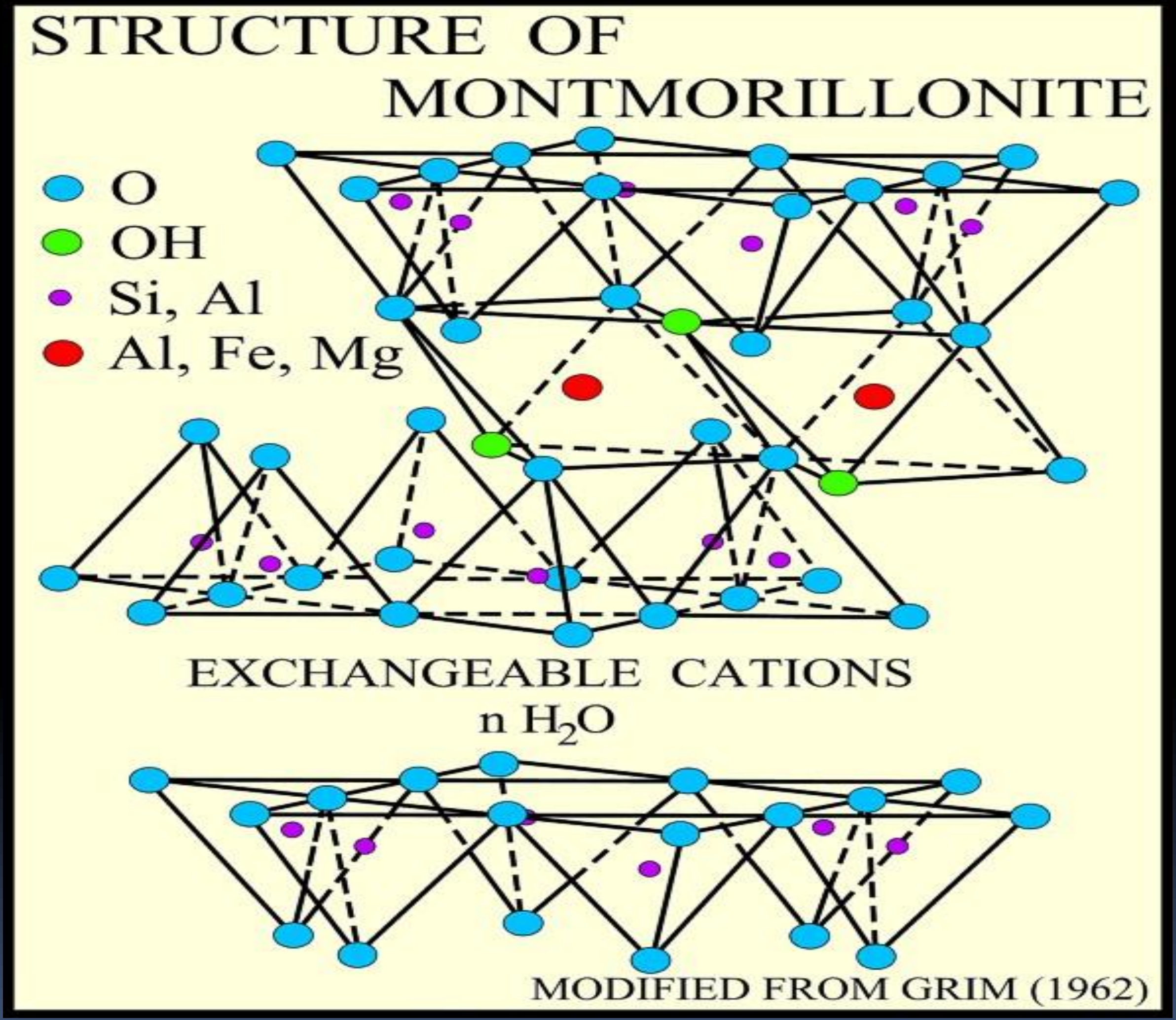
c. Permukaan yg tbtk oleh rangkaian -Si-OH atau -Al-OH dari senyawa amorf

KIMIA PERMUKAAN LIAT TANAH



KARAKTERISTIK KOLOID LIAT





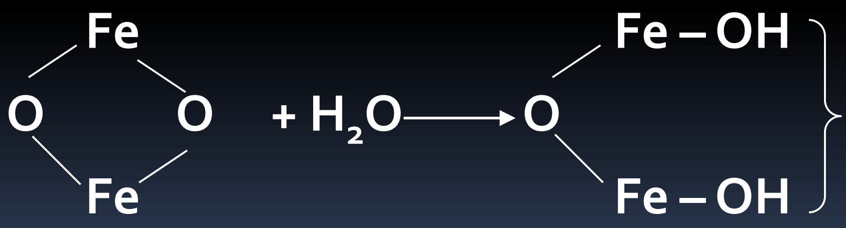
STRUCTURE OF MONTMORILLONITE

MODIFIED FROM GRIM (1962)

- Permk –Si-OH disebut Silanol, e.g. Gel silika
- Permk –Al-OH disebut Aluminol, e.g. Alofan

Kedua permukaan tsb mempunyai luas permukaan besar dan semua gugus OH mudah dicapai.

- Permk –Fe-OH disebut Ferrol, e.g. Fe oksida
- Permukaan Al atau Fe oksida dapat mengikat Air (terhidrasi) shg tbtk permk Aluminol atau Ferrol, e.g.



muatan tgt pH

4. Luas Permukaan

- Penting utk interpretasi kuantitatif sifat² permukaan dlm hubungannya dg sifat tanah dan liat.
- Laju jerapan dan pertukaran kation proporsional dengan luas permukaan.
- Luas permukaan meningkat dg ukuran partikel yg semakin kecil.
- Luas permukaan diukur dg beberapa metode: perhitungan, analisis jerapan, dll.
- Pengukuran luas permukaan dg metode Perhitungan:

a. Permukaan Total

Wadah kubus dg sisi L, terisi partikel dg diameter d, jumlah partikel N, dengan luas permukaan total semua partikel A, maka $N = (L/d)^3$. Karena luas permukaan 1 partikel = πd^2 maka

$A = N \pi d^2$ atau $A = (L/d)^3 \pi d^2 = \pi L^3/d$

b. Luas Permukaan Spesifik

adalah luas permk per satuan volume atau satuan massa partikel.

- Jika luas permukaan partikel = πd^2 dan volumenya v = 1/6 πd^3 maka S = πd^2 / 1/6 πd^3 atau S = 6/d

- Jika kita anggap partikel liat adalah sphere (bola) dg d = 0,002 mm, maka luas permukaan spesifik S = 6/0,002 = 3000 mm^2/mm^3. Bgm dg liat koloidal misal 1 mikron, brp luas permukaan spesifiknya?

5. Asal muatan negatif

a. Substitusi isomorfik (muatan permanen)

b. Disosiasi gugus hidroksil tersembul (muatan variabel)

ad.a. Umum terjadi pd liat tipe 2:1. Bagian Si dr lembar tetrahedra diganti oleh ion berukuran mirip biasanya Al^{3+}

juga Al dr lembar oktahedra diganti Mg^{2+} tanpa gangguan pada struktur kristal.

- Substitusi Isomorfik tgt pd ukuran dan valensi ion yg terlibat. Perbedaan diameter tdk lebih dr 15%. valensi tdk beda lbh dr 1 unit.

ad.b.

Gugus OH pd tepi kristal dpt memunculkan muatan negatif, khusunya pd pH tinggi

Pada pH tinggi $Al\text{-}OH + OH \longrightarrow Al\text{-}O^- + H_2O$

Pada pH rendah $Al\text{-}OH + H^+ \longrightarrow Al\text{-}OH_2^+$

- Muatan negatif yg tbtk tgt pH, shg disebut muatan tgt pH. Besarnya tgt pH dan tipe koloid.
- Muatan tgt pH penting utk liat 1:1, oksida Al, Fe, dll, dan koloid organik.
- Karena muatan tgt pH maka dikenal mineral dg ZPC

apa itu ZPC?

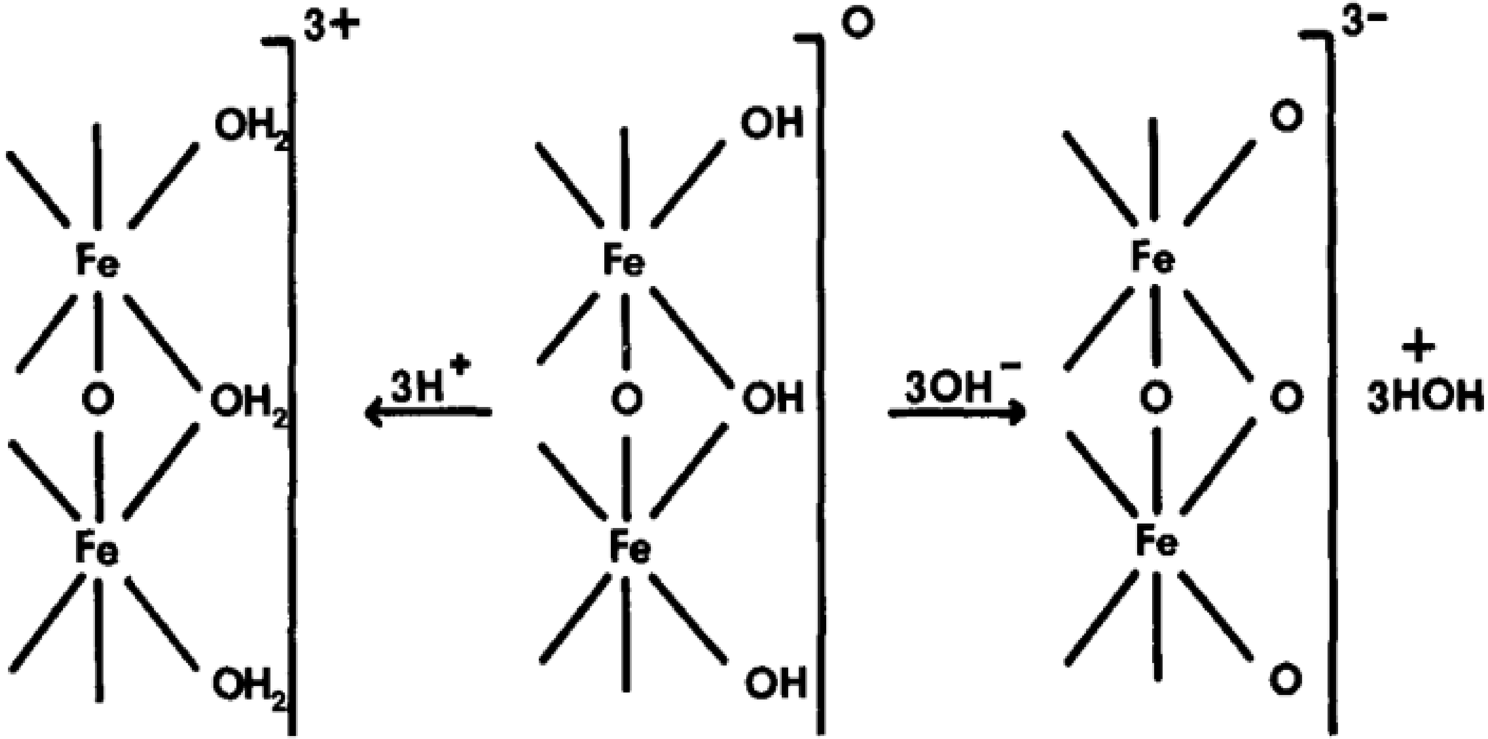


Figure 3.1. Charging of a hydroxylated surface by protonation and deprotonation.

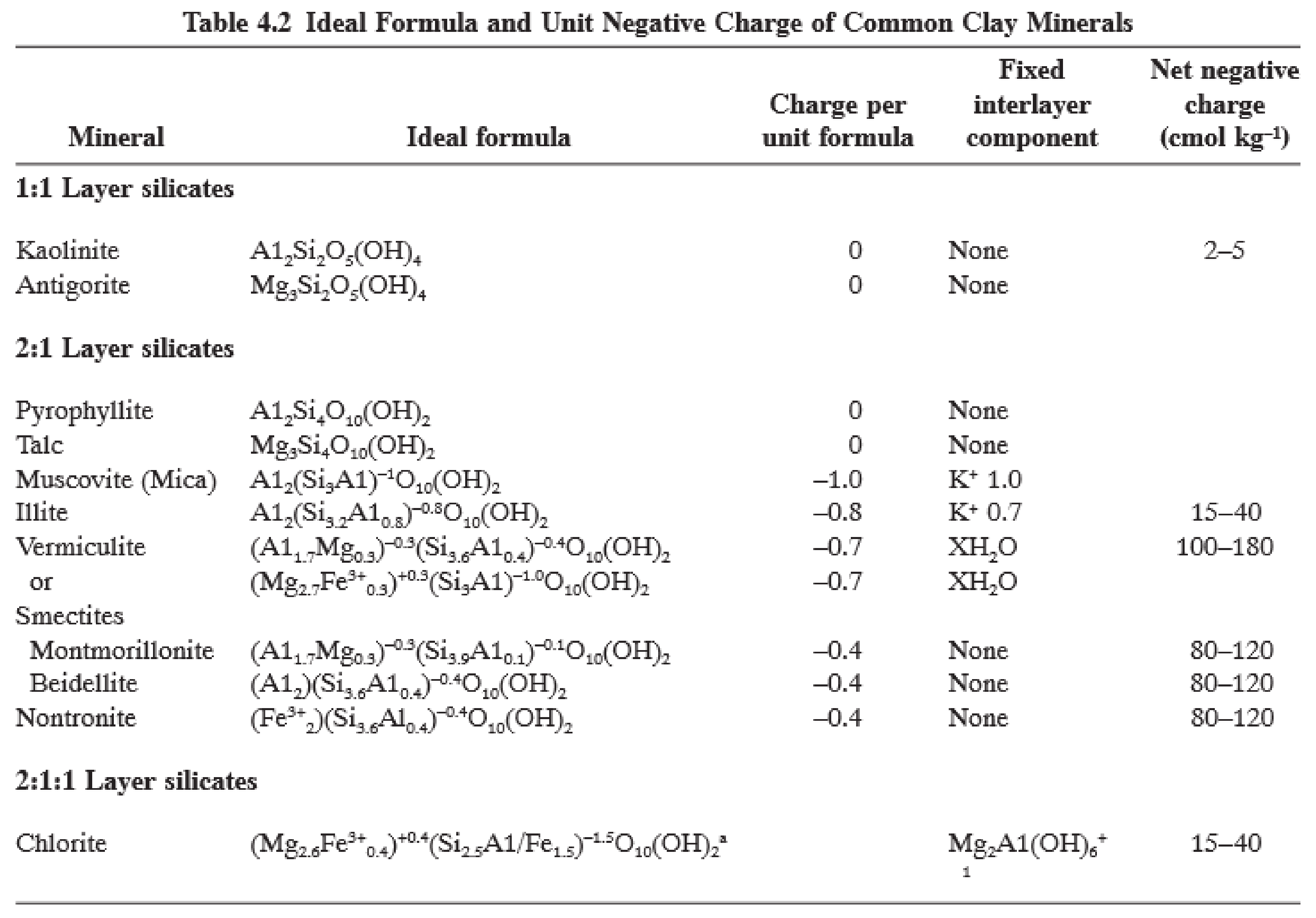


Table 4.2 Ideal Formula and Unit Negative Charge of Common Clay Minerals

Mineral	Ideal formula	Charge per unit formula	Fixed interlayer component	Net negative charge (cmol kg^{-1})
1:1 Layer silicates				
Kaolinite	$A1_2Si_2O_5(OH)_4$	0	None	2–5
Antigorite	$Mg_3Si_2O_5(OH)_4$	0	None	
2:1 Layer silicates				
Pyrophyllite	$A1_2Si_4O_{10}(OH)_2$	0	None	
Talc	$Mg_3Si_4O_{10}(OH)_2$	0	None	
Muscovite (Mica)	$A1_2(Si_3A1)^{-1}O_{10}(OH)_2$	–1.0	K^+ 1.0	
Illite	$A1_2(Si_{3.2}A1_{0.8})^{-0.8}O_{10}(OH)_2$	–0.8	K^+ 0.7	15–40
Vermiculite	$(A1_{1.7}Mg_{0.3})^{-0.3}(Si_{3.6}A1_{0.4})^{-0.4}O_{10}(OH)_2$	–0.7	XH_2O	100–180
or	$(Mg_{2.7}Fe^{3+}{}_{0.3})^{+0.3}(Si_3A1)^{-1.0}O_{10}(OH)_2$	–0.7	XH_2O	
Smectites				
Montmorillonite	$(A1_{1.7}Mg_{0.3})^{-0.3}(Si_{3.9}A1_{0.1})^{-0.1}O_{10}(OH)_2$	–0.4	None	80–120
Beidellite	$(A1_2)(Si_{3.6}A1_{0.4})^{-0.4}O_{10}(OH)_2$	–0.4	None	80–120
Nontronite	$(Fe^{3+}{}_2)(Si_{3.6}Al_{0.4})^{-0.4}O_{10}(OH)_2$	–0.4	None	80–120
2:1:1 Layer silicates				
Chlorite	$(Mg_{2.6}Fe^{3+}{}_{0.4})^{+0.4}(Si_{2.5}A1/Fe_{1.5})^{-1.5}O_{10}(OH)_2{}^a$		$Mg_2A1(OH)_6{}^+$ 1	15–40

6. Muatan Positif dan Muatan Titik Nol (ZPC)

- ZPC adalah pH dimana muatan koloid sama dg nol
- Koloid liat dapat bermuatan positif, negatif dan nol.
- Jika pH tanah > ZPC maka koloid bermuatan negtif
- Jika pH tanah < ZPC maka koloid bermuatan positif.

7. Penggunaan ΔpH untuk penetapan muatan

$\Delta pH = pH_{H_2O} - pH_{KCl}$

- Jika ΔpH positip muatan koloid negatif
- Jika ΔpH negatif muatan koloid positif
- Jika ΔpH nol muatan koloid nol.

8. Potensial Permukaan

Adanya muatan yg berlawanan pd permk koloid dan dlm fase cair, maka muncul potensial listrik yg disebut Potensial permukaan.

9. Lapisan Rangkap Listrik (Electric Double Layer)

adalah muatan negatif pd permukaan liat beserta kumpulan ion lawan yg bermuatan positif.

- EDL, krn menyebar spt atmosfir, mk disebut Diffuse double layer (DDL).
- Ada bbrp teori ttg EDL, al: teori Helmholtz, Gouy-Chapman, dan Stern (lihat kimia tanah).

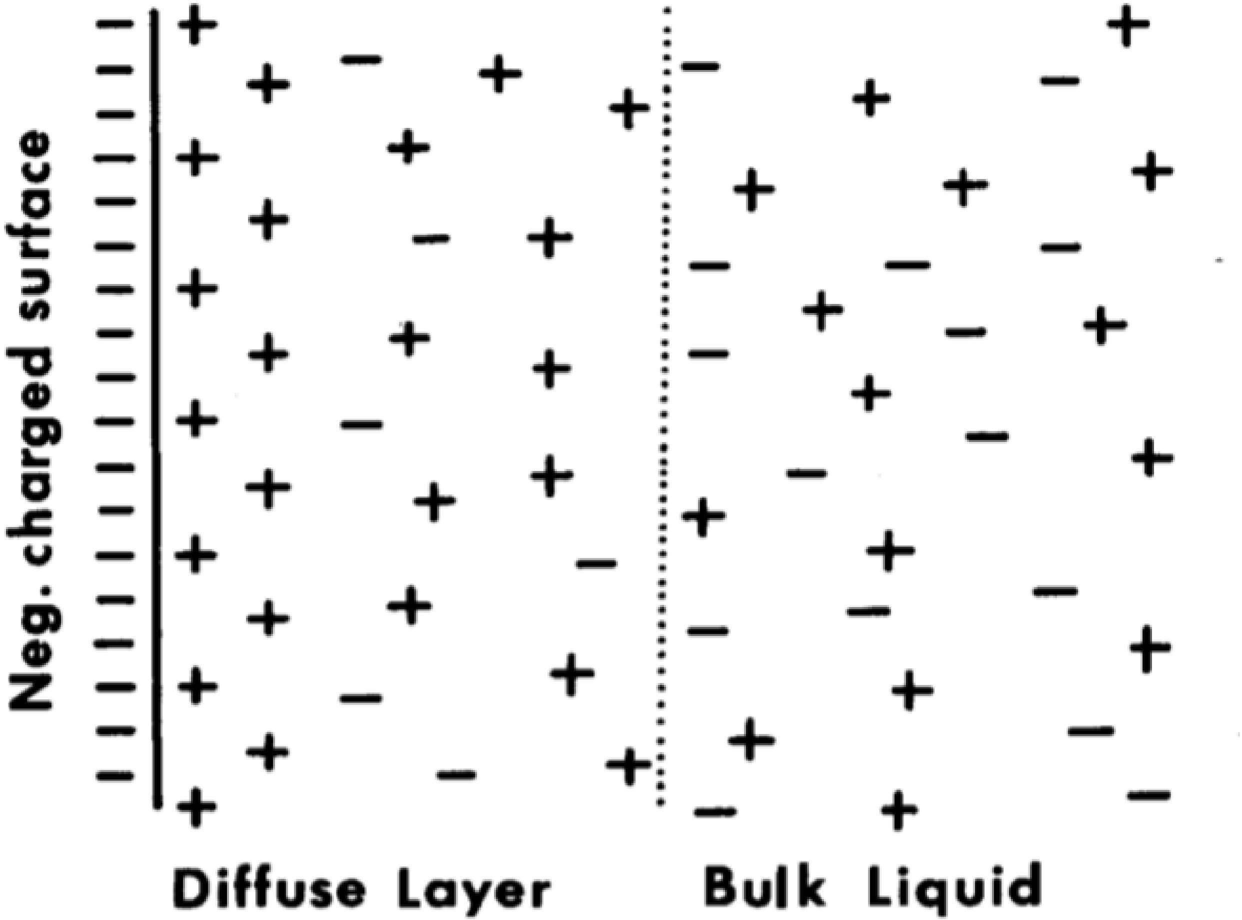


Figure 3.2. Distribution of electric charges in Double Layer according to Gouy-Chapman theory.

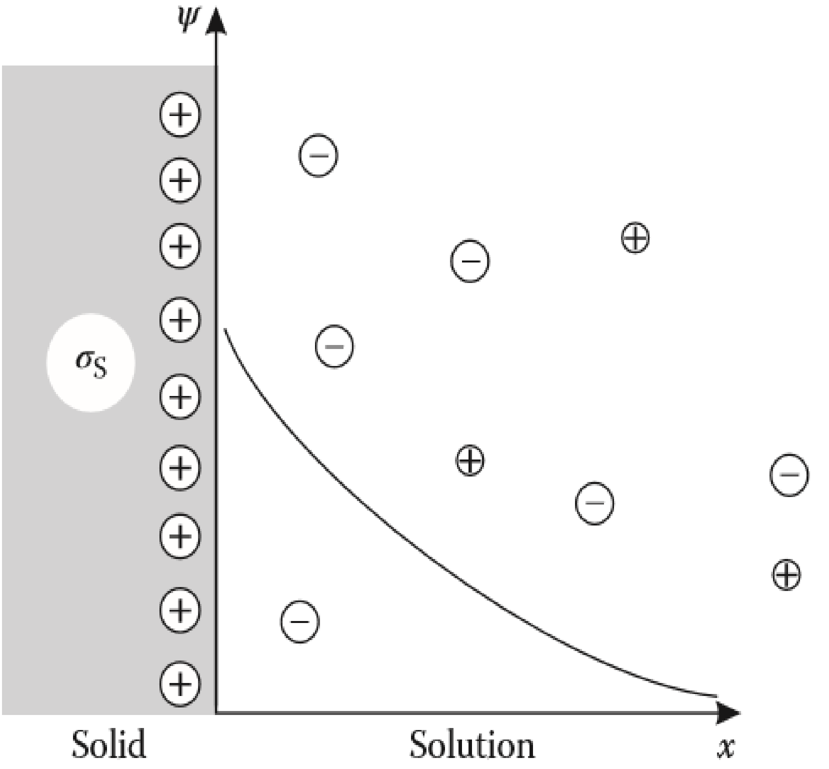


FIGURE 3.3 Schematic drawing of the Gouy–Chapman model of the interface. A plane surface bearing a surface charge σ_S (which in turn determines a surface potential ψ_0) is in contact with an electrolyte solution, where a diffuse layer is present.

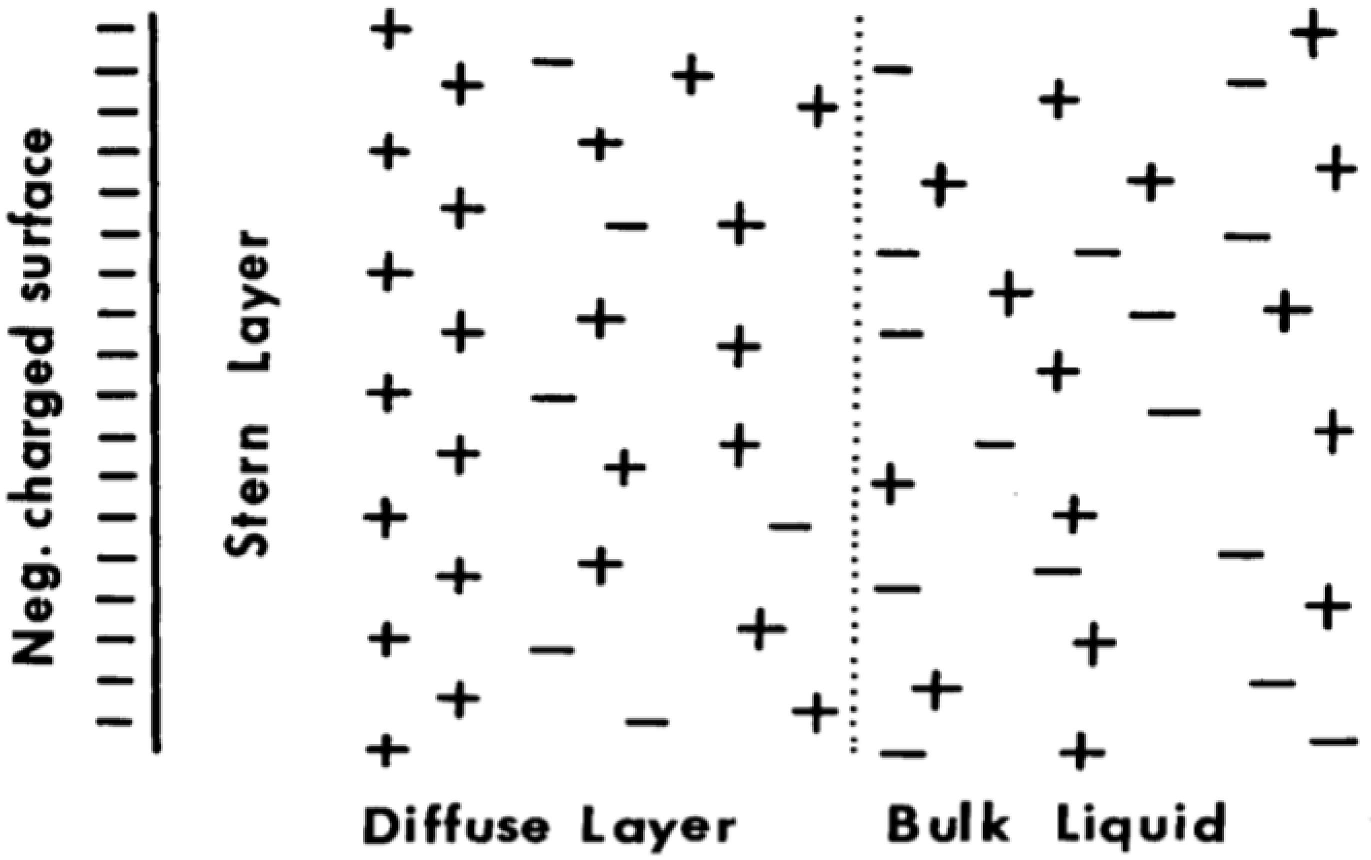


Figure 3.4. Distribution of electric charges in Double Layer according to Stern theory.

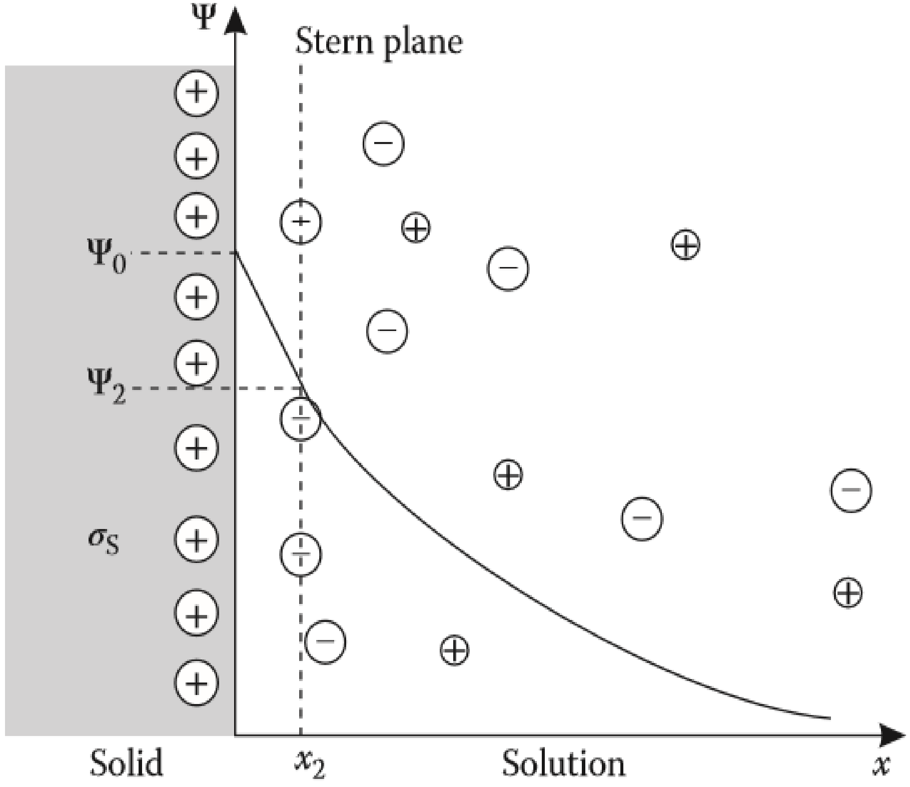


FIGURE 3.11 Schematic representation of the Gouy–Chapman–Stern theory. Compare with Figure 3.3: an additional plane, the Stern plane, is defined as the distance of closest ionic approach to the surface. The region between the Stern plane and the surface behaves as a dielectric.

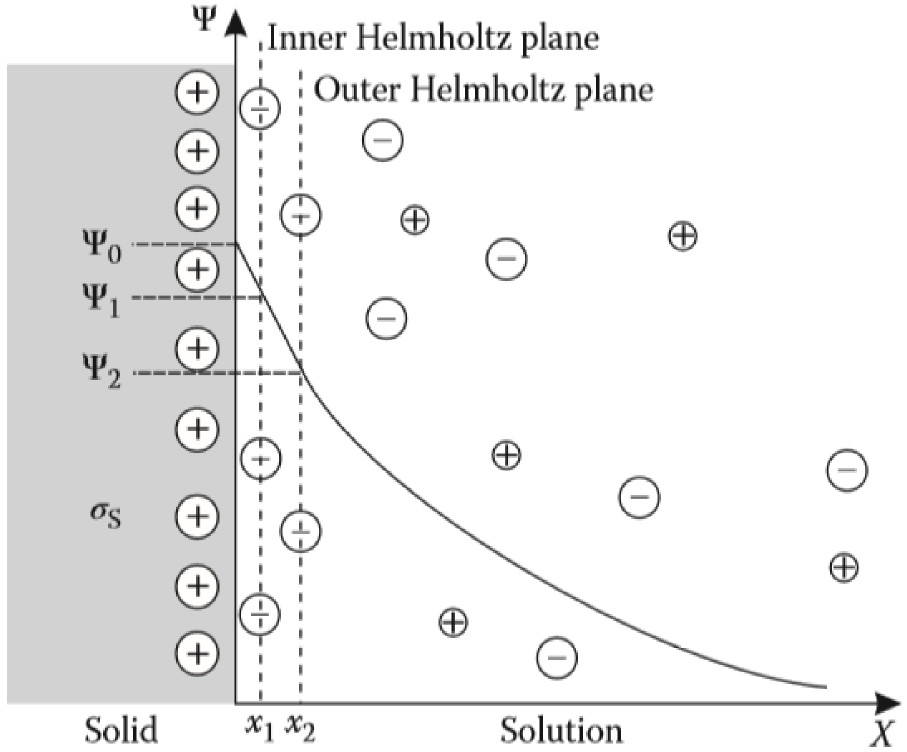


FIGURE 3.13 Schematic representation of the Gouy–Chapman–Stern–Grahame theory. Compare with Figure 3.11: Two planes of closest approach are defined, the outer Helmholtz plane, where ions that retain their hydration layer are adsorbed (nonspecific adsorption) and the inner Helmholtz plane, is defined as the distance where ions loosing the hydration layer (specifically adsorbed) to the surface.

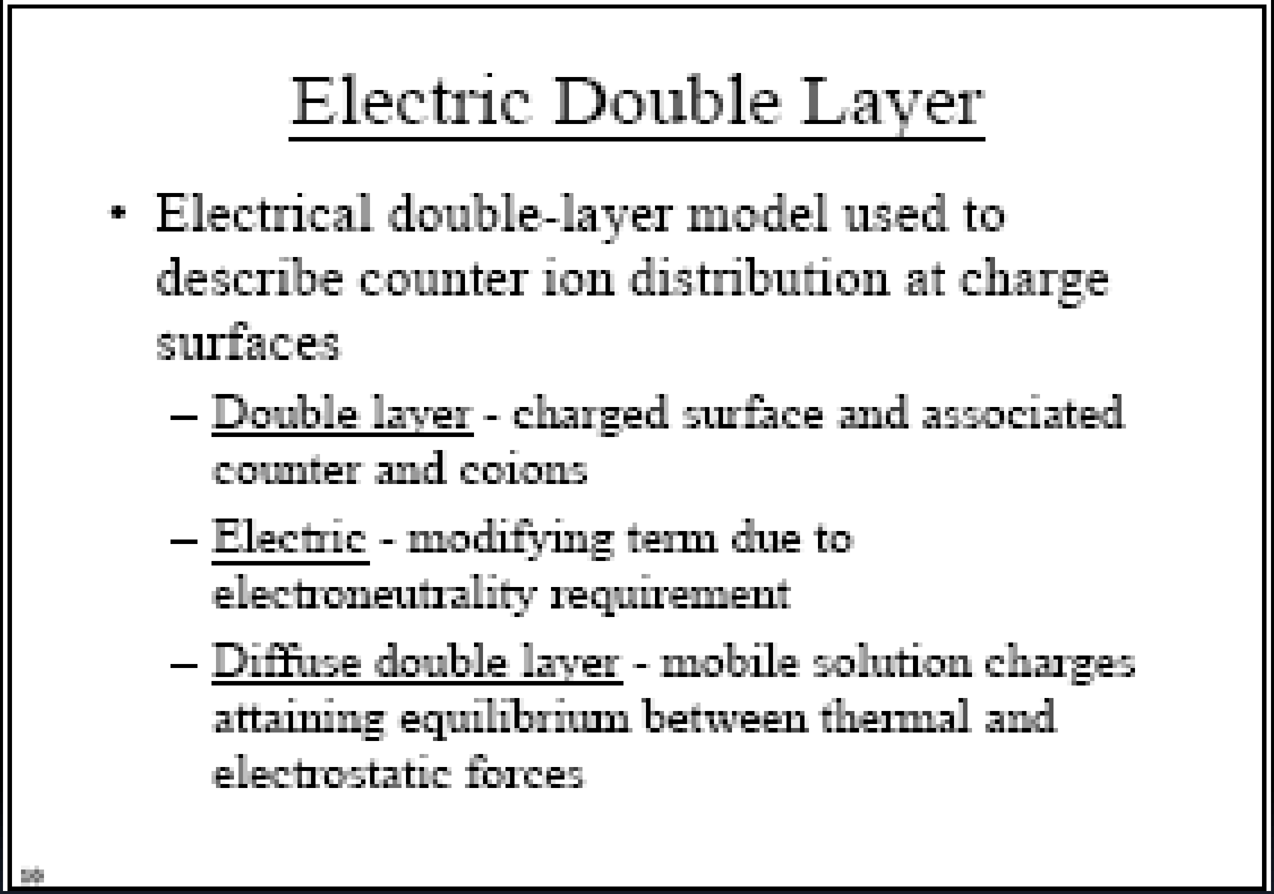
9. Lapisan Rangkap Listrik (Electric Double Layer)

Dua faktor utama yg mempengaruhi ketebalan EDL:

a. Konsentrasi elektrolit

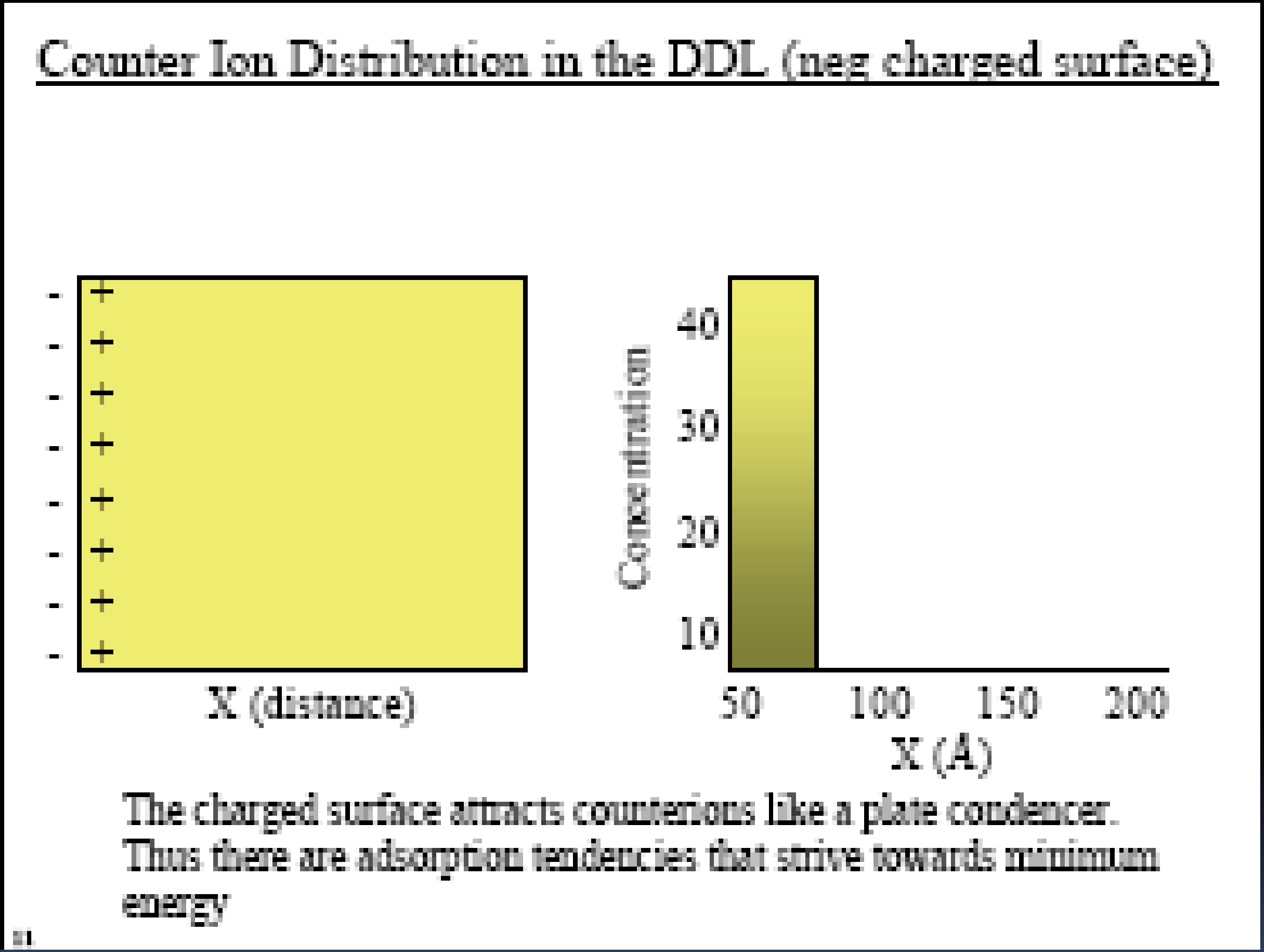
b. Valensi kation

- Semakin tinggi konsentrasi elektrolit maka EDL makin tipis.
- Semakin tinggi valensi kation, EDL makin tipis.
- Ketebalan EDL berpengaruh terhadap flokulasi atau dispersi liat. Apa itu?



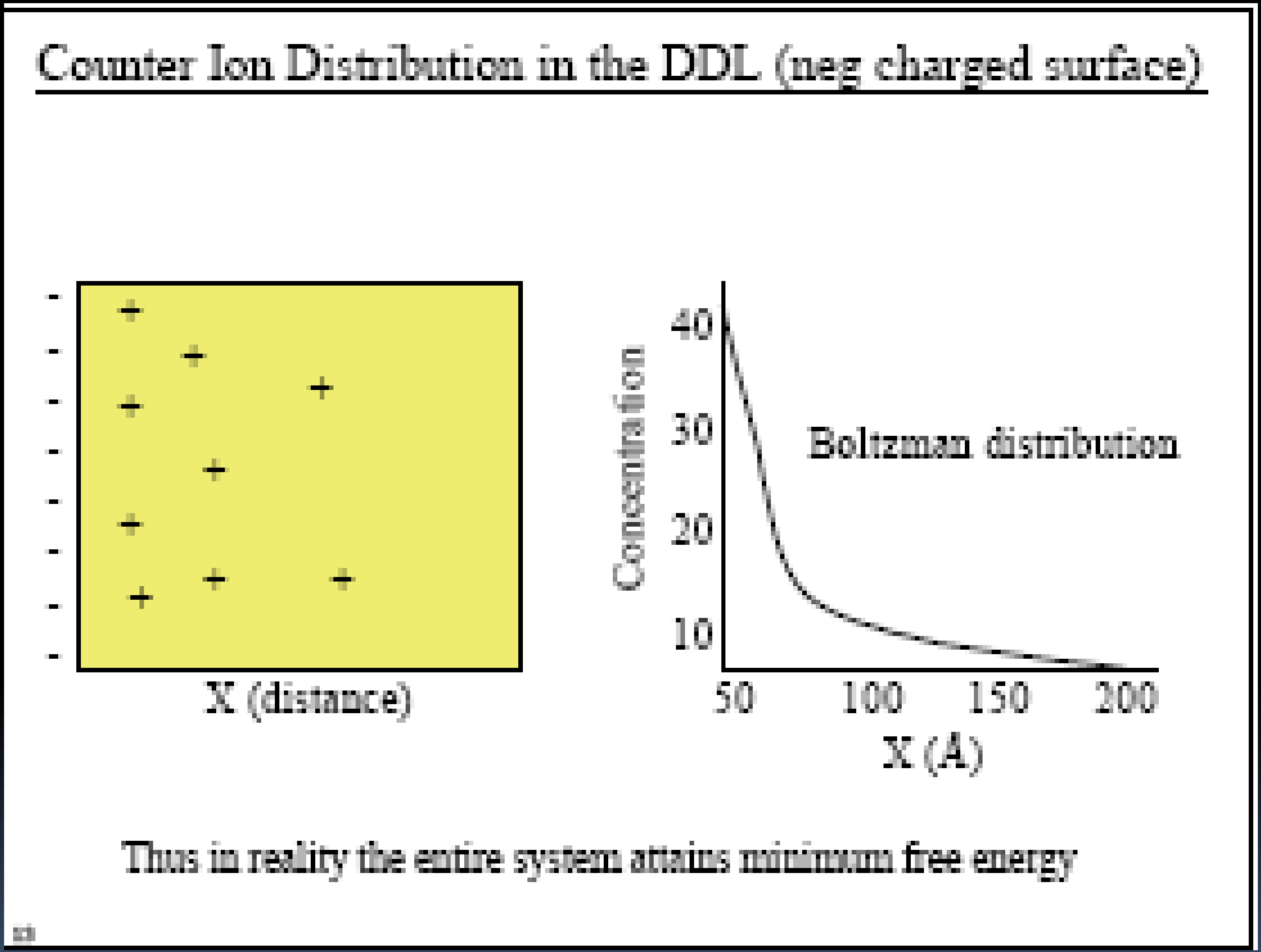
Electric Double Layer

- Electrical double-layer model used to describe counter ion distribution at charge surfaces
  - Double layer - charged surface and associated counter and coions
  - Electric - modifying term due to electroneutrality requirement
  - Diffuse double layer - mobile solution charges attaining equilibrium between thermal and electrostatic forces



Counter Ion Distribution in the DDL (neg charged surface)

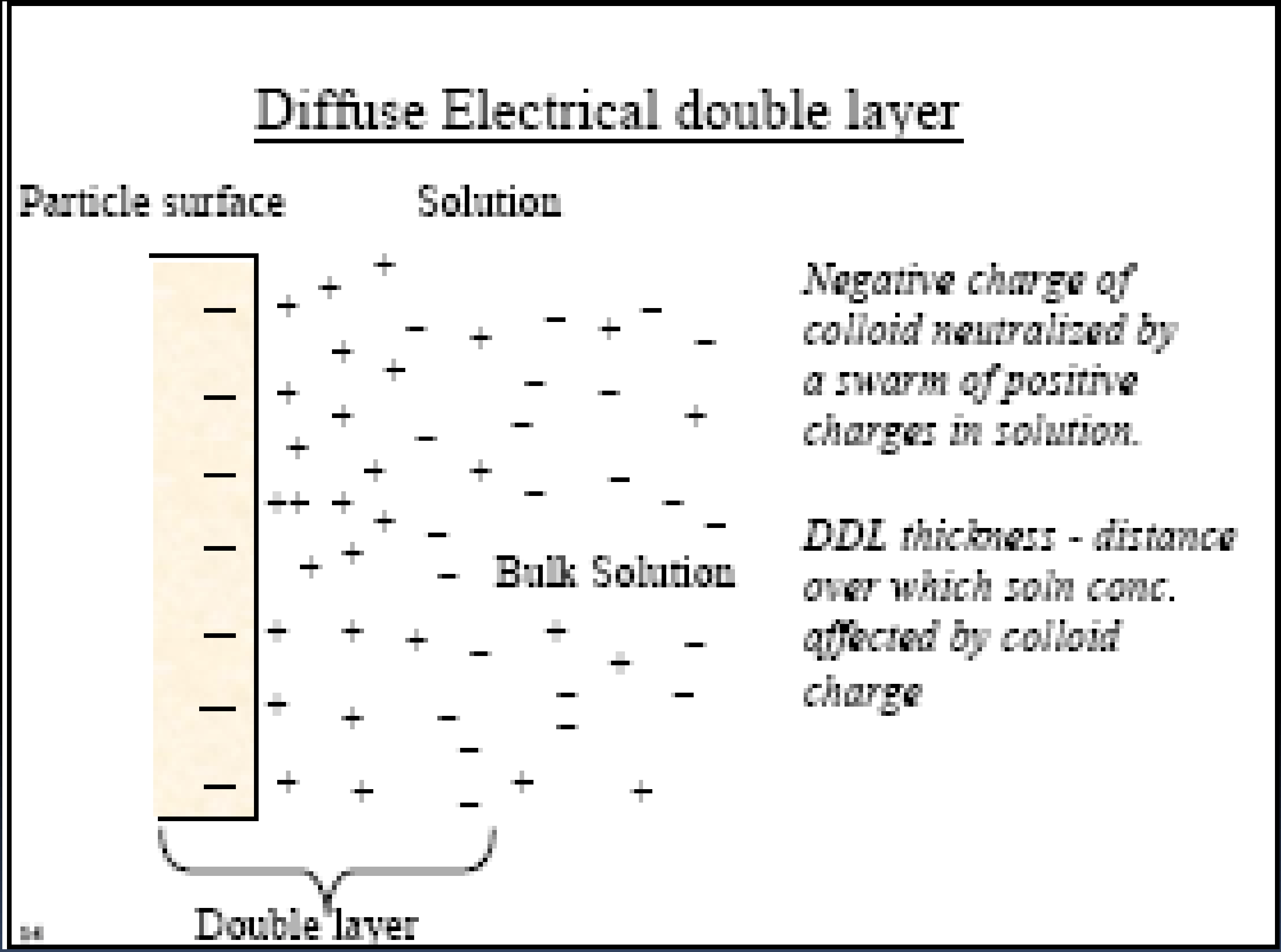
The charged surface attracts counterions like a plate condencer. Thus there are adsorption tendencies that strive towards minimum energy



Counter Ion Distribution in the DDL (neg charged surface)

Thus in reality the entire system attains minimum free energy

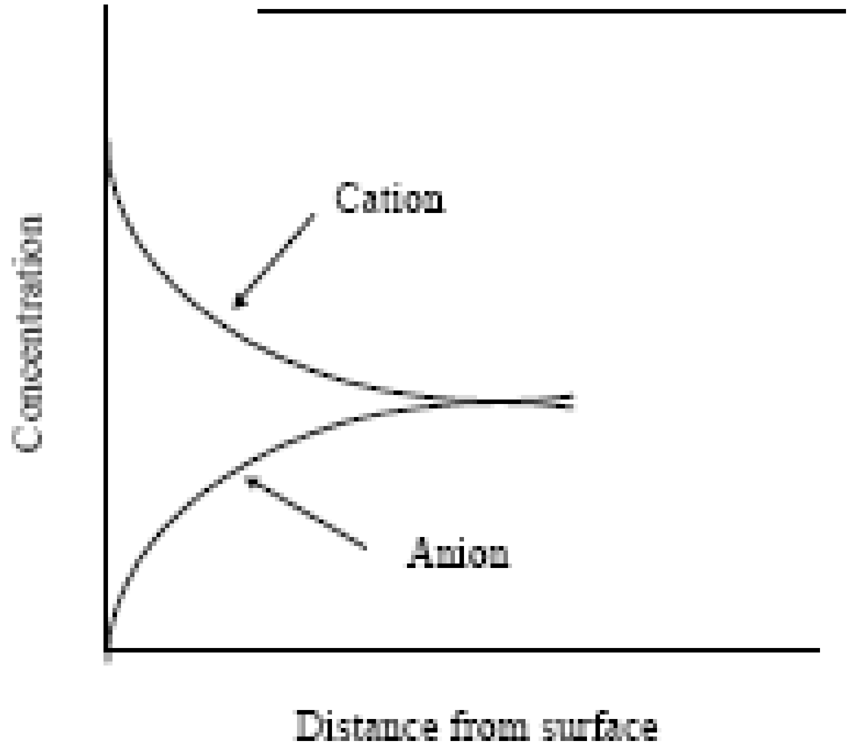
Diffuse Electrical double layer

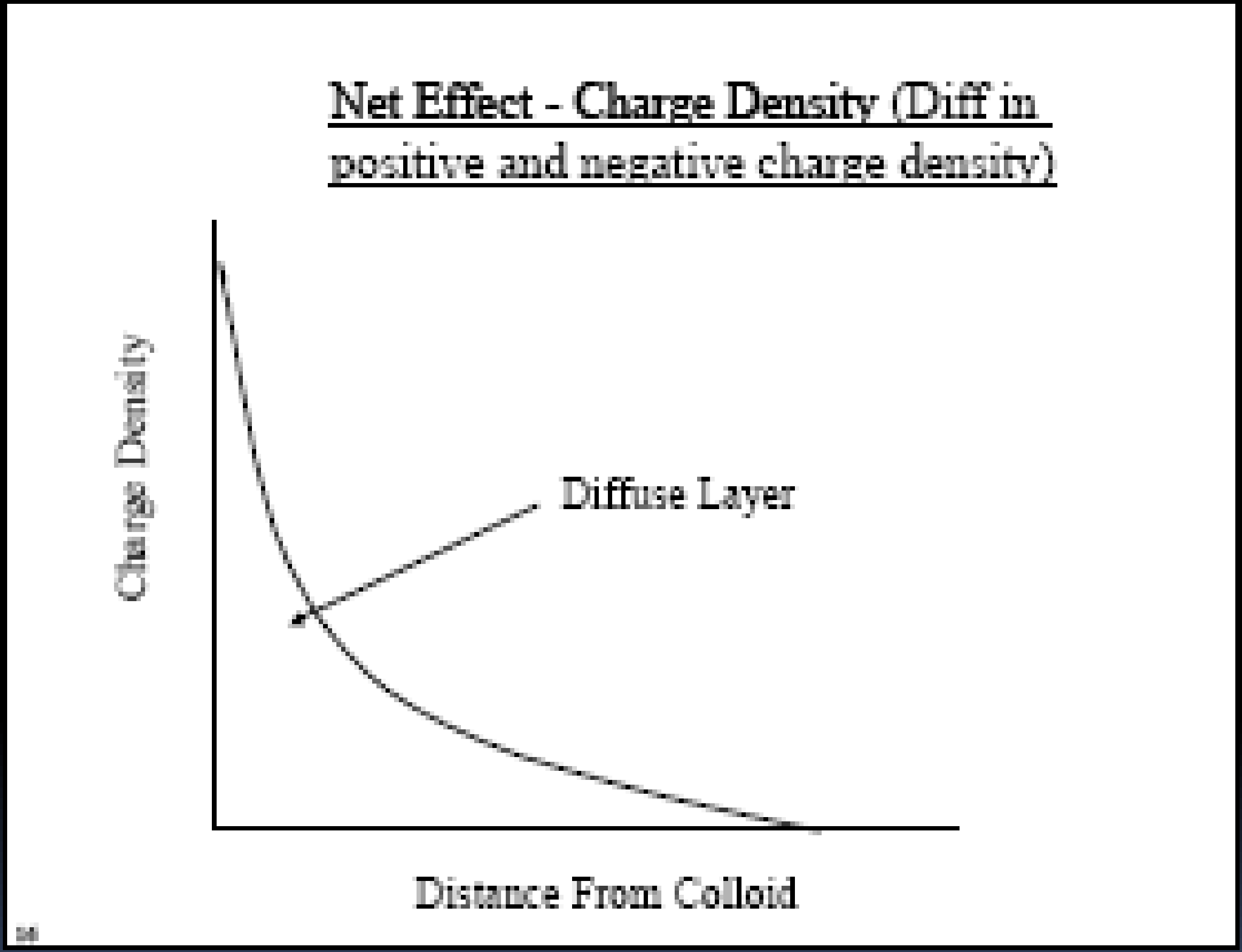


Negative charge of colloid neutralized by a swarm of positive charges in solution.

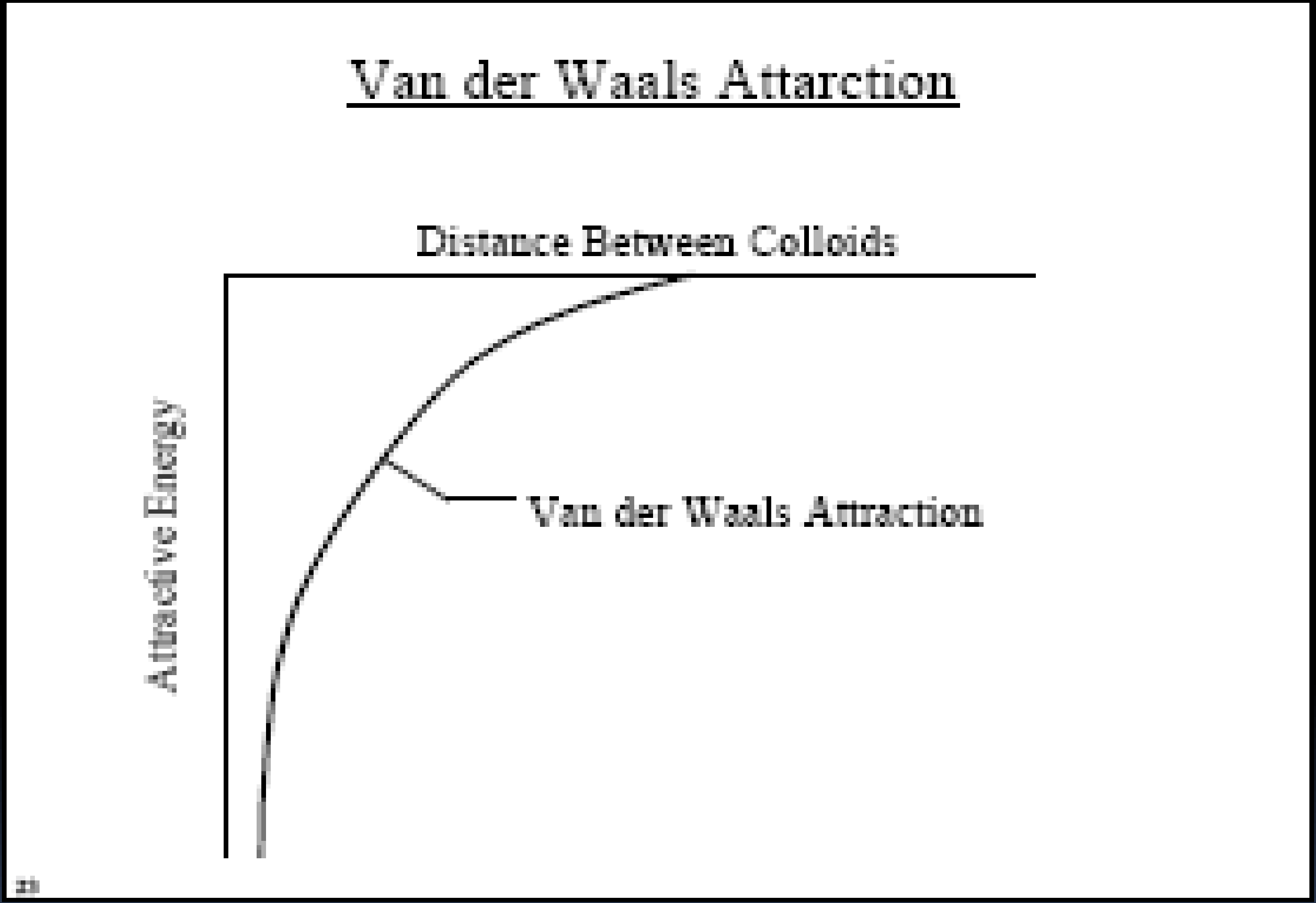
DDL thickness - distance over which soln conc. affected by colloid charge

Variation of cation and anion concentration with distance from the surface

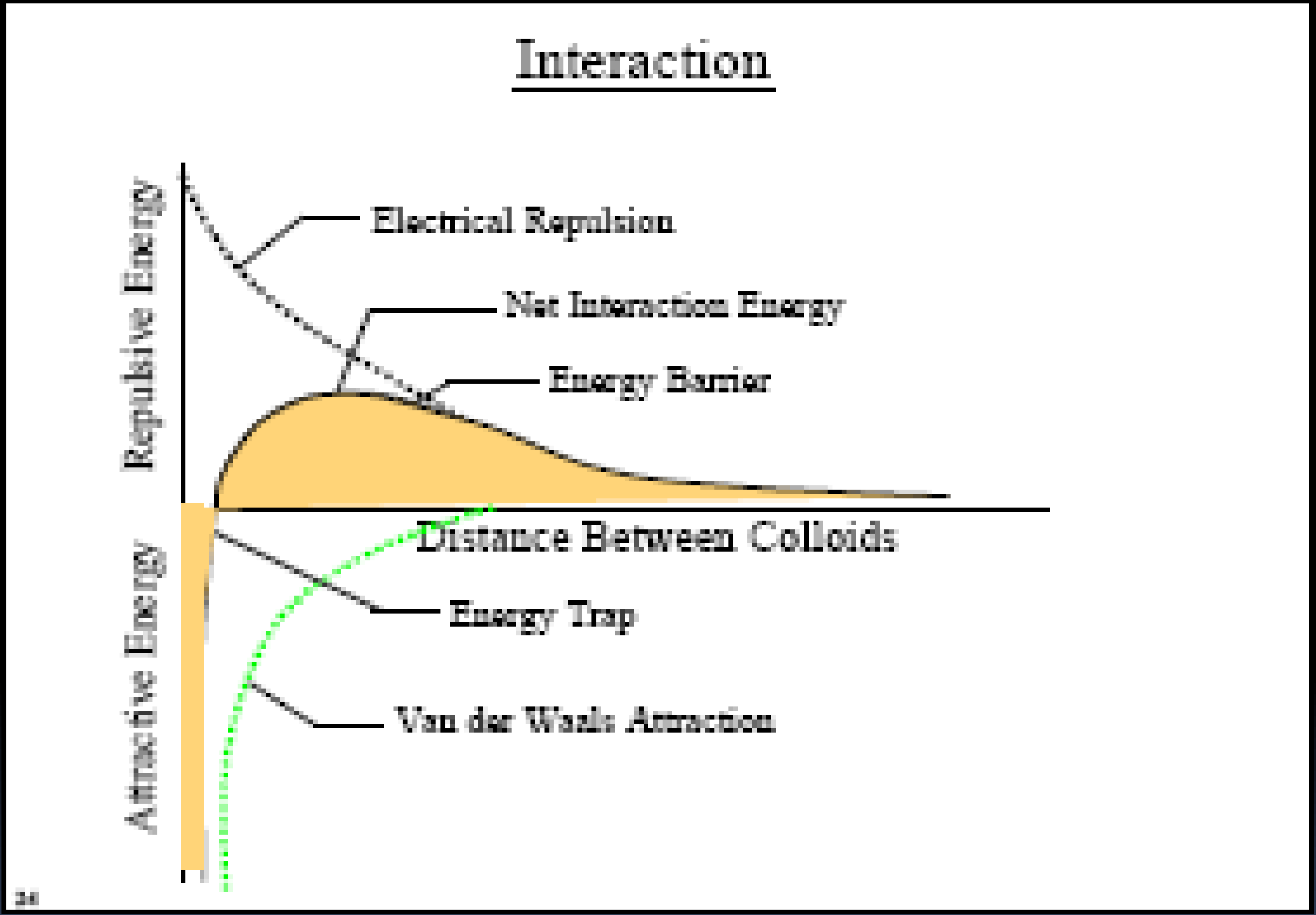




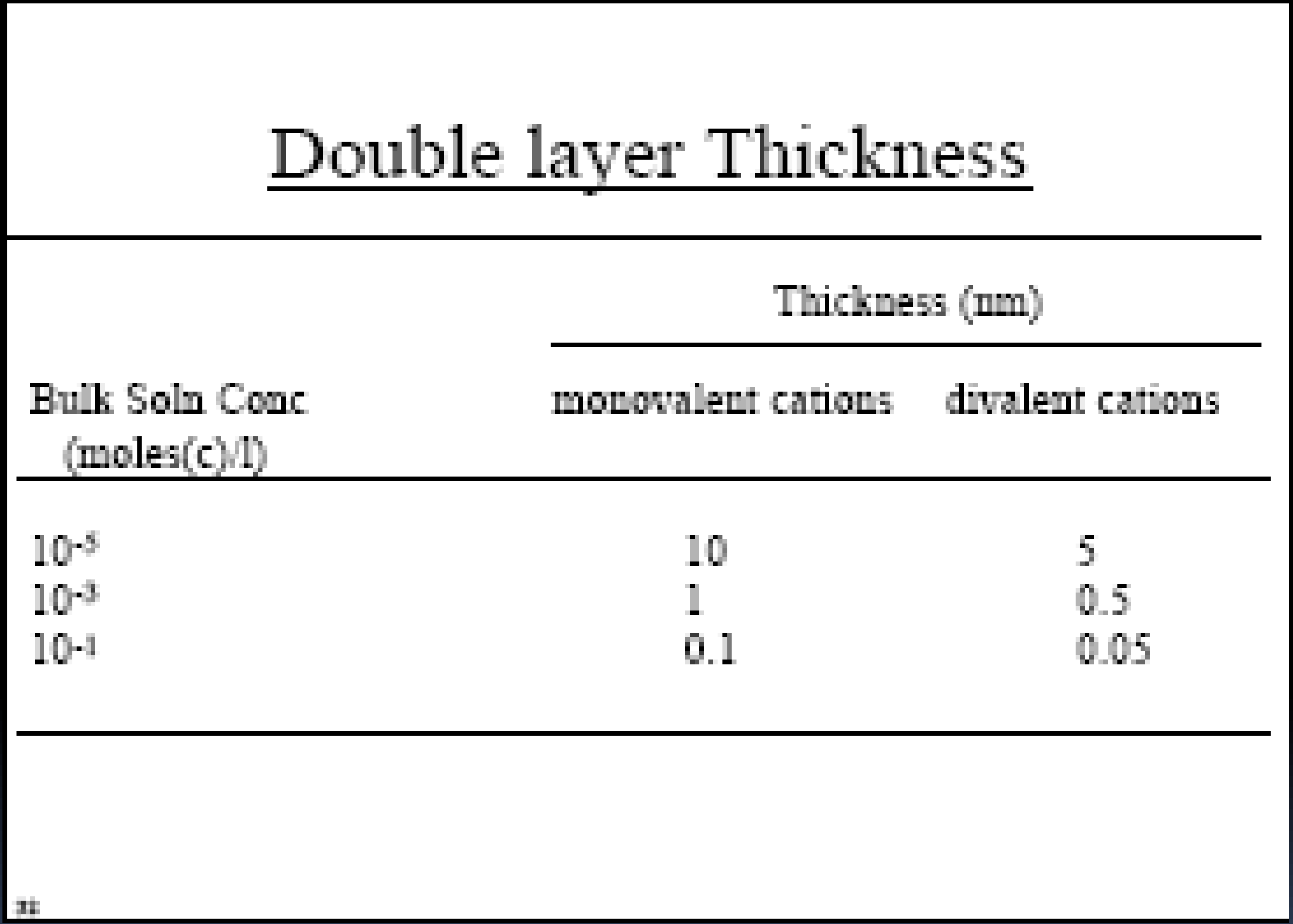
Net Effect - Charge Density (Diff in positive and negative charge density)



Van der Waals Attarction



Interaction



Double layer Thickness

Bulk Soln Conc (moles(c)/l)	Thickness (nm) monovalent cations	 divalent cations
10^{-5}	10	5
10^{-3}	1	0.5
10^{-1}	0.1	0.05

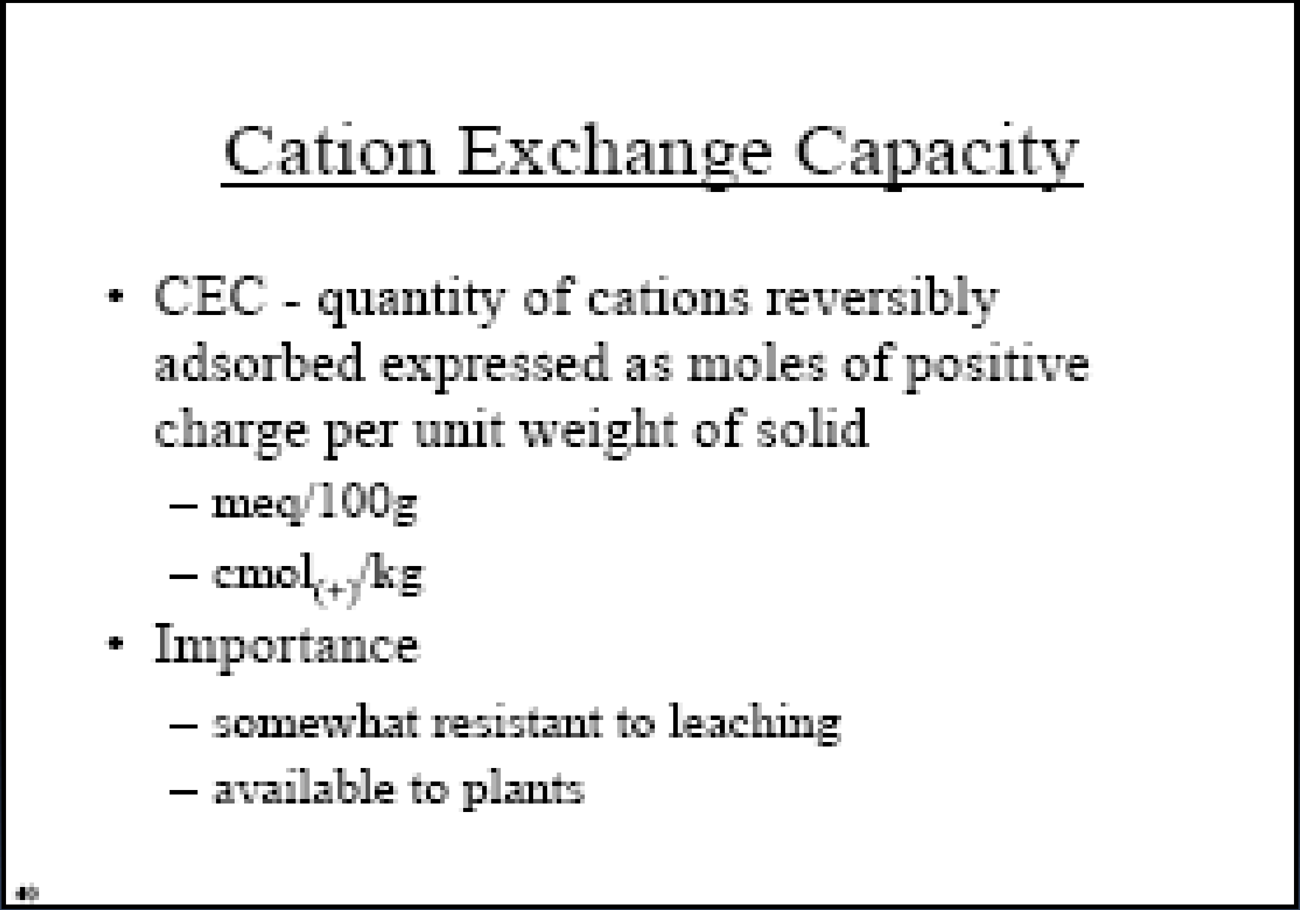
10. EDL dan Stabilitas Liat

Liat dg EDLnya, jika saling mendekat pd jarak ttt akan ditolak namun jika jaraknya semakin dekat akan terjadi gaya van der waals dan liat tertarik. Jika saling tolak liat akan terdispersi, sedang jika saring terikat disebut terflokulasi.

- Jarak kritis 20 A°, jika < 20 A° maka gaya van der waals dominan shg liat terflokulasi. Jika jarak > 20 A° gaya tolak dominan, mk liat terdispersi atau suspensi liat stabil.

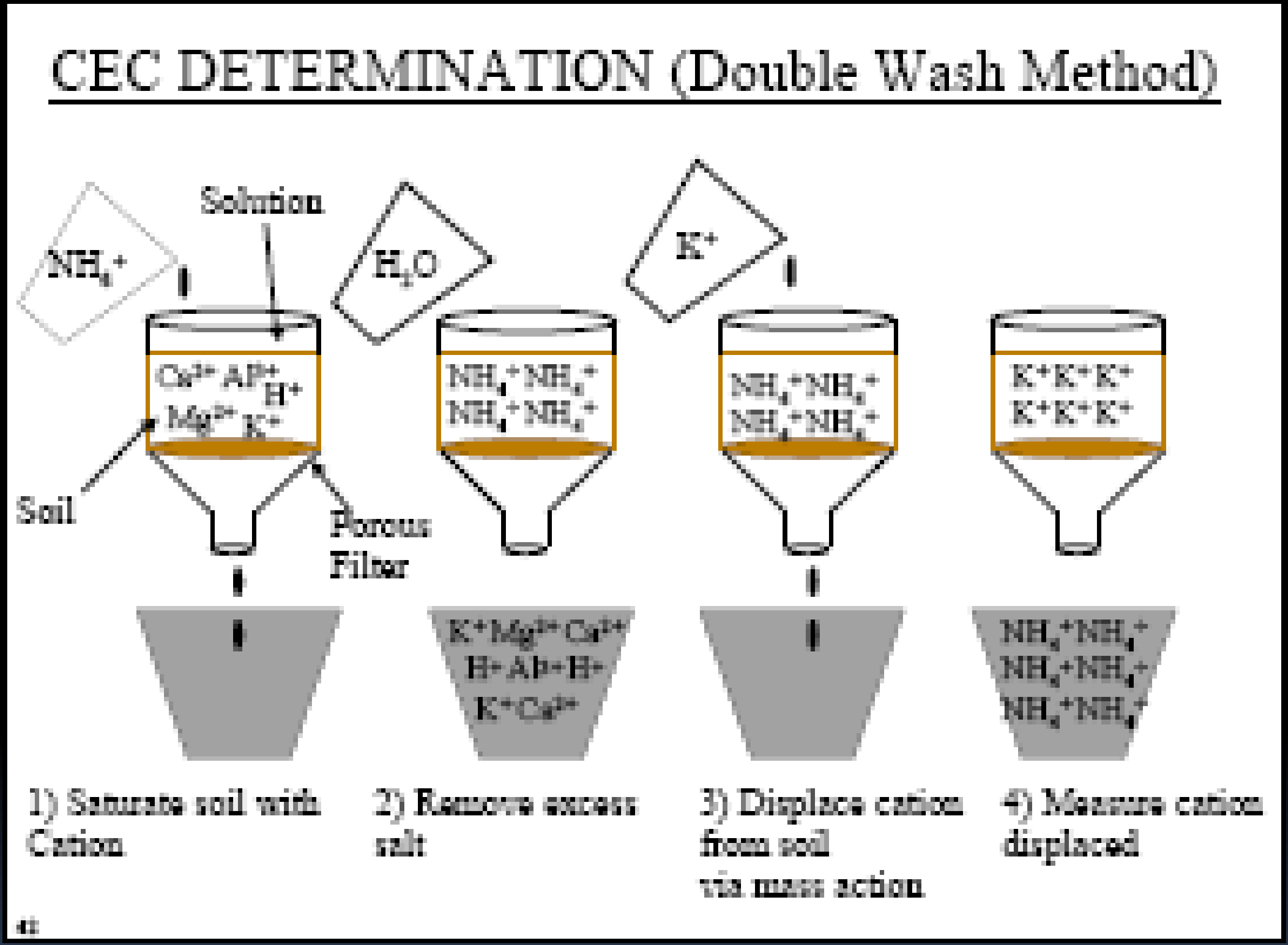
11. Hubungan EDL dg stabilitas liat dan Pembentukan agregat

- Pada EDL yang tipis, maka liat terflokulasi. Liat terflokulasi mrp salah satu syarat terbentuknya agregat. Syarat lain harus terjadi sementasi.
- Jadi bagaimana hubungan valensi dan konsentrasi elektrolit terhadap pembentukan agregat?



Cation Exchange Capacity

- CEC - quantity of cations reversibly adsorbed expressed as moles of positive charge per unit weight of solid
  - meq/100g
  - $\text{cmol}_{(+)}/\text{kg}$
- Importance
  - somewhat resistant to leaching
  - available to plants



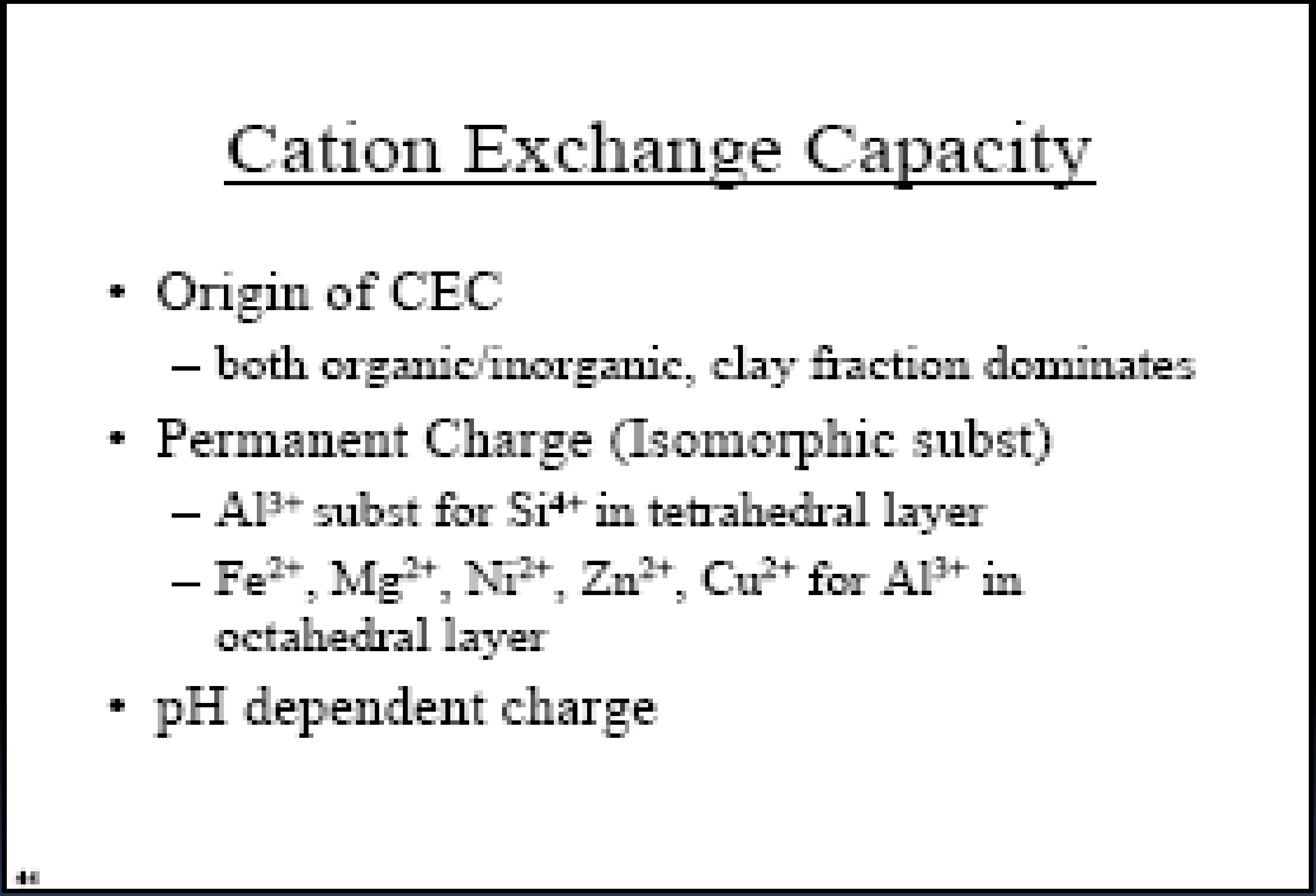
CEC DETERMINATION (Double Wash Method)

1) Saturate soil with Cation

2) Remove excess salt

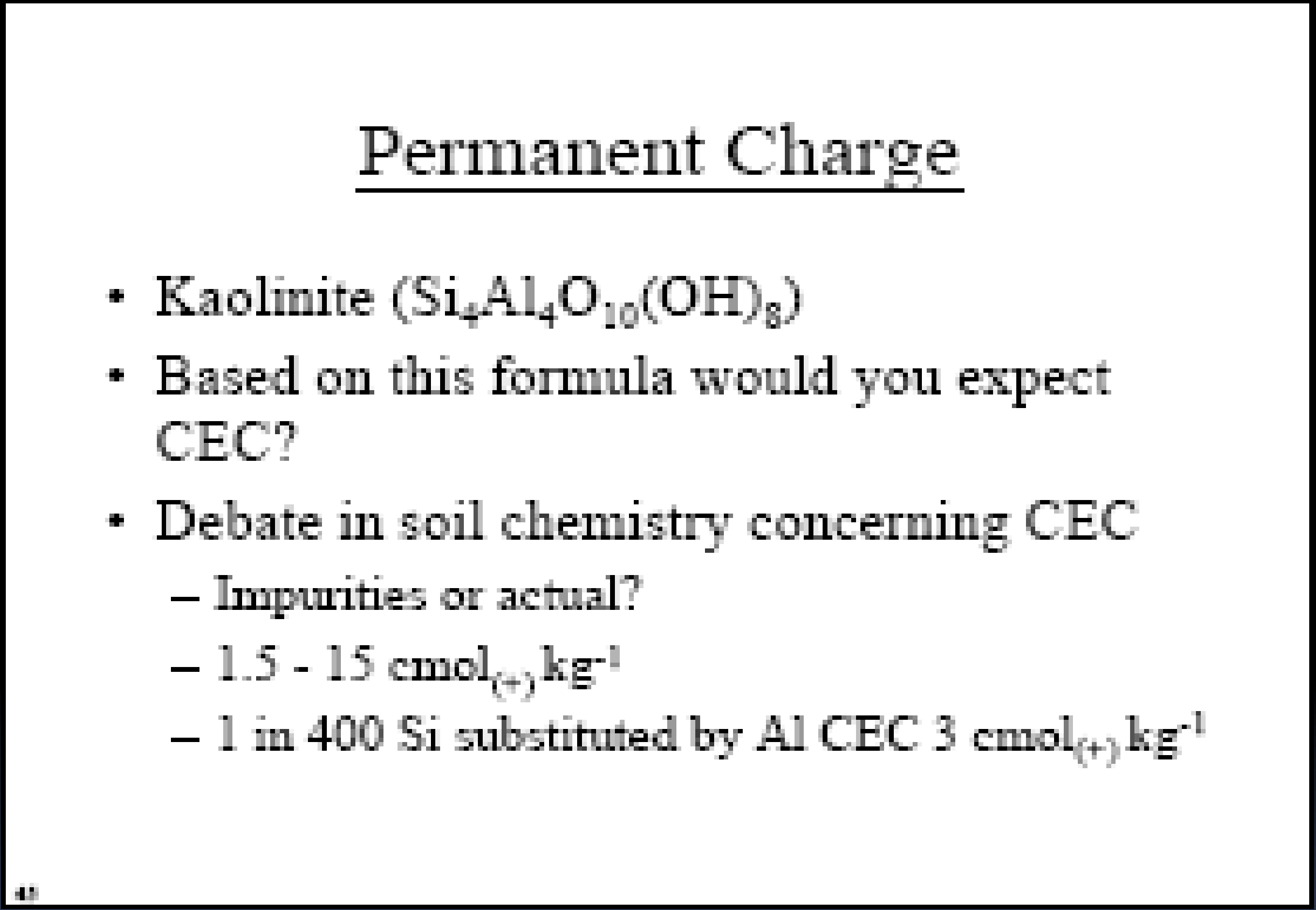
3) Displace cation from soil via mass action

4) Measure cation displaced



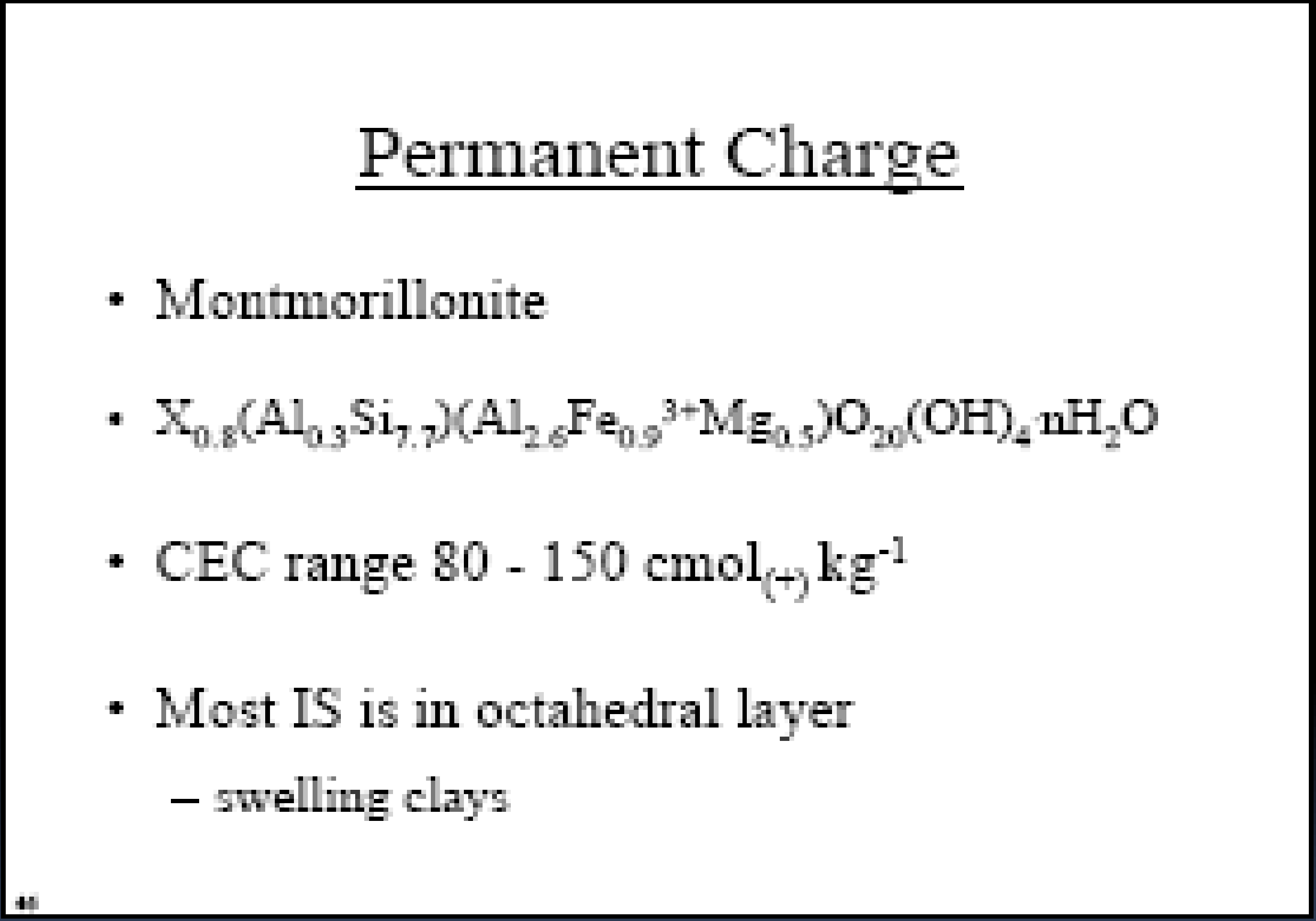
Cation Exchange Capacity

- Origin of CEC
  - both organic/inorganic, clay fraction dominates
- Permanent Charge (Isomorphic subst)
  - Al^{3+} subst for Si^{4+} in tetrahedral layer
  - Fe^{2+}, Mg^{2+}, Ni^{2+}, Zn^{2+}, Cu^{2+} for Al^{3+} in octahedral layer
- pH dependent charge



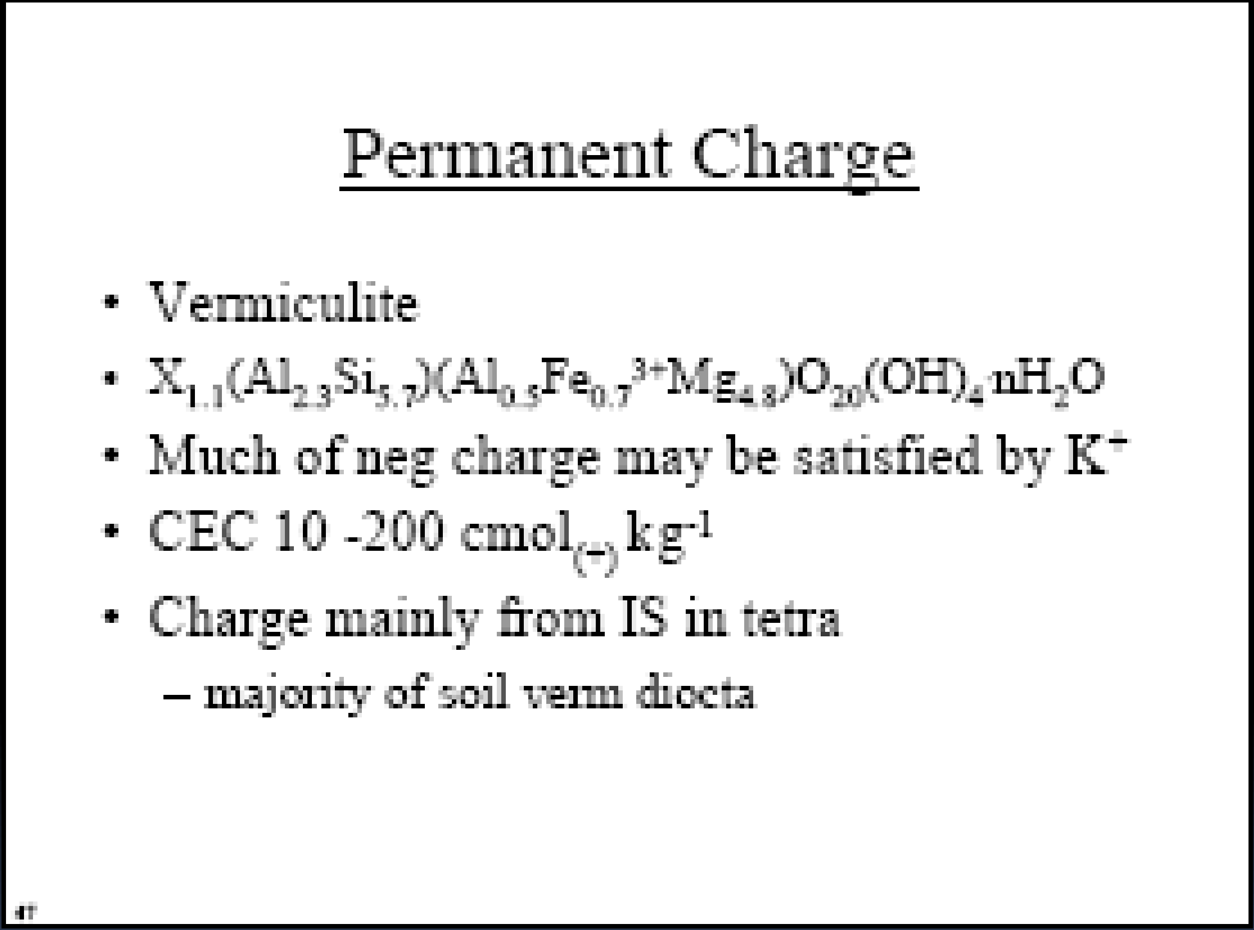
Permanent Charge

- Kaolinite ($Si_4Al_4O_{10}(OH)_8$)
- Based on this formula would you expect CEC?
- Debate in soil chemistry concerning CEC
  - Impurities or actual?
  - 1.5 - 15 $cmol_{(+)}kg^{-1}$
  - 1 in 400 Si substituted by Al CEC 3 $cmol_{(+)}kg^{-1}$



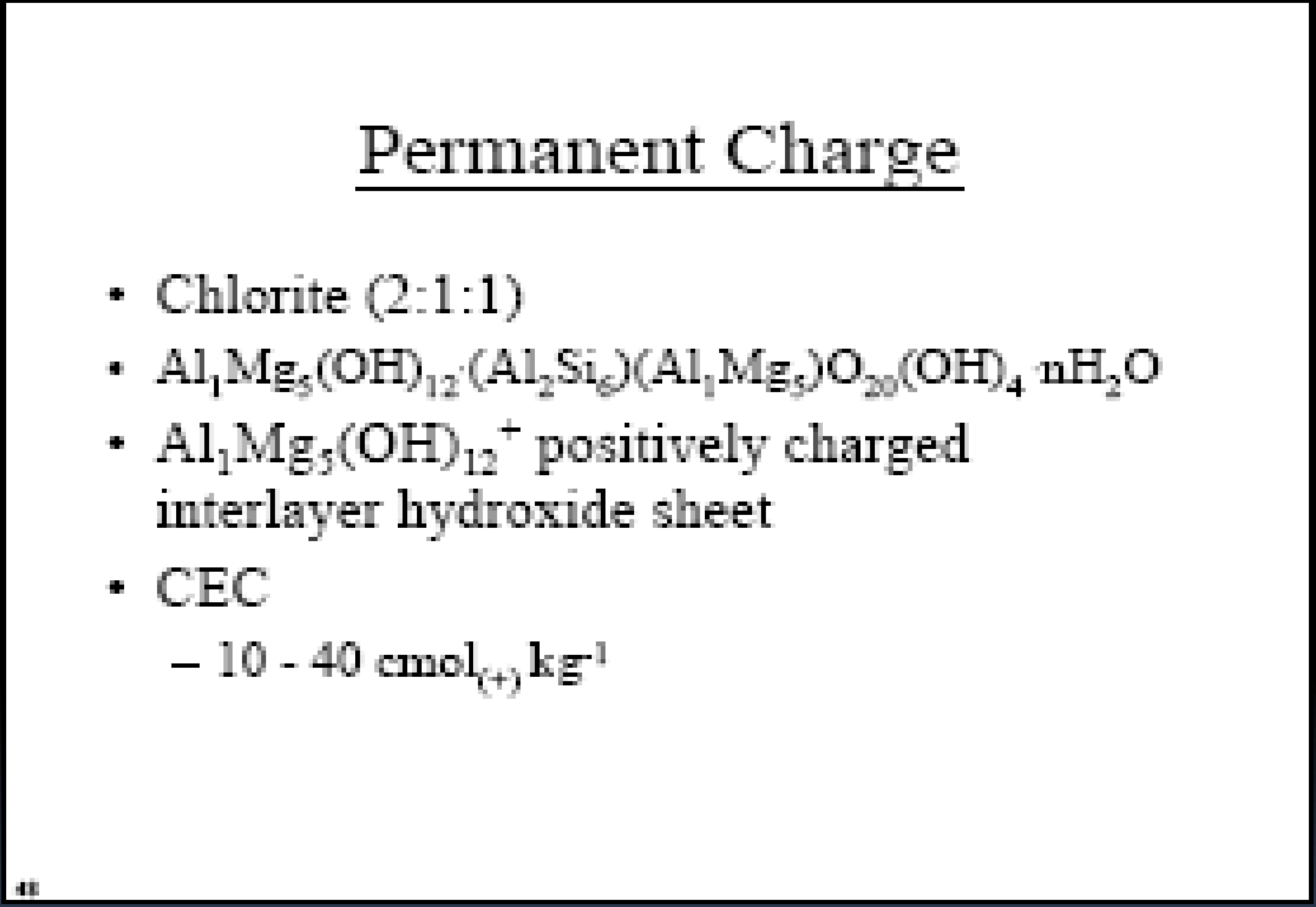
Permanent Charge

- Montmorillonite
- $X_{0.8}(Al_{0.3}Si_{7.7})(Al_{2.6}Fe_{0.9}^{3+}Mg_{0.5})O_{20}(OH)_4 \cdot nH_2O$
- CEC range 80 - 150 $cmol_{(+)}\,kg^{-1}$
- Most IS is in octahedral layer
  - – swelling clays



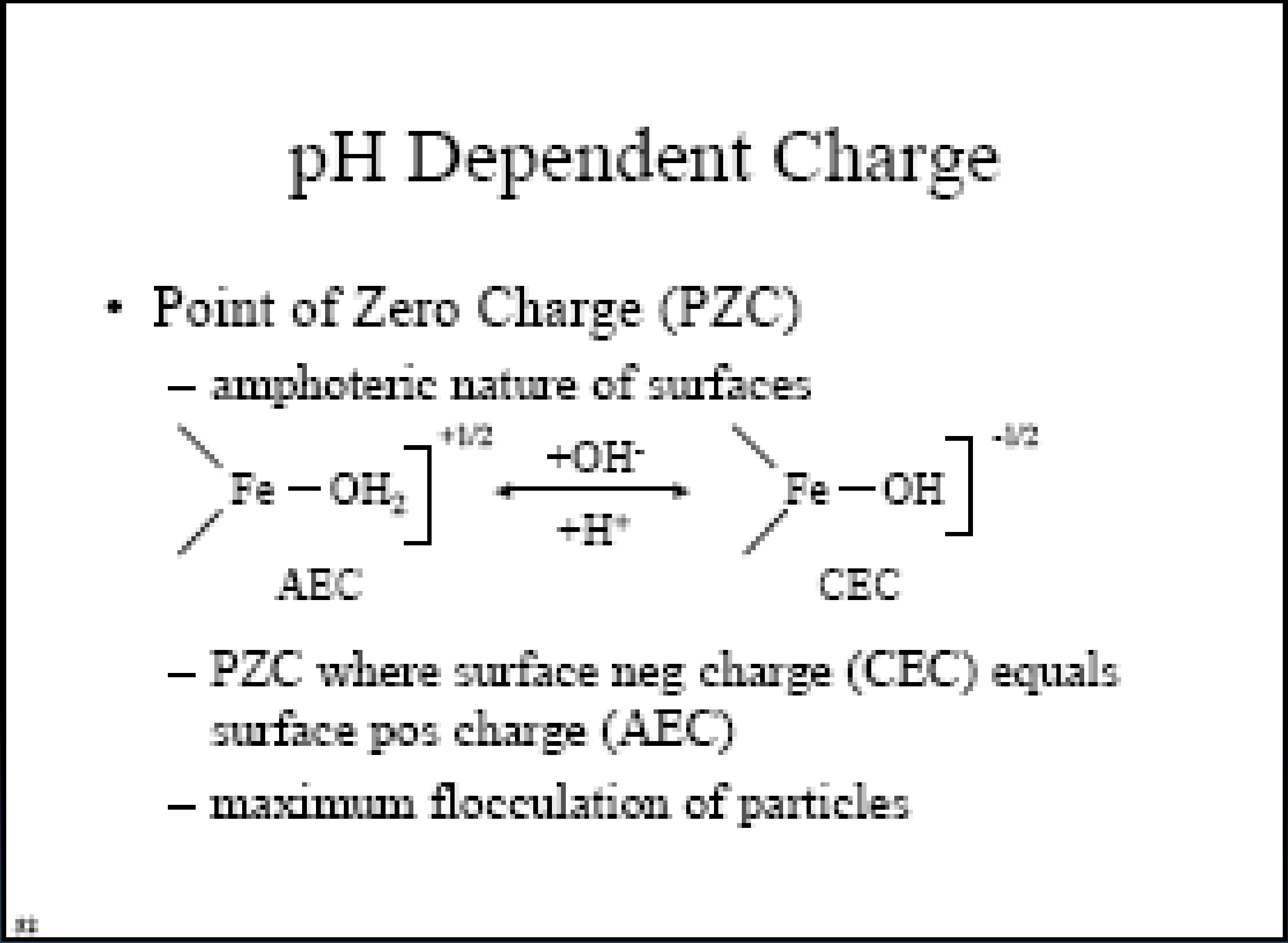
Permanent Charge

- Vermiculite
- $X_{1.1}(Al_{2.3}Si_{5.7})(Al_{0.5}Fe_{0.7}{}^{3+}Mg_{4.8})O_{20}(OH)_4 \cdot nH_2O$
- Much of neg charge may be satisfied by K^+
- CEC 10 -200 $cmol_{(+)}\,kg^{-1}$
- Charge mainly from IS in tetra
  - – majority of soil verm diocta



Permanent Charge

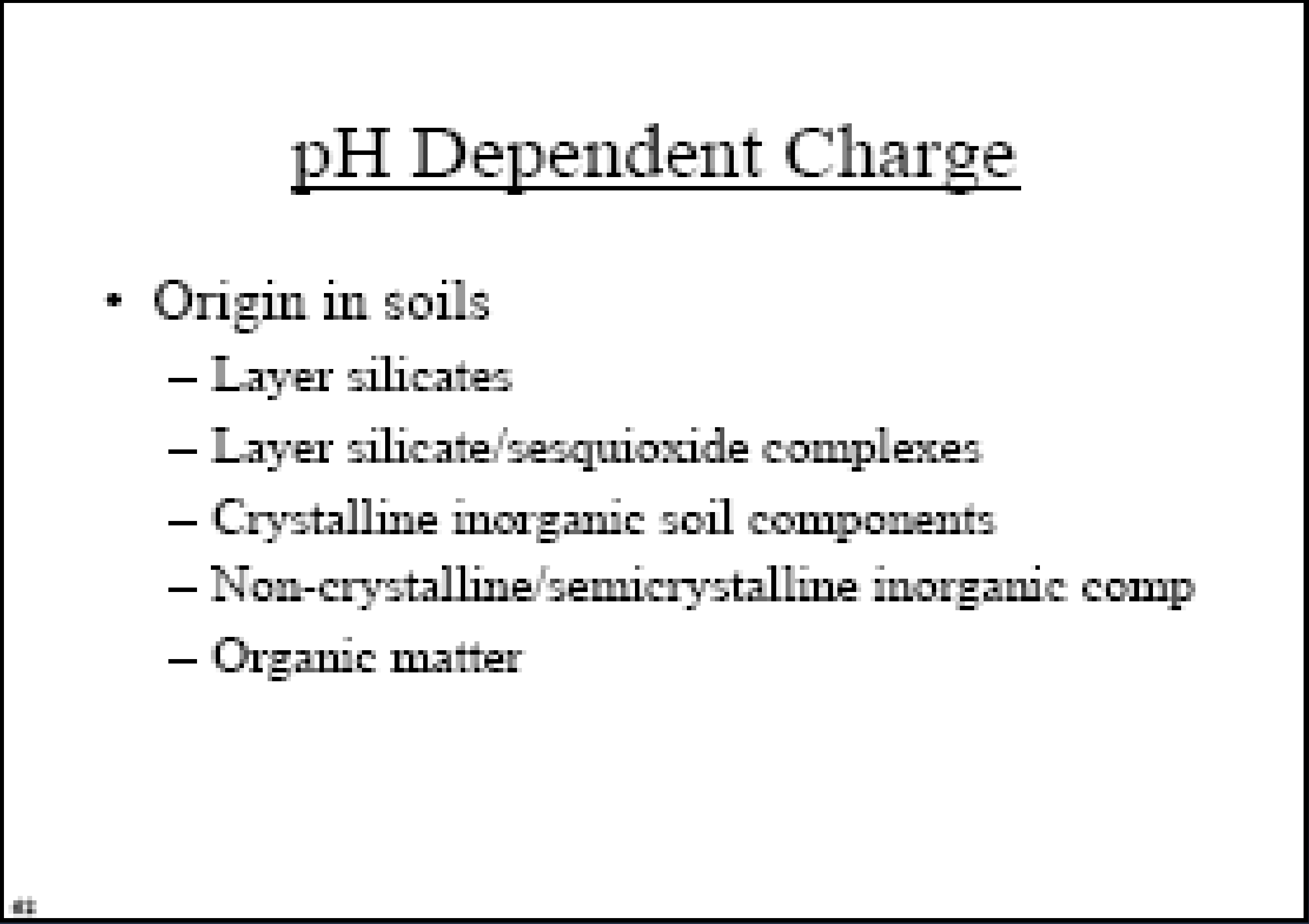
- Chlorite (2:1:1)
- $Al_1Mg_5(OH)_{12}\cdot(Al_2Si_6)(Al_1Mg_5)O_{20}(OH)_4\cdot nH_2O$
- $Al_1Mg_5(OH)_{12}^{+}$ positively charged interlayer hydroxide sheet
- CEC
  - 10 - 40 $cmol_{(+)}\,kg^{-1}$



pH Dependent Charge

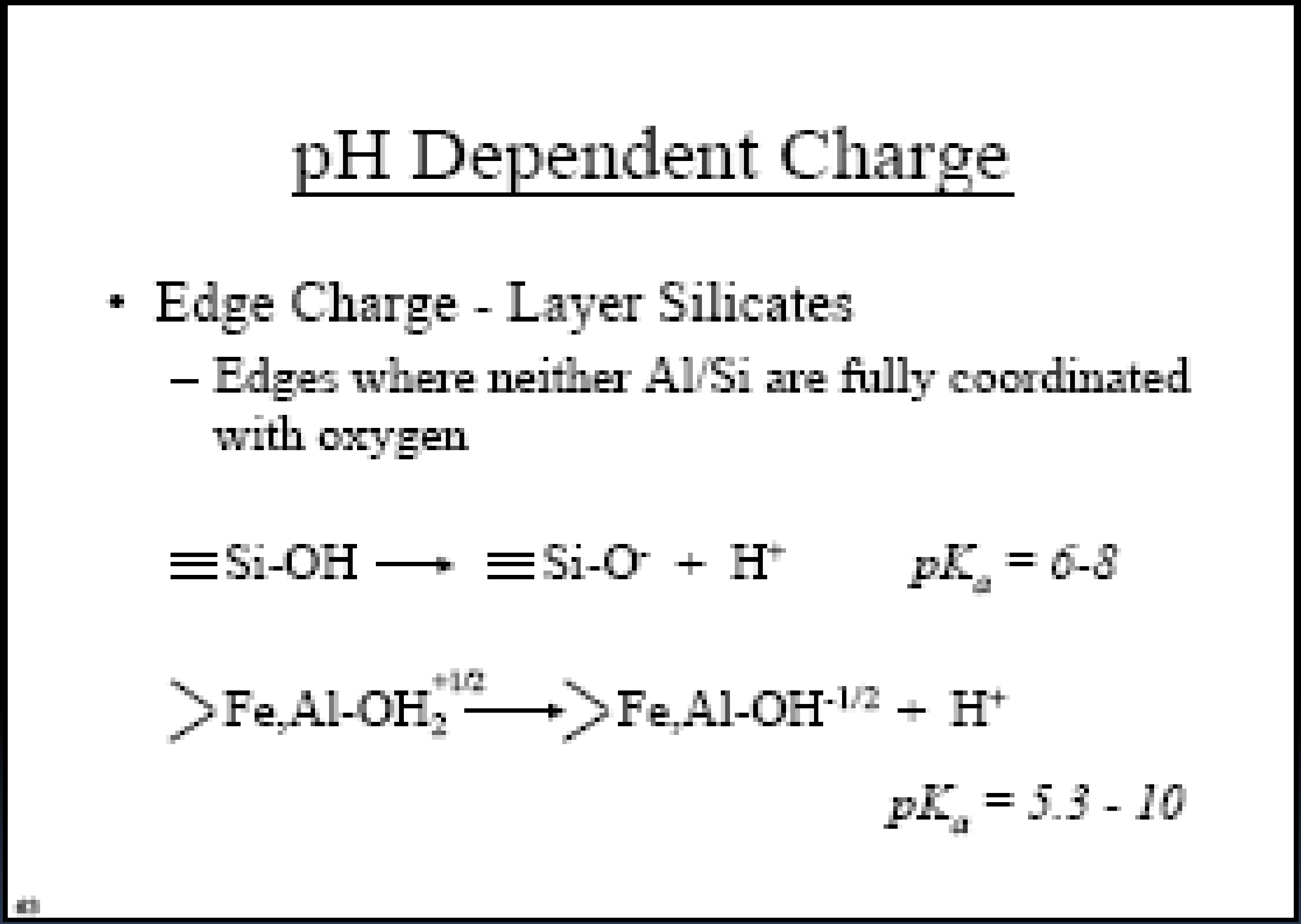
- Point of Zero Charge (PZC)
  - amphoteric nature of surfaces

  - PZC where surface neg charge (CEC) equals surface pos charge (AEC)
  - maximum flocculation of particles



pH Dependent Charge

- Origin in soils
  - – Layer silicates
  - – Layer silicate/sesquioxide complexes
  - – Crystalline inorganic soil components
  - – Non-crystalline/semicrystalline inorganic comp
  - – Organic matter



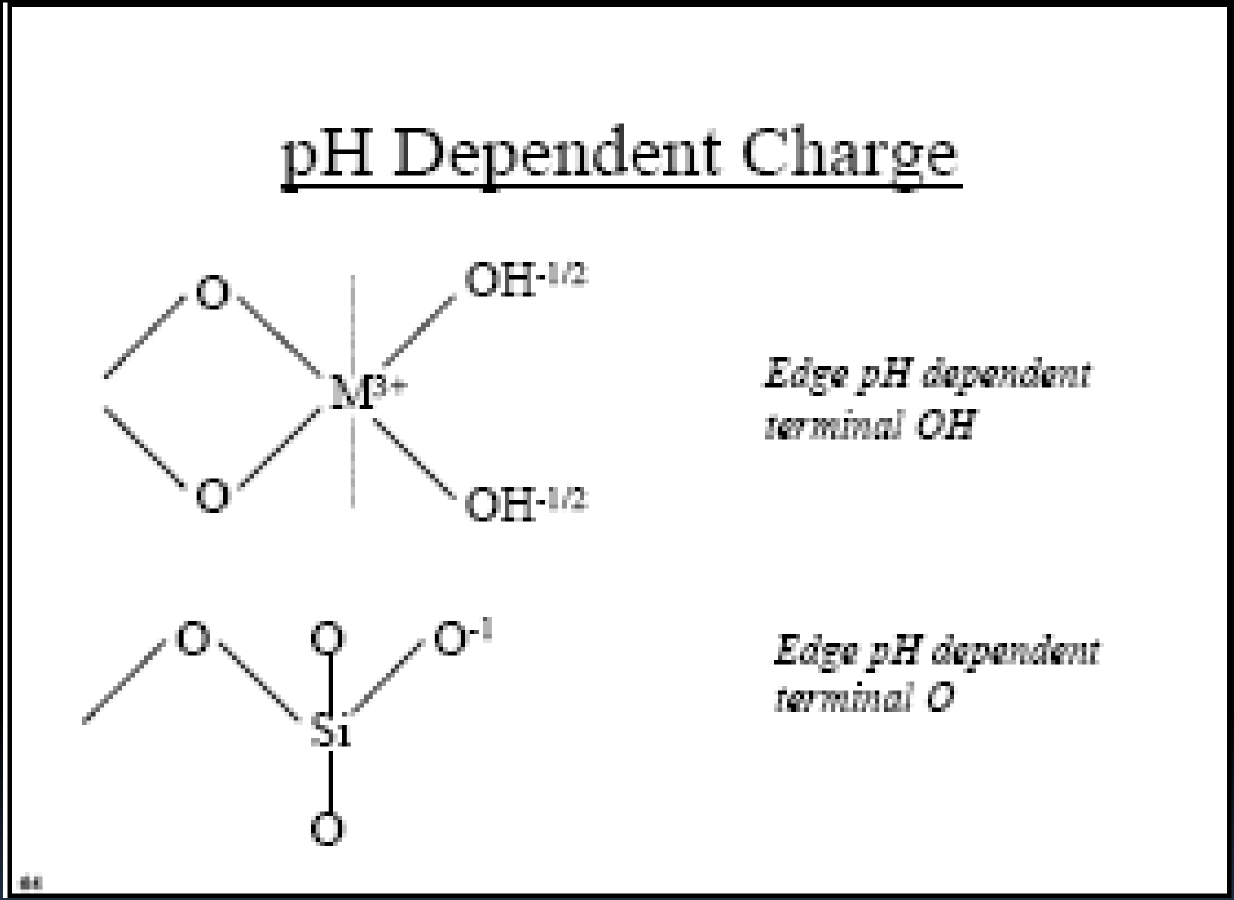
pH Dependent Charge

- Edge Charge - Layer Silicates
  - Edges where neither Al/Si are fully coordinated with oxygen

$$\equiv\text{Si-OH} \longrightarrow \equiv\text{Si-O}^{-} + \text{H}^{+} \qquad pK_a = 6\text{-}8$$

$$>\text{Fe,Al-OH}_2^{+1/2} \longrightarrow >\text{Fe,Al-OH}^{-1/2} + \text{H}^{+}$$

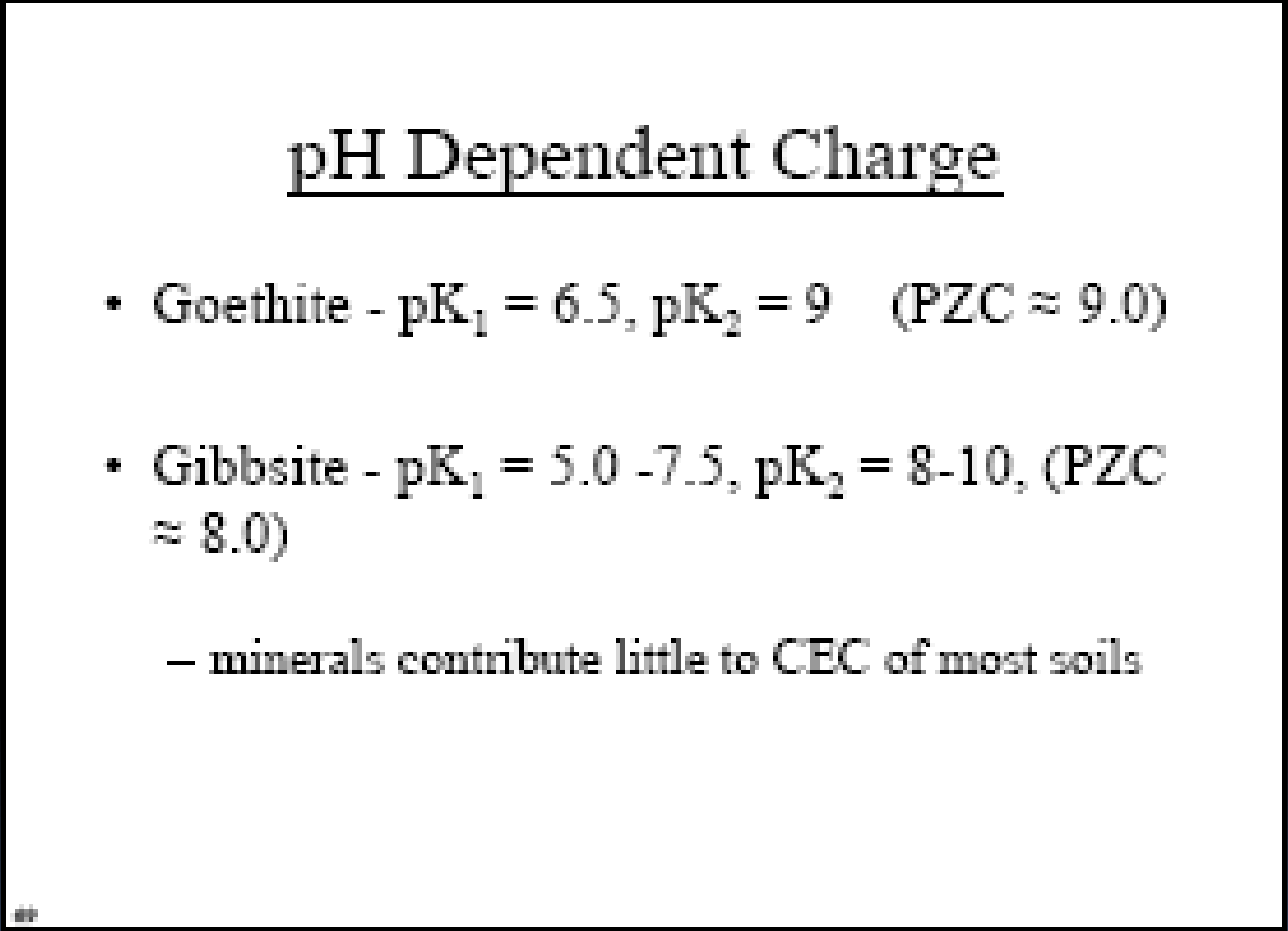
$$pK_a = 5.3 - 10$$



pH Dependent Charge

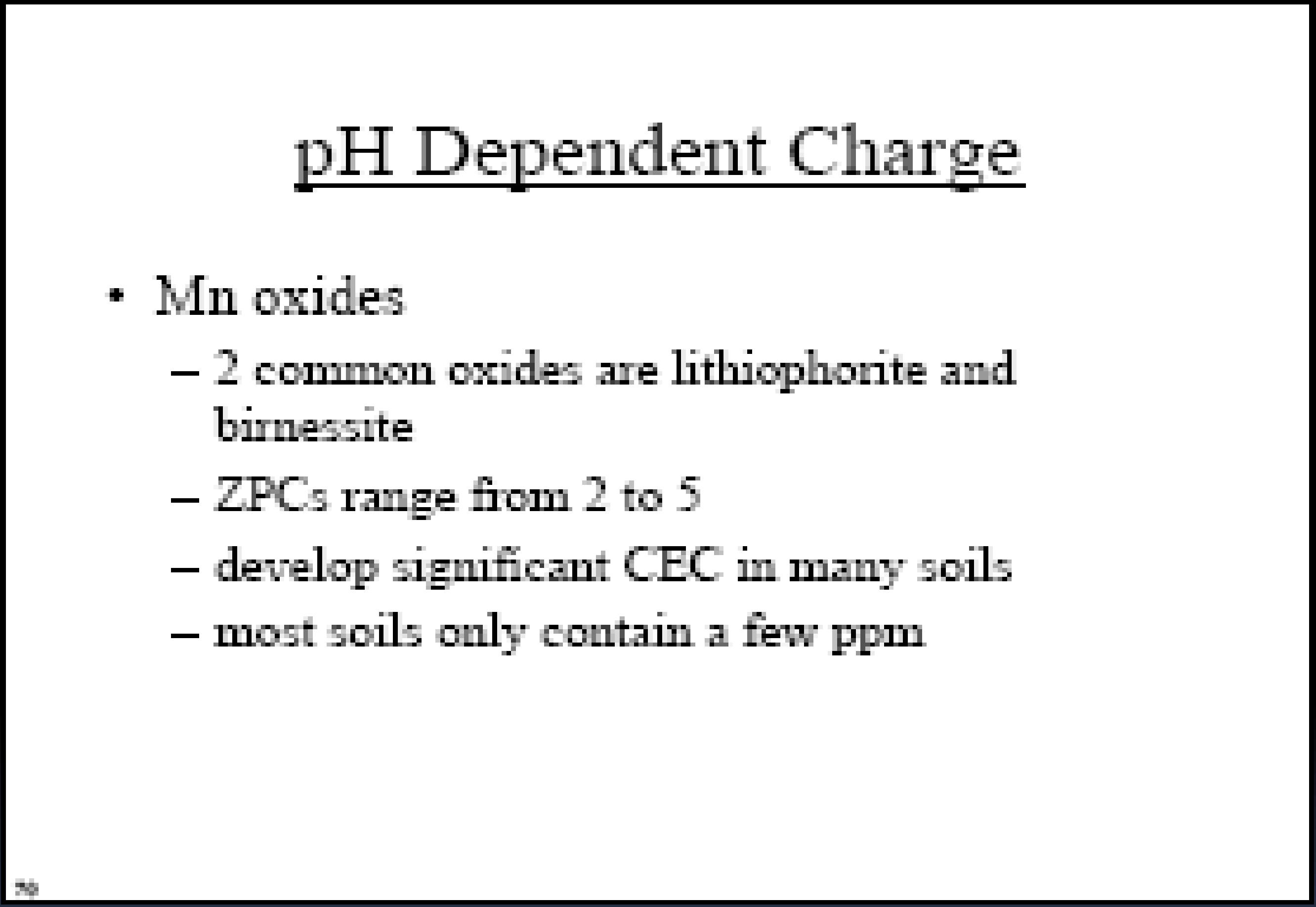
Edge pH dependent terminal OH

Edge pH dependent terminal O



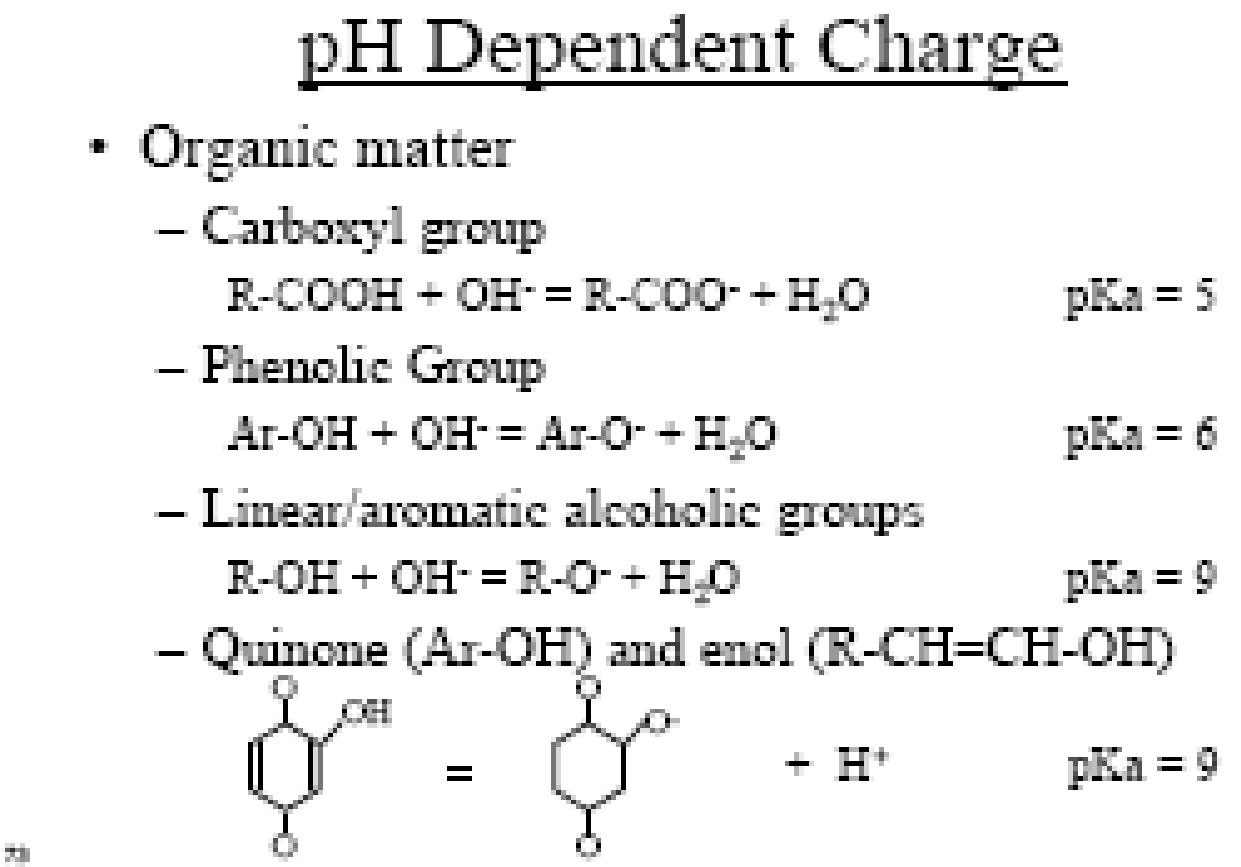
pH Dependent Charge

- Goethite - $pK_1 = 6.5$, $pK_2 = 9$ (PZC ≈ 9.0)
- Gibbsite - $pK_1 = 5.0$ -7.5, $pK_2 = 8$-10, (PZC ≈ 8.0)
  - – minerals contribute little to CEC of most soils



pH Dependent Charge

- Mn oxides
  - – 2 common oxides are lithiophorite and birnessite
  - – ZPCs range from 2 to 5
  - – develop significant CEC in many soils
  - – most soils only contain a few ppm



pH Dependent Charge

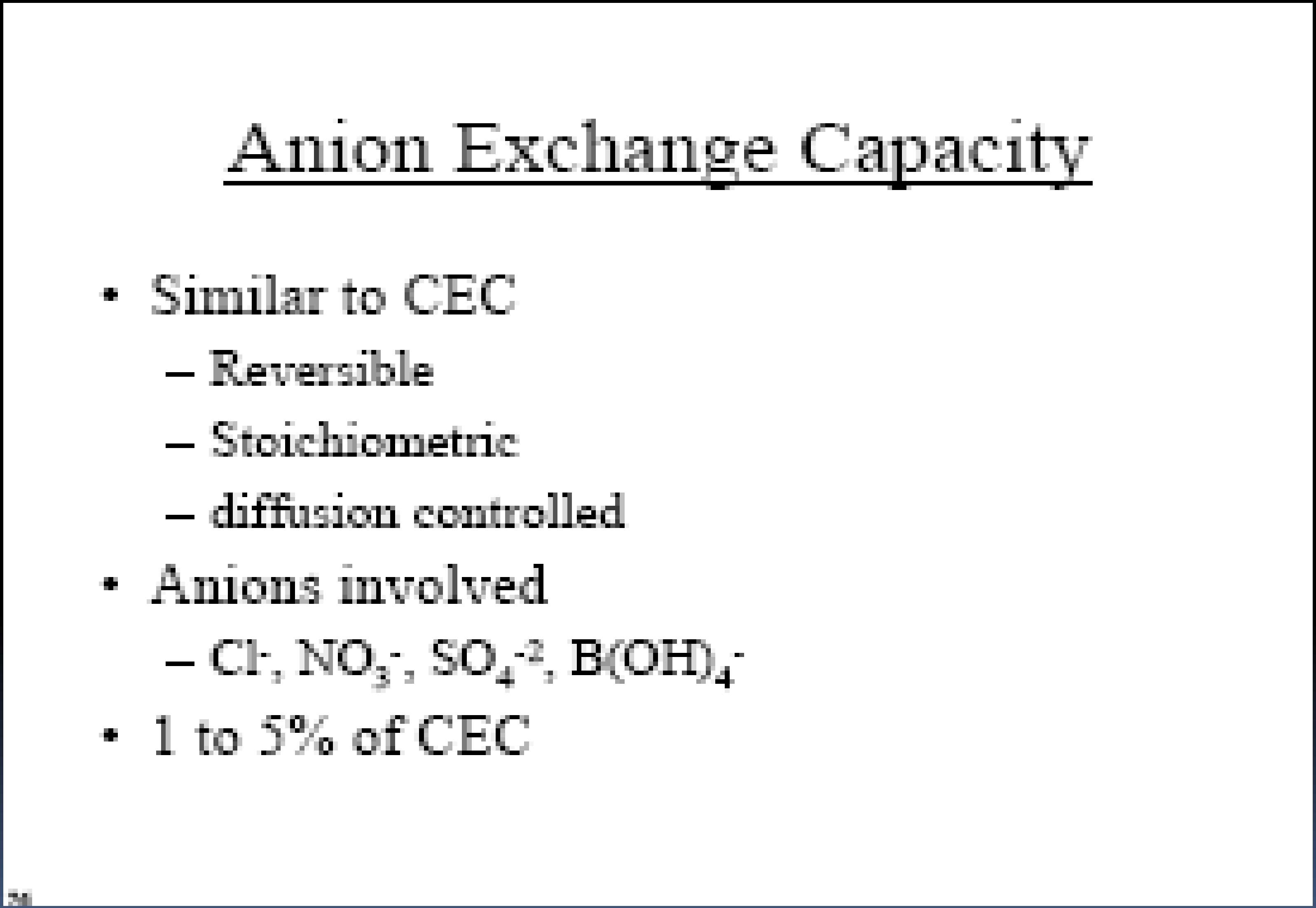
- Organic matter
  - Carboxyl group

    $R\text{-}COOH + OH^- = R\text{-}COO^- + H_2O$ pKa = 5
  - Phenolic Group

    $Ar\text{-}OH + OH^- = Ar\text{-}O^- + H_2O$ pKa = 6
  - Linear/aromatic alcoholic groups

    $R\text{-}OH + OH^- = R\text{-}O^- + H_2O$ pKa = 9
  - Quinone (Ar-OH) and enol (R-CH=CH-OH)

    = + H^+ pKa = 9

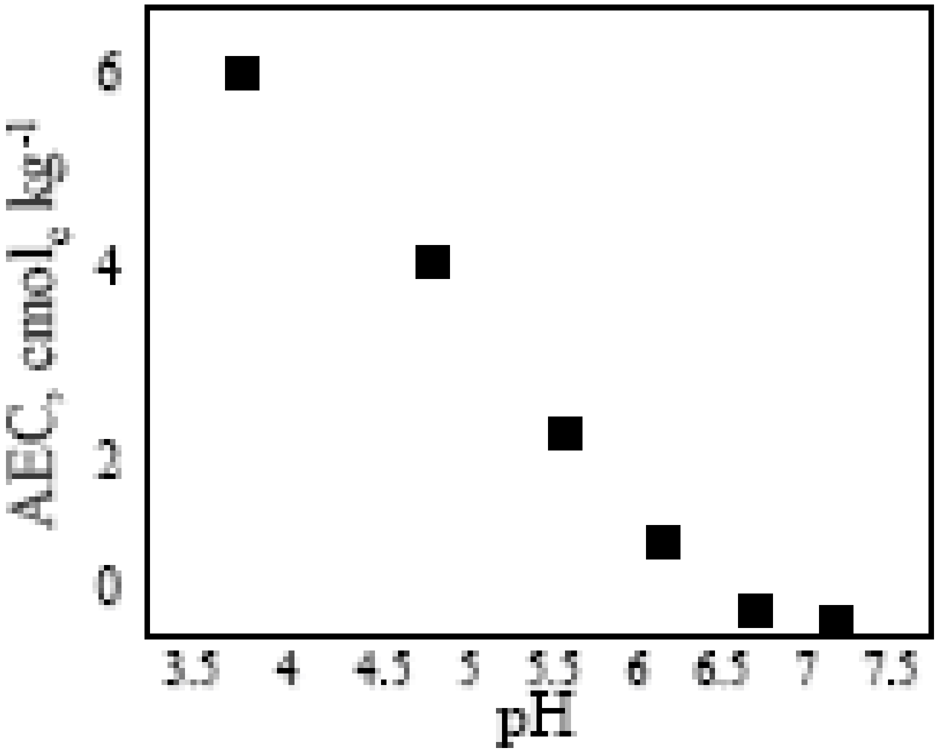


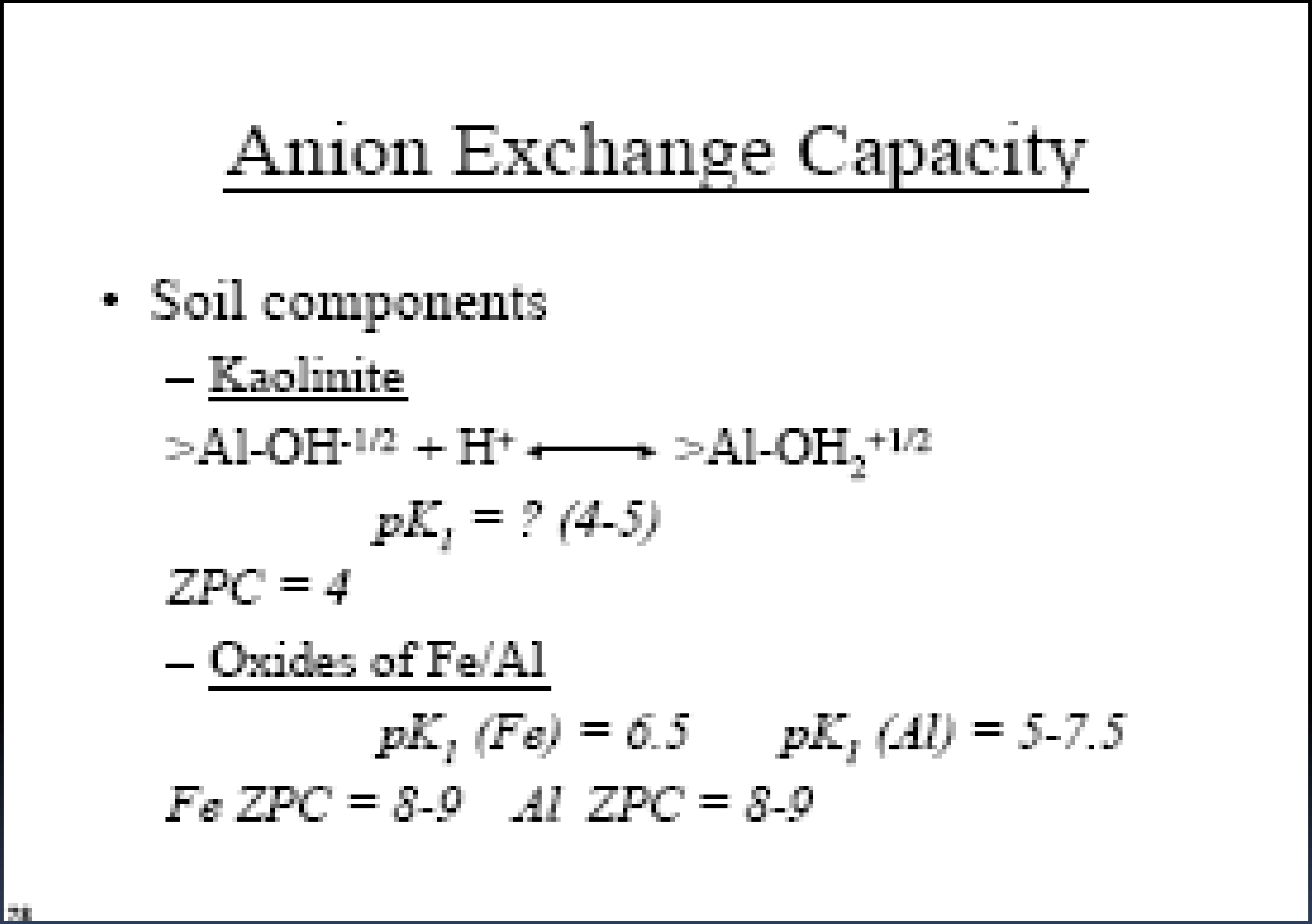
Anion Exchange Capacity

- Similar to CEC
  - Reversible
  - Stoichiometric
  - diffusion controlled
- Anions involved
  - Cl^-, NO_3^-, SO_4^{-2}, $B(OH)_4^-$
- 1 to 5% of CEC

Anion Exchange Capacity

Kaolinite





Anion Exchange Capacity

- Soil components
  - Kaolinite

$>Al\text{-}OH^{-1/2} + H^{+} \longleftrightarrow >Al\text{-}OH_2^{+1/2}$

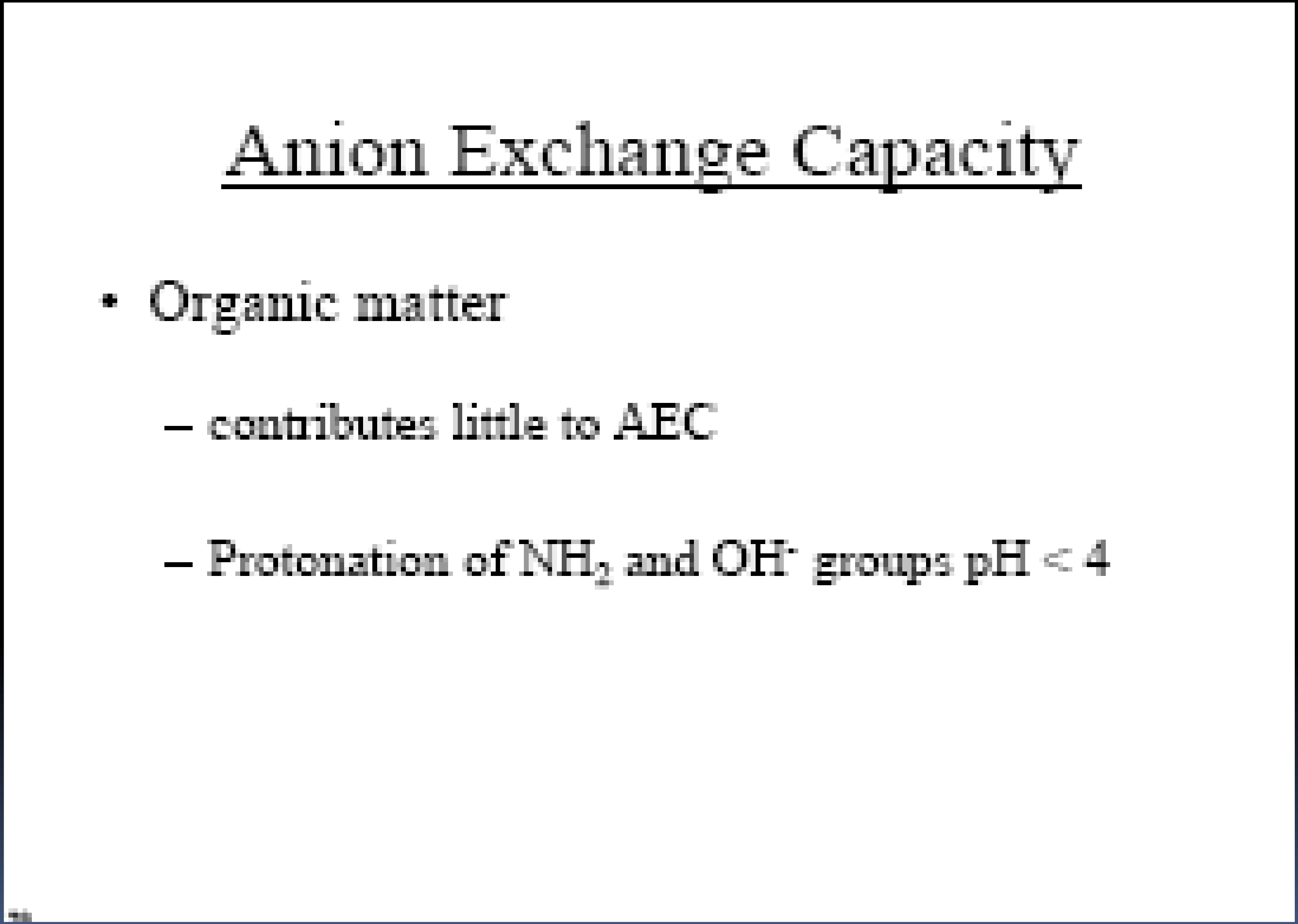
$pK_1 = ?\ (4\text{-}5)$

$ZPC = 4$

  - Oxides of Fe/Al

$pK_1\ (Fe) = 6.5 \qquad pK_1\ (Al) = 5\text{-}7.5$

$Fe\ ZPC = 8\text{-}9 \quad Al\ ZPC = 8\text{-}9$



Anion Exchange Capacity

- Organic matter
  - contributes little to AEC
  - Protonation of NH_2 and OH^- groups $pH < 4$

P ADSORPTION

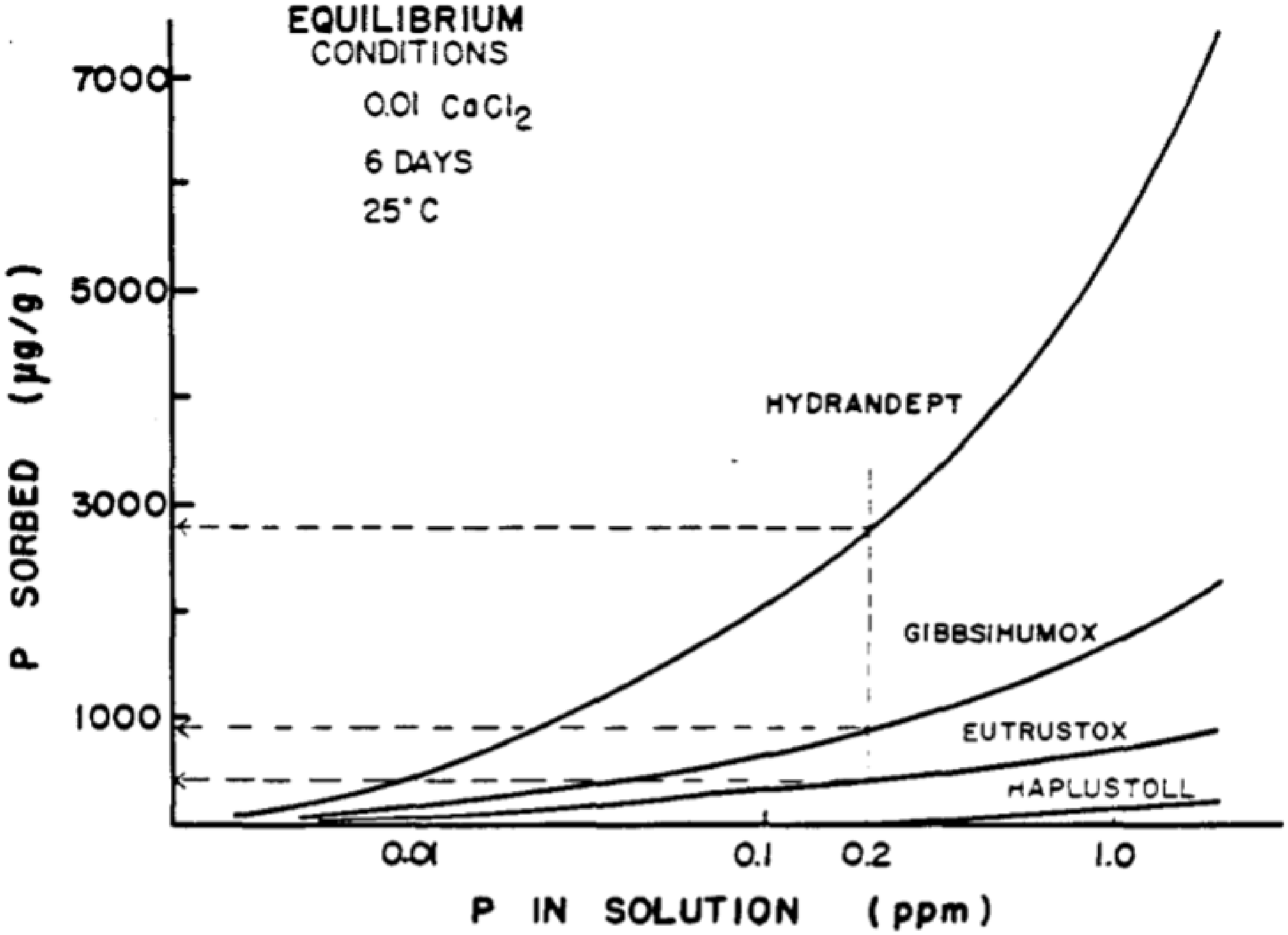


Figure 3.18. Phosphorus sorption curves for four clayey soils with different clay mineralogies (Fox, 1978).

EFFECT OM ON P ADSORPTION

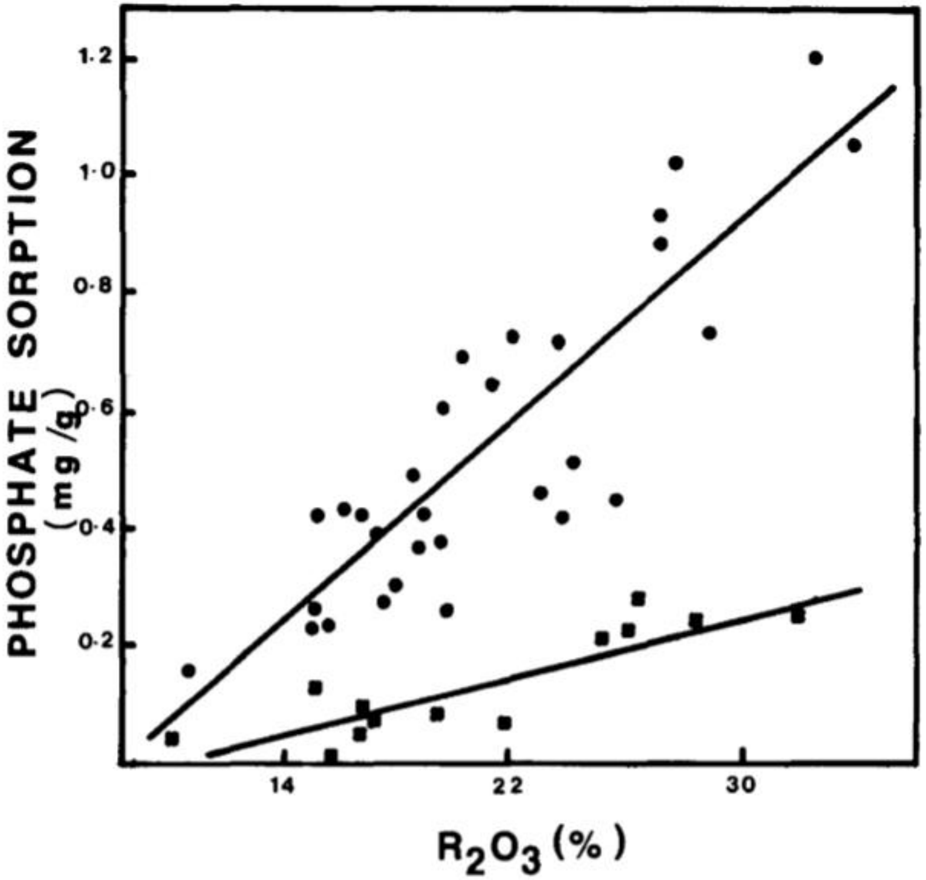


Figure 3.20. Effect of organic matter content in reducing phosphorus sorption on high sesquioxide (R_2O_3) soils. The lower and upper curves represent surface and subsurface horizons (Gillman, 1970).

EFFECT pH ON P ADSORPTION

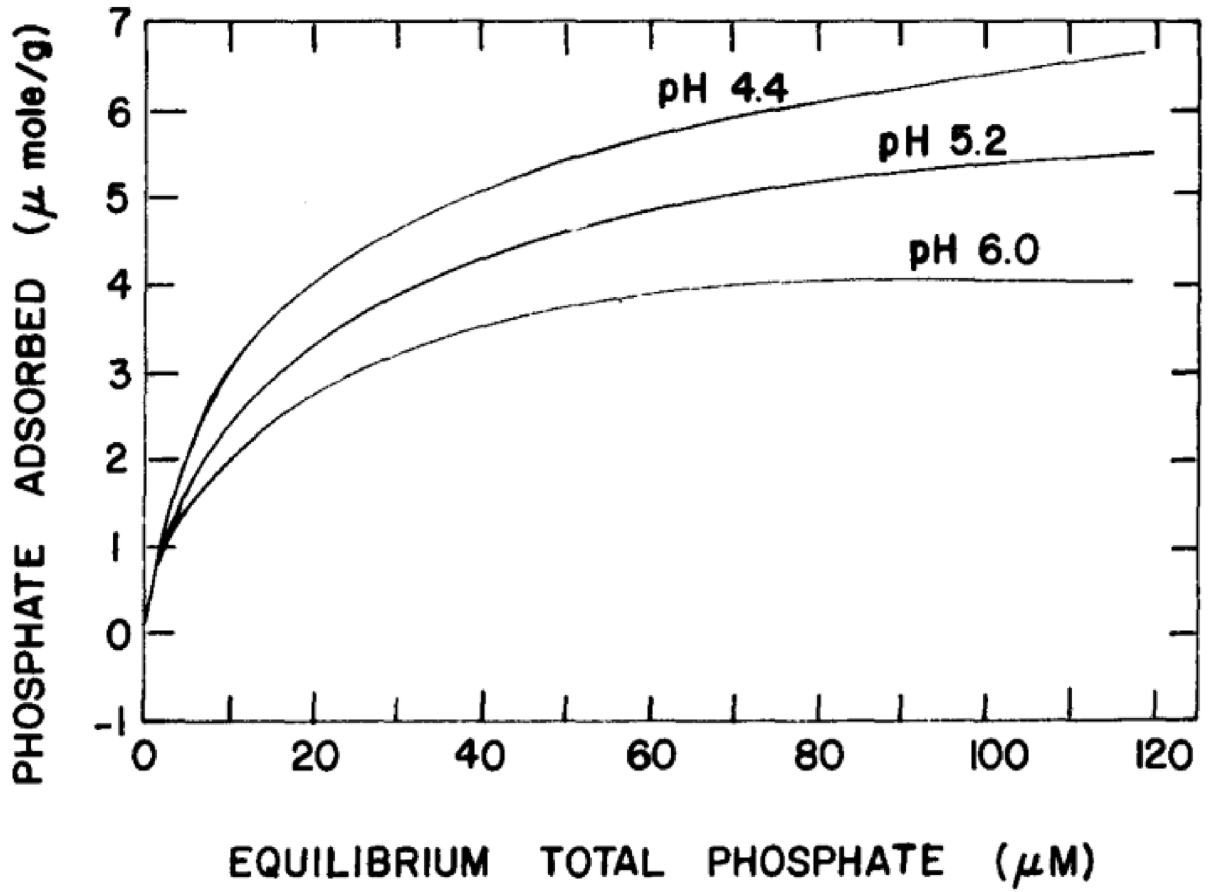


Figure 3.21. Phosphate sorption on kaolinite as a function of pH (Chen et al. 1973).

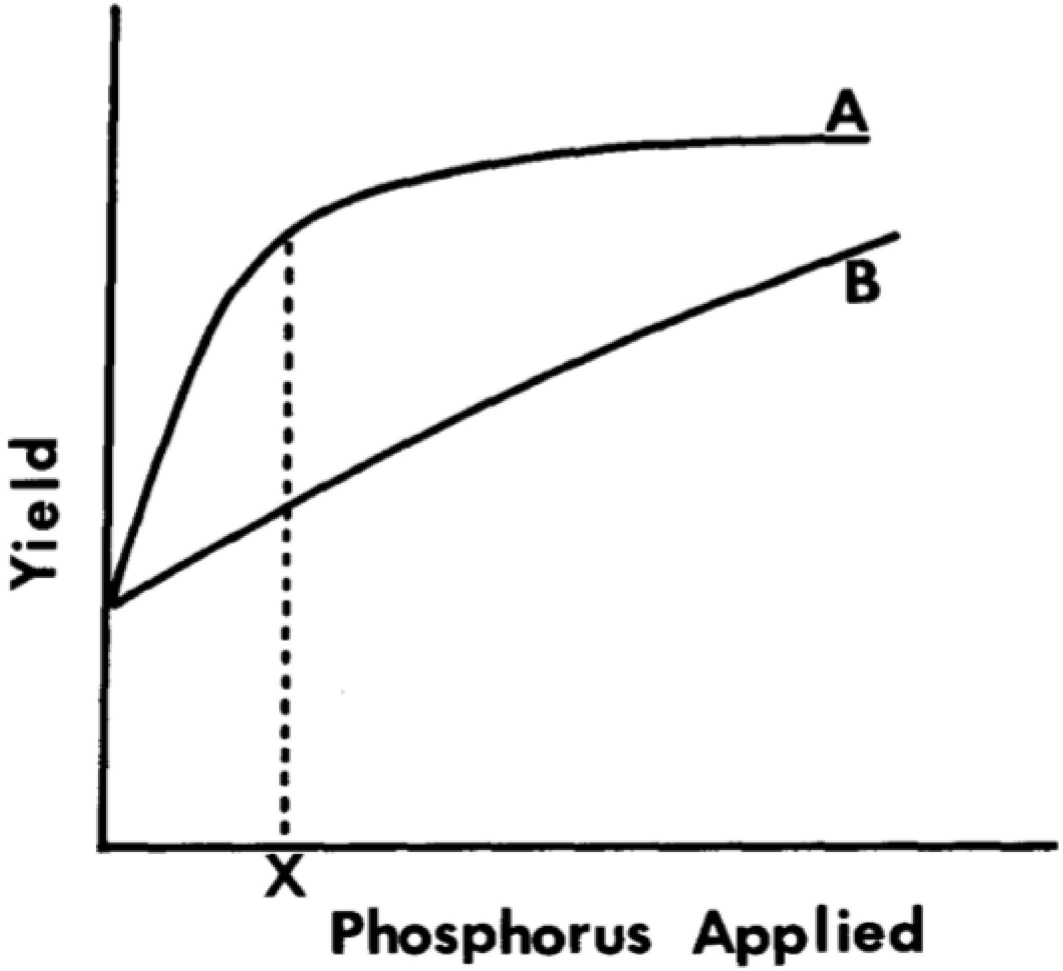


Figure 3.17. Relationship between crop yield and phosphorus applied for a low P-fixing soil (A) and a high P-fixing soil (B).

Effect Anion P&Si on Ca Leached

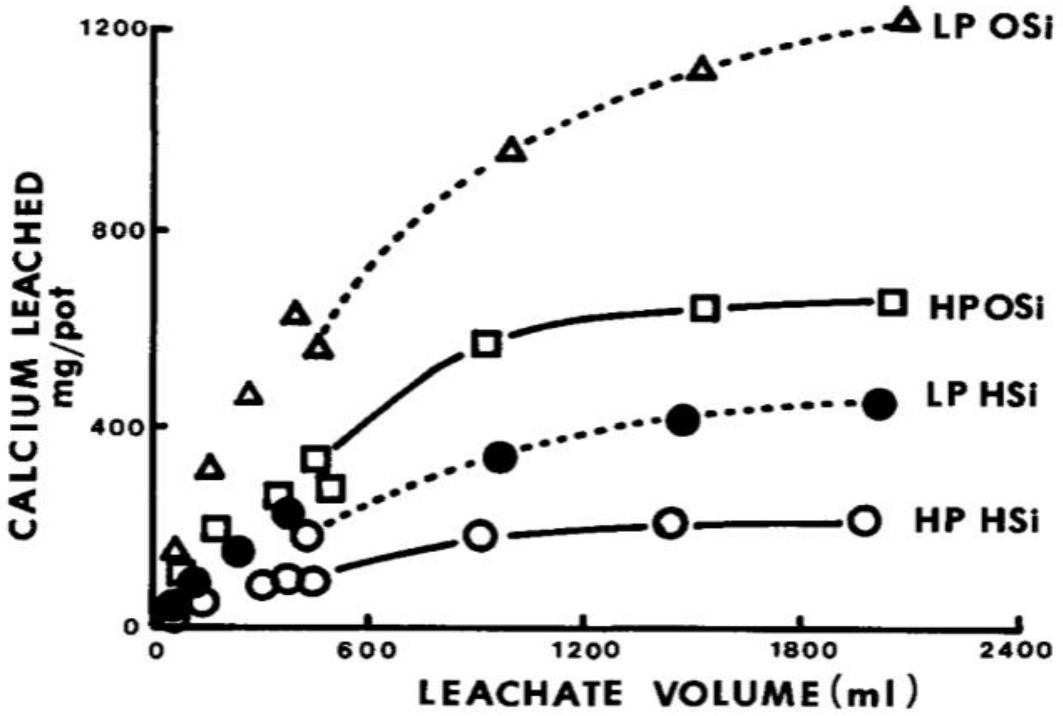


Figure 4.5. Cumulative Ca leached from a Gibbsihumox as a function of Leachate volume and P and Si application rate. (LP = 100 ppm P, HP = 750 ppm P, OSi = zero Si, HSi = 968 ppm Si). (Syed-Fadzil, 1972)

Effect Anion P & Si on Mg Leached

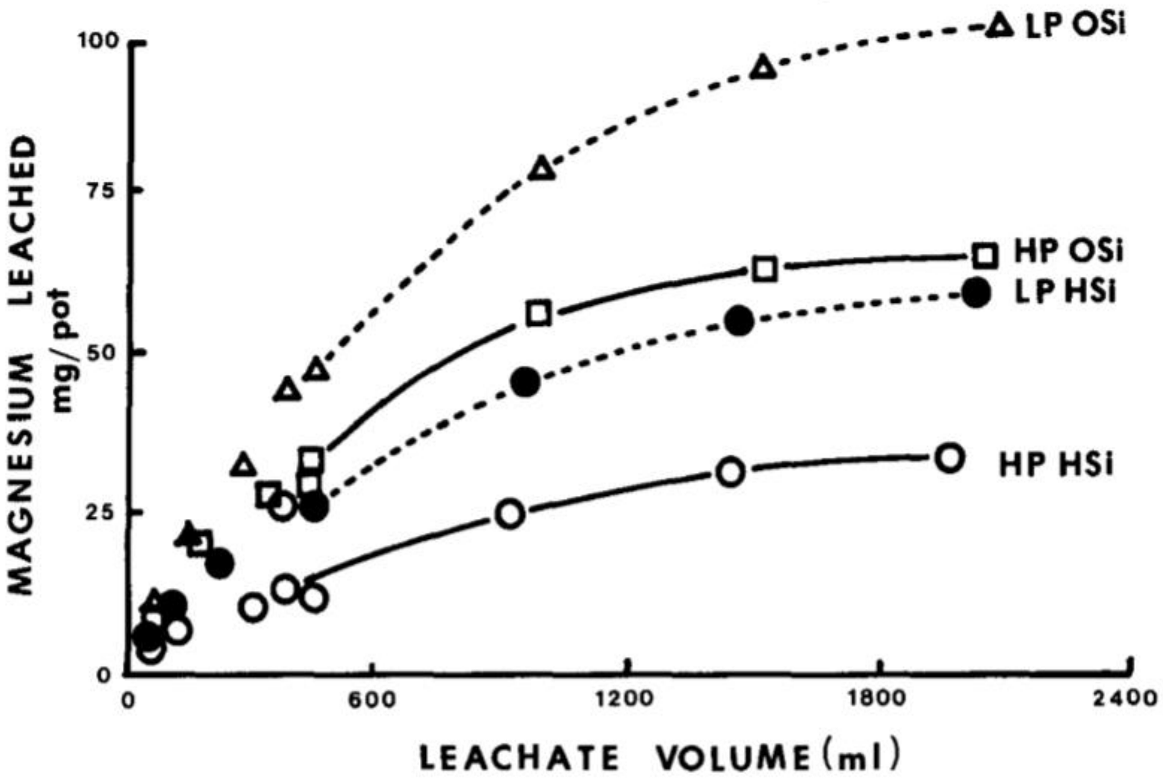


Figure 4.6. Cumulative Mg leached from a Gibbsihumox as a function of leachate volume and P and Si application rate. (LP = 100 ppm P, HP = 750 ppm P, OSi = zero Si, HSi = 968 ppm Si). (Syed-Fadzil, 1972)

Effect Anion P & Si on K Leached

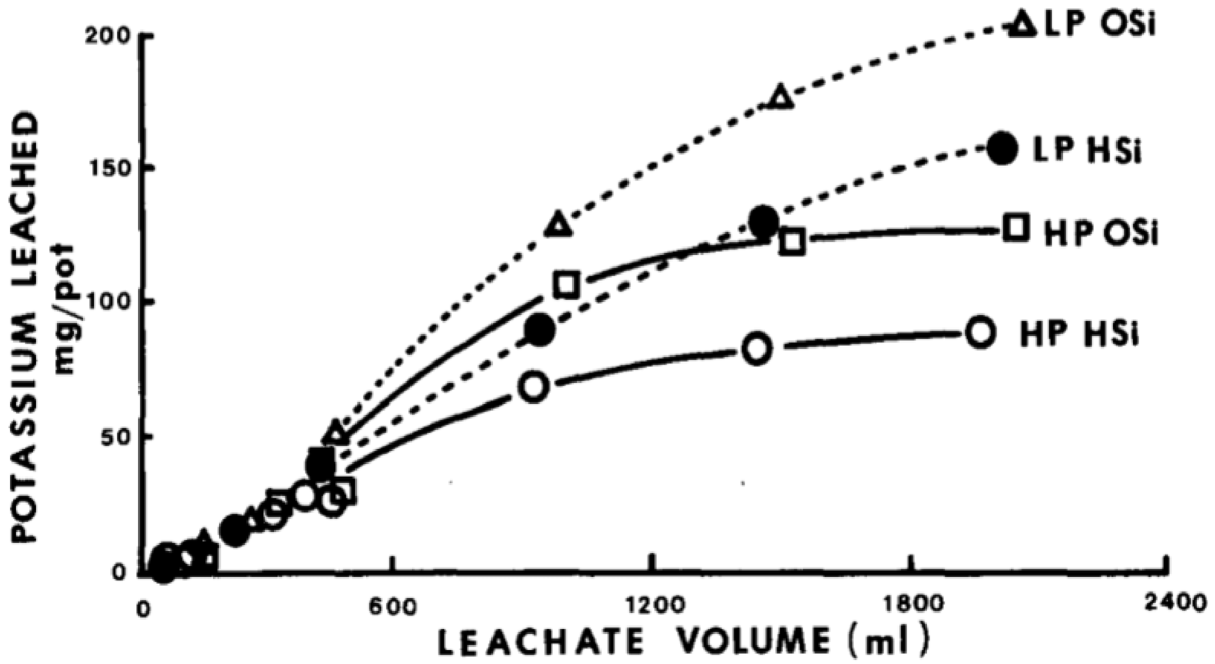


Figure 4.7. Cumulative K leached from a Gibbsihumox as a function of leachate volume and P and Si application rate. (LP = 100 ppm P, HP = 750 ppm P, OSi = zero Si, HSi = 968 ppm Si.) (Syed-Fadzil, 1972)

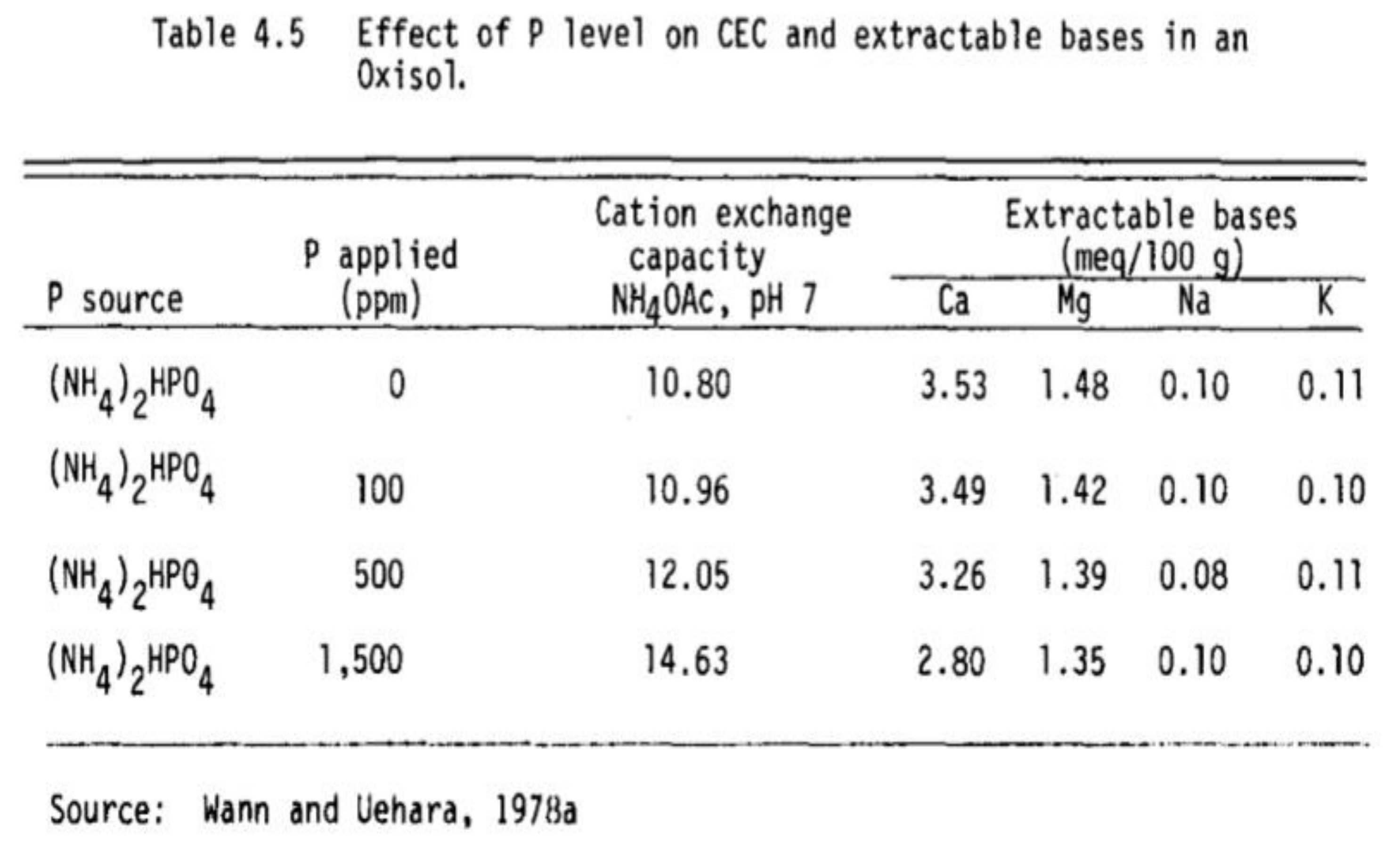


Table 4.5 Effect of P level on CEC and extractable bases in an Oxisol.

P source	P applied (ppm)	Cation exchange capacity NH_4OAc, pH 7	Extractable bases (meq/100 g)			
			Ca	Mg	Na	K
$(NH_4)_2HPO_4$	0	10.80	3.53	1.48	0.10	0.11
$(NH_4)_2HPO_4$	100	10.96	3.49	1.42	0.10	0.10
$(NH_4)_2HPO_4$	500	12.05	3.26	1.39	0.08	0.11
$(NH_4)_2HPO_4$	1,500	14.63	2.80	1.35	0.10	0.10

Source: Wann and Uehara, 1978a

TUGAS

- Setelah mempelajari karakteristik koloid tanah:

1. Bagaimana pengaruh pemberian kapur atau abu terhadap tanah dan tanaman?
2. Bagaimana pengaruh pemberian bahan organik terhadap tanah dan tanaman?