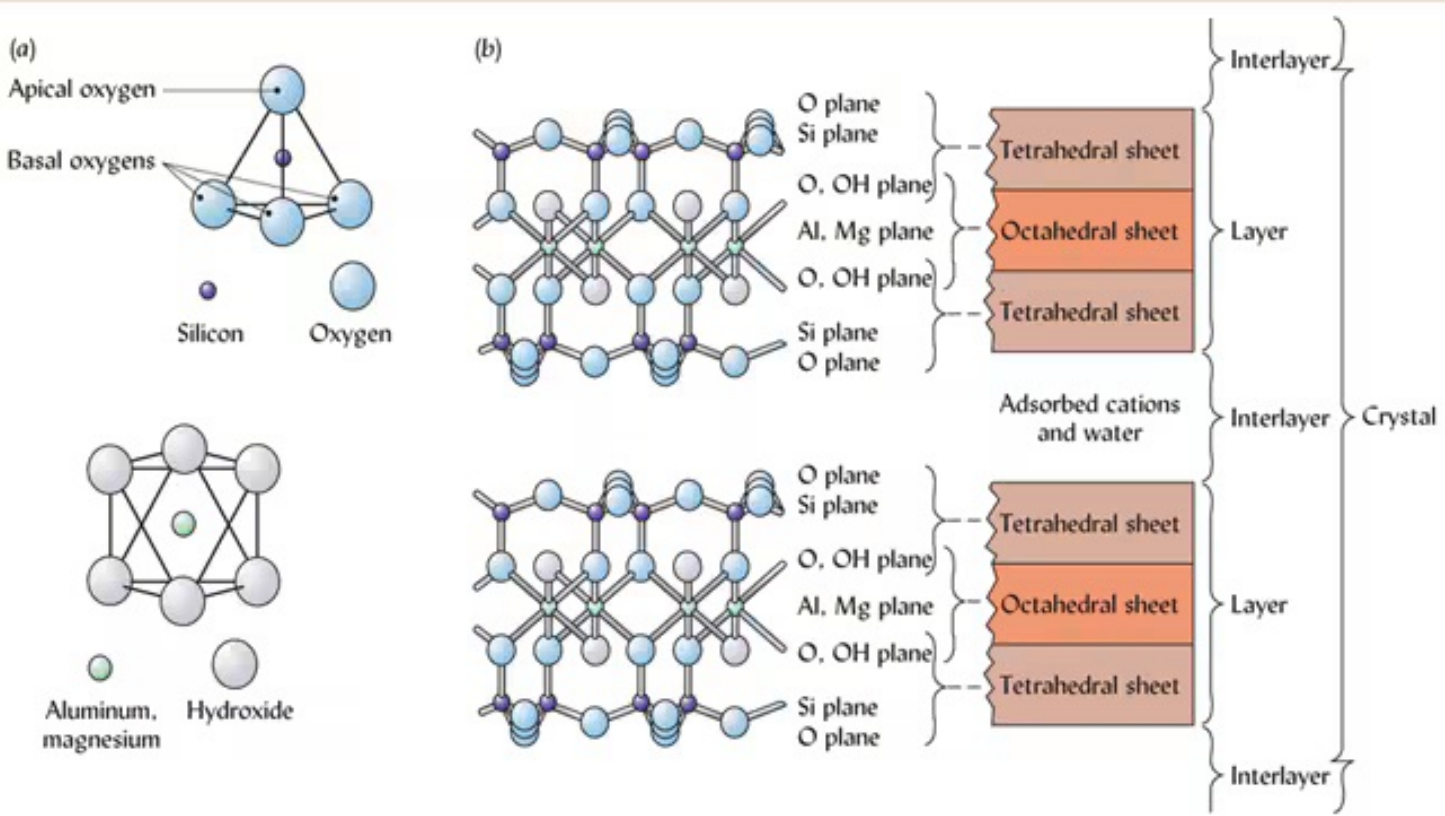
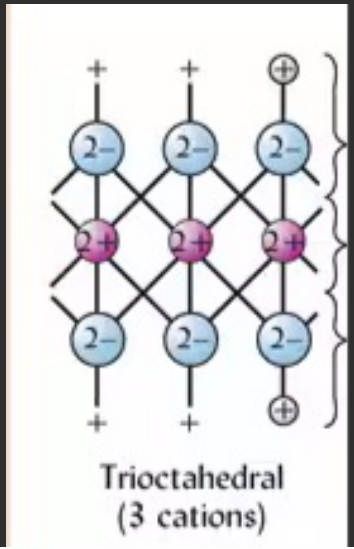
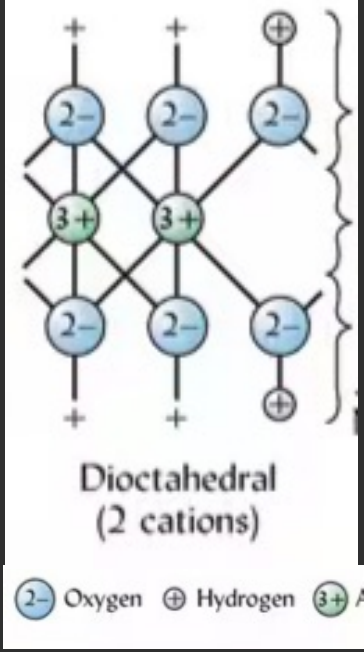

(a)
Apical oxygen
Basal oxygens
Silicon
Oxygen
Aluminum, magnesium
Hydroxide
(b)
O plane
Si plane
O, OH plane
Al, Mg plane
O, OH plane
Si plane
O plane
Tetrahedral sheet
Octahedral sheet
Tetrahedral sheet
Adsorbed cations and water
Interlayer
Layer
Interlayer
Crystal
Layer
Interlayer



Total net charge = 0



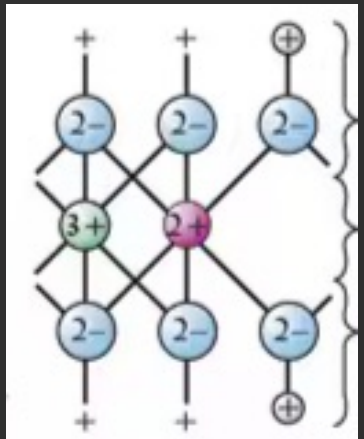
-3

+6

-3

Net charge of 0

Isomorphic substitution = Cation or molecule with same or similar share and size substitutes with another molecule



-3

+5

-3

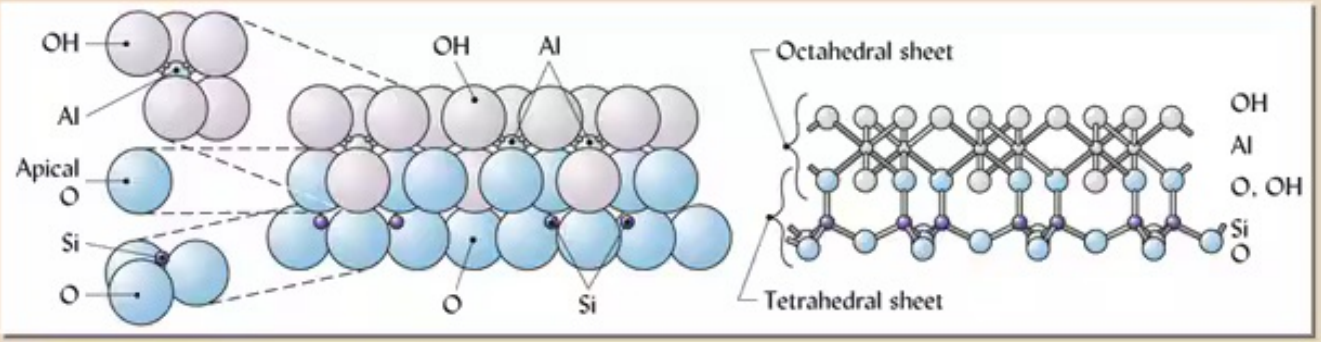
Dioctahedral with isomorphic substitution

Total net charge: -1

2– Oxygen ⊕ Hydrogen 3+ Aluminum 2+ Magnesium or iron

Ion	Radius, nm (10^{-9} m)	Found in
Si^{4+}	0.042	Tetrahedral sheet
Al^{3+}	0.051	Tetrahedral sheet
Fe^{3+}	0.064	Octahedral sheet
Mg^{2+}	0.066	Octahedral sheet
Zn^{2+}	0.074	Octahedral sheet
Fe^{2+}	0.076	Exchange or interlayer sites
Na^{+}	0.095	Exchange or interlayer sites
Ca^{2+}	0.099	Exchange or interlayer sites
K^{+}	0.133	Exchange or interlayer sites
O^{2-}	0.140	Both sheets
OH^{-}	0.155	Both sheets

Particles within 0.02 nm can substitute


OH
Al
Apical O
Si
O
OH
Al
O
Si
Octahedral sheet
Tetrahedral sheet
OH
Al
O, OH
Si
O

2: 1Silicate clays

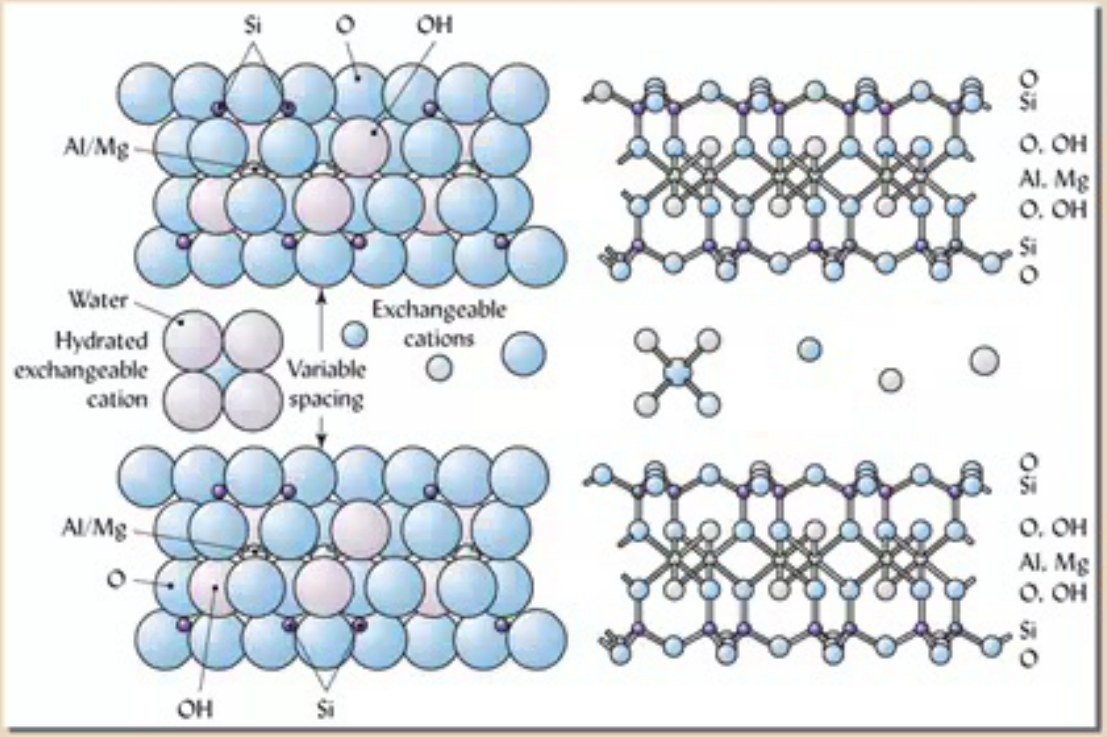
2 tetrahedral sheets : 1 octahedral sheet

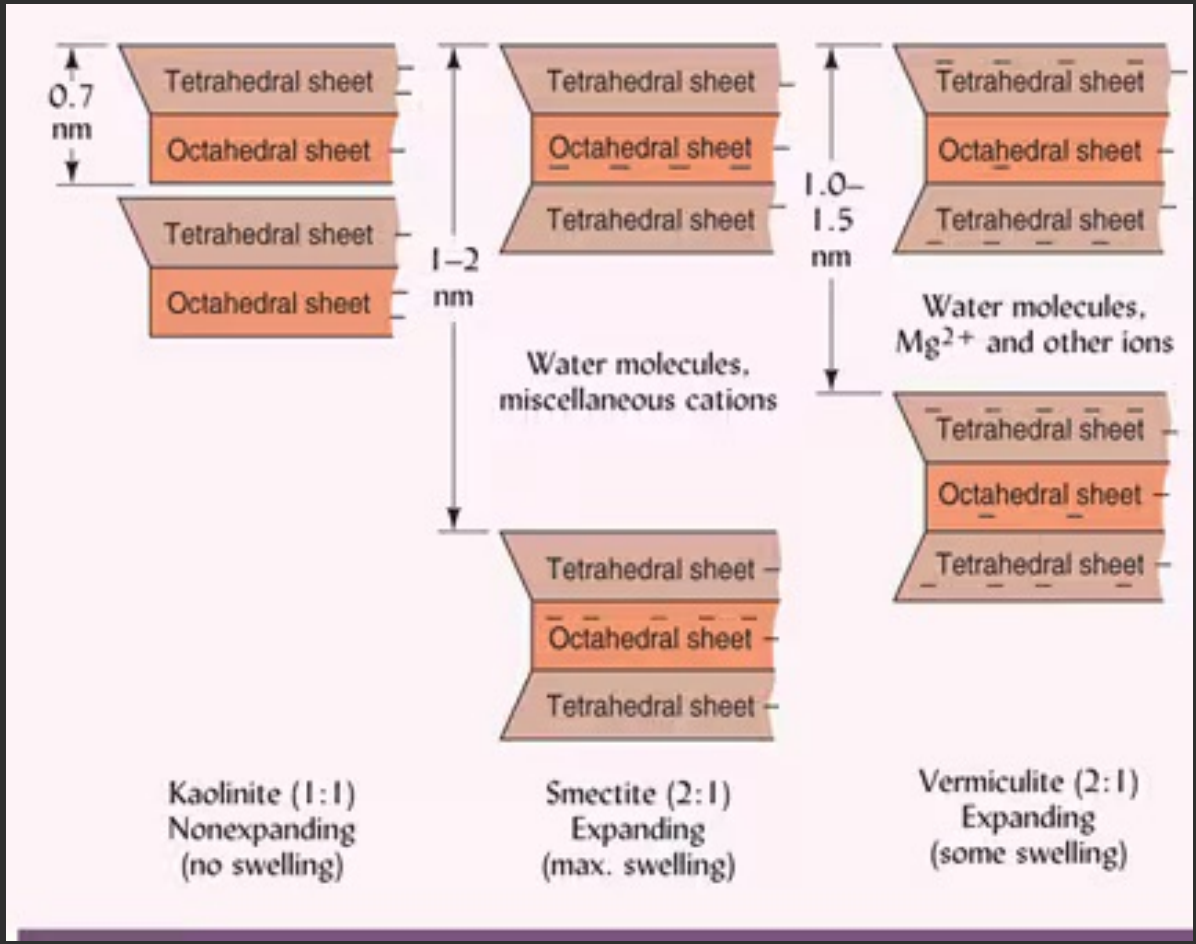
Strong negative charges from isomorphic substitution;

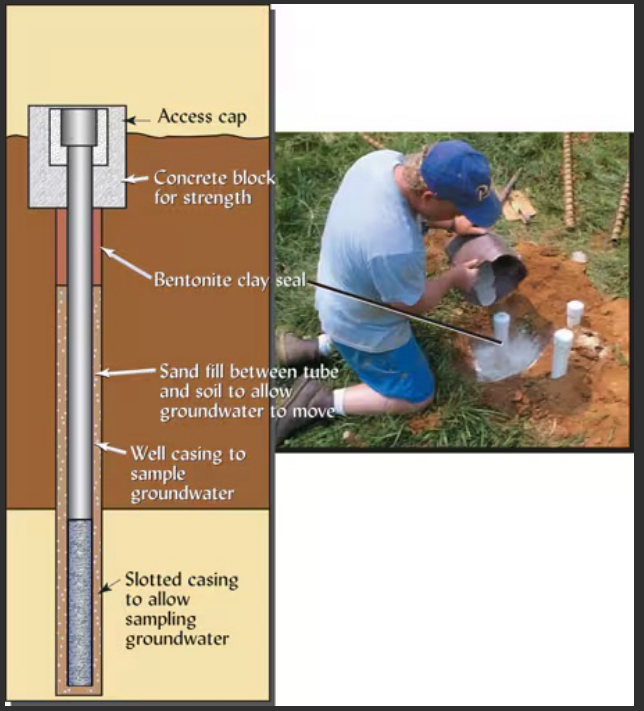
Repelling of negatice charge in one tetrahedral from another to give rise to a large interspace between clay sheets -

Vermiculites and Smectites (shrink-swell, water abosrbing clays)

- High cation abosorbing capacity




0.7 nm
Tetrahedral sheet
Octahedral sheet
Tetrahedral sheet
Octahedral sheet
1–2 nm
Tetrahedral sheet
Octahedral sheet
Tetrahedral sheet
Water molecules, miscellaneous cations
Tetrahedral sheet
Octahedral sheet
Tetrahedral sheet
1.0–1.5 nm
Tetrahedral sheet
Octahedral sheet
Tetrahedral sheet
Water molecules, Mg^{2+} and other ions
Tetrahedral sheet
Octahedral sheet
Tetrahedral sheet
Kaolinite (1:1) Nonexpanding (no swelling)
Smectite (2:1) Expanding (max. swelling)
Vermiculite (2:1) Expanding (some swelling)



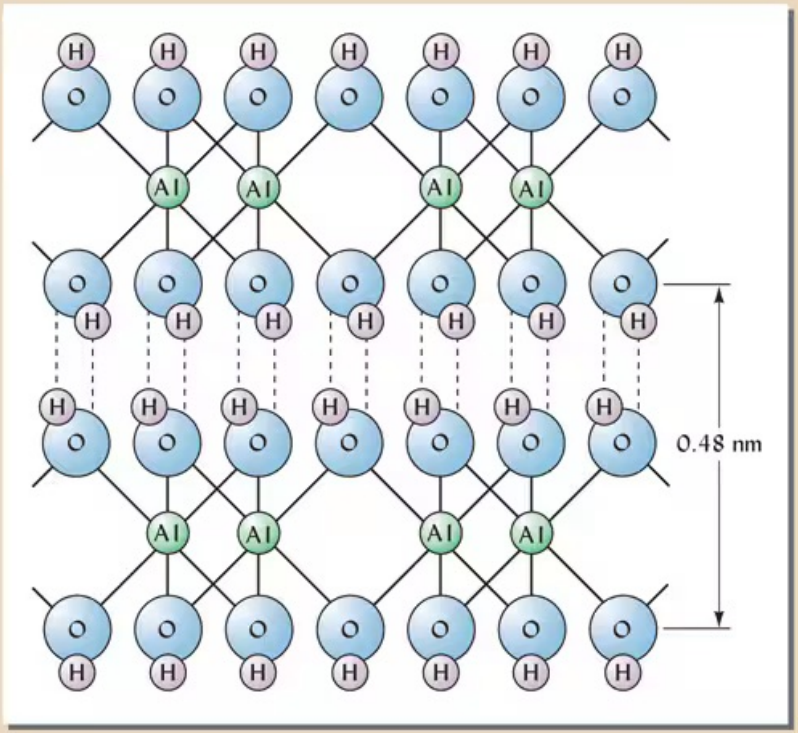
Smectites are clays used as engineering medium to seal soil surfaces

Colloid	Type	Size, μm	Shape	Surface area, m^2/g		Interlayer Spacing,[a] nm	Net charge,[b] $cmol_c/kg$
				External	Internal		
Smectite	2:1 silicate	0.01–1.0	Flakes	80–150	550–650	1.0–2.0	−80 to −150
Vermiculite	2:1 silicate	0.1–0.5	Plates, flakes	70–120	600–700	1.0–1.5	−100 to −200
Fine mica	2:1 silicate	0.2–2.0	Flakes	70–175	—	1.0	−10 to −40
Chlorite	2:1 silicate	0.1–2.0	Variable	70–100	—	1.41	−10 to −40
Kaolinite	1:1 silicate	0.1–5.0	Hexagonal crystals	5–30	—	0.72	−1 to −15
Gibbsite	Al oxide	<0.1	Hexagonal crystals	80–200	—	0.48	+10 to −5
Goethite	Fe oxide	<0.1	Variable	100–300	—	0.42	+20 to −5
Allophane & Imogolite	Noncrystalline silicates	<0.1	Hollow spheres or tubes	100–1000	—	—	+20 to −150
Humus	Organic	0.1–1.0	Amorphous	Variable[c]	—	—	−100 to −500

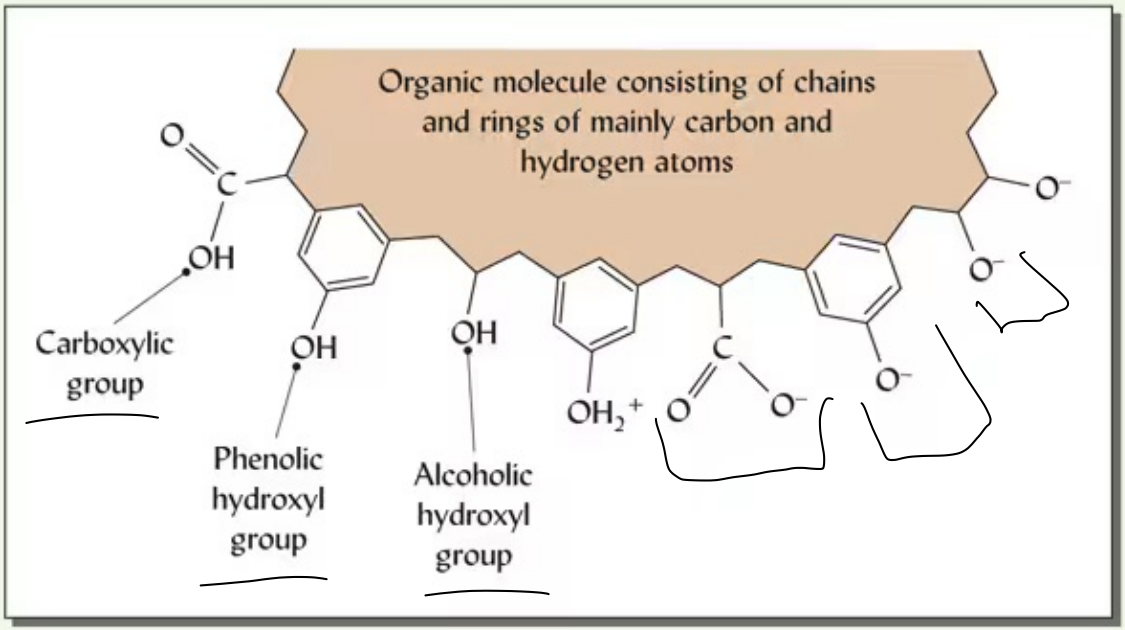
[a]From the top of one layer to the next similar layer, 1 nm = 10^{-9} m = 10 Å.

[b]Centimoles of unbalanced or net charge per kilogram of colloid ($cmol_c/kg$), a measure of ion exchange capacity (see Section 8.9).

[c]It is very difficult to determine the surface area of organic matter. Different procedures give values ranging from 20 to 800 m^2/g.



Gibbsite

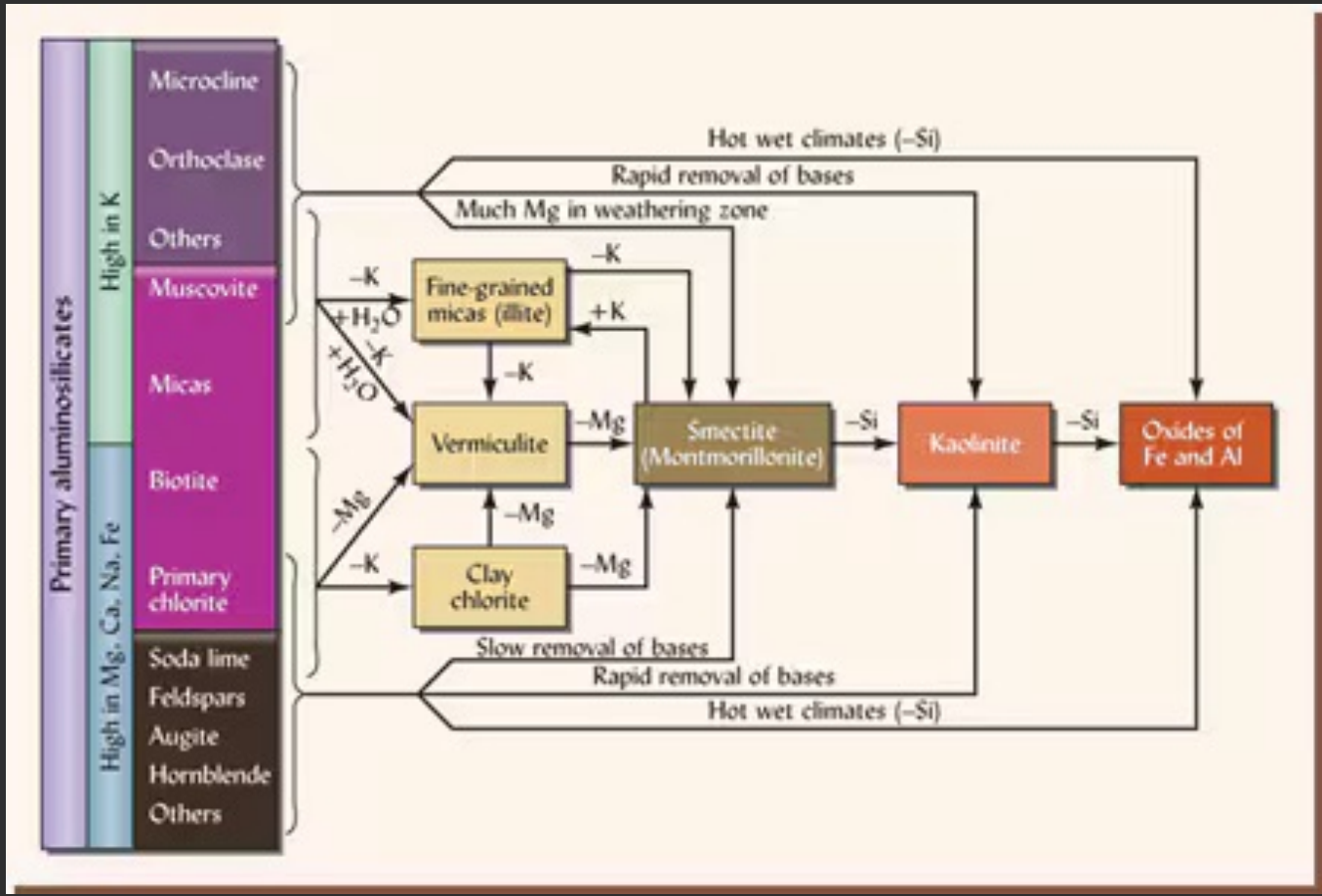


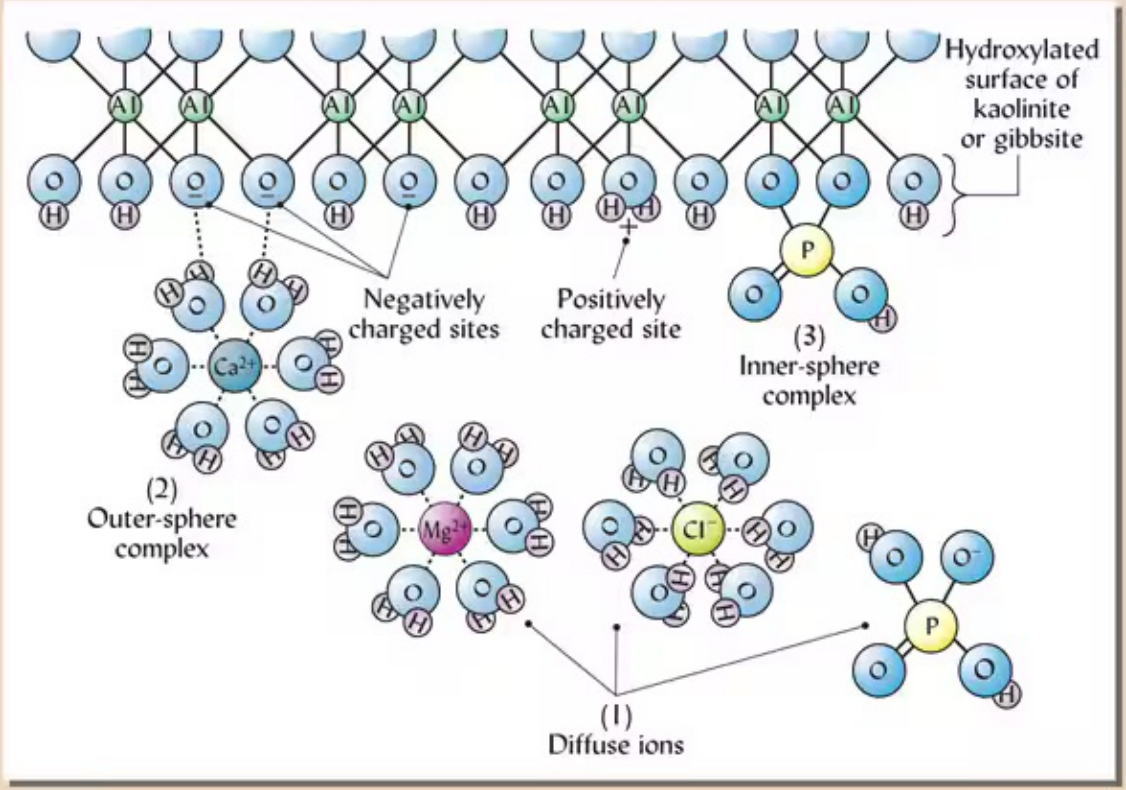
Humus

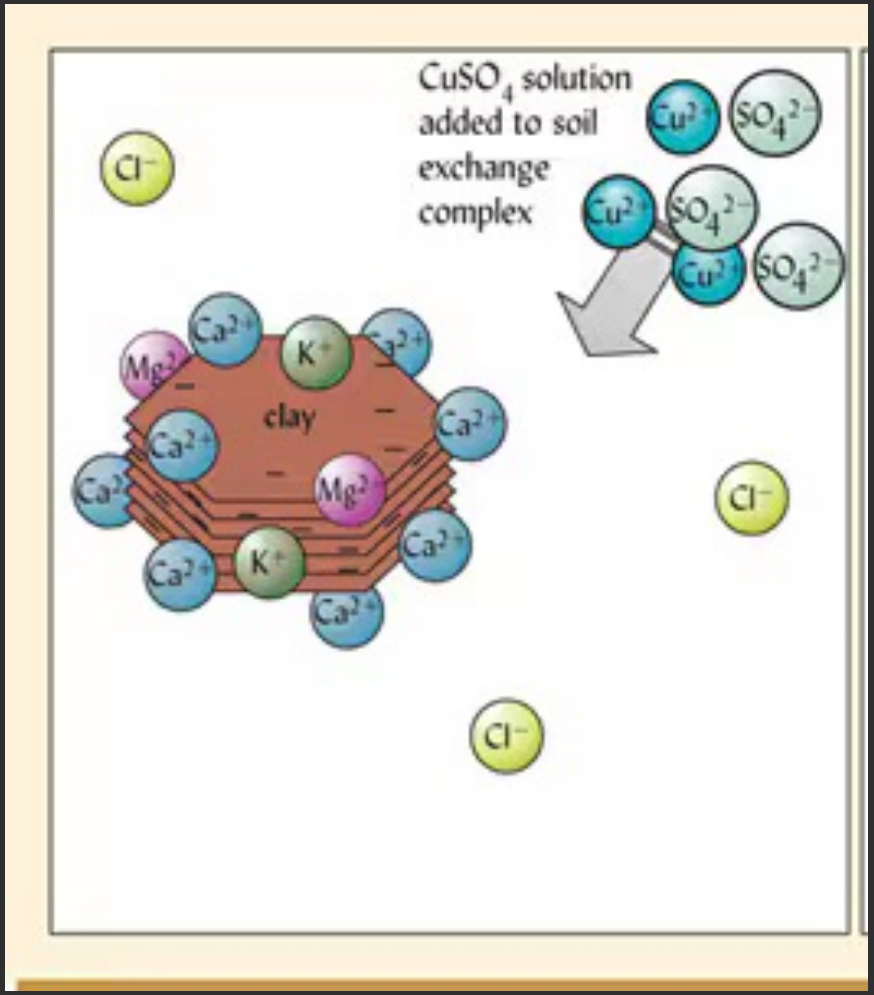
Types of carbon chains

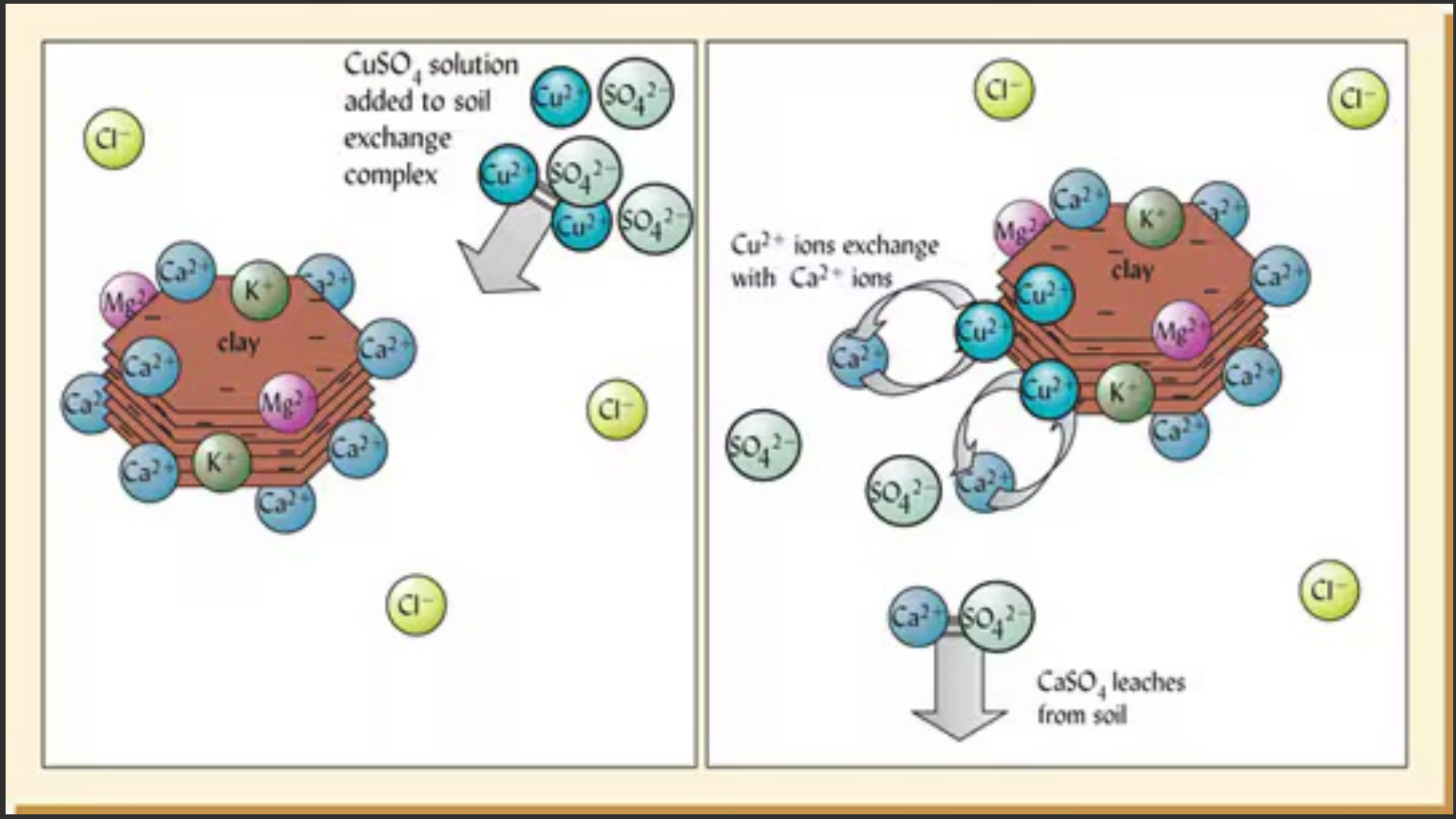
- Cellulose
- Lignin
- Chitin
- Glucose
- Amino Acids

→ Groups bonded to carbon chain can donate H, become negatively charged

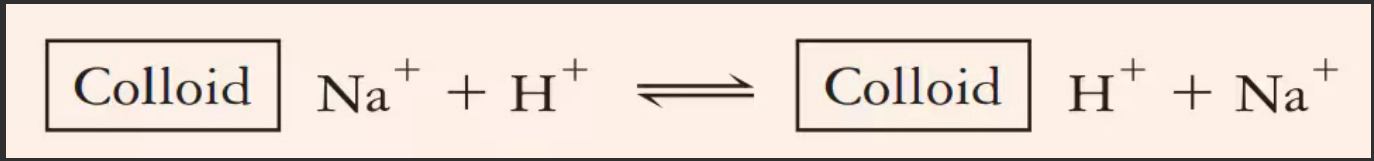

Primary aluminosilicates
High in K
Microcline
Orthoclase
Others
Muscovite
Micas
Biotite
Primary chlorite
High in Mg, Ca, Na, Fe
Soda lime Feldspars
Augite
Hornblende
Others
Hot wet climates (–Si)
Rapid removal of bases
Much Mg in weathering zone
–K
+H2O
–K
+H2O
Fine-grained micas (illite)
–K
+K
–K
Vermiculite
–Mg
Smectite (Montmorillonite)
–Si
Kaolinite
–Si
Oxides of Fe and Al
–Mg
–Mg
–K
Clay chlorite
–Mg
Slow removal of bases
Rapid removal of bases
Hot wet climates (–Si)


Hydroxylated surface of kaolinite or gibbsite
Negatively charged sites
Positively charged site
(3) Inner-sphere complex
(2) Outer-sphere complex
(1) Diffuse ions


$CuSO_4$ solution added to soil exchange complex
Cu^{2+}
SO_4^{2-}
Cl^-
clay
Ca^{2+}
Mg^{2+}
K^+



Cation Exchange



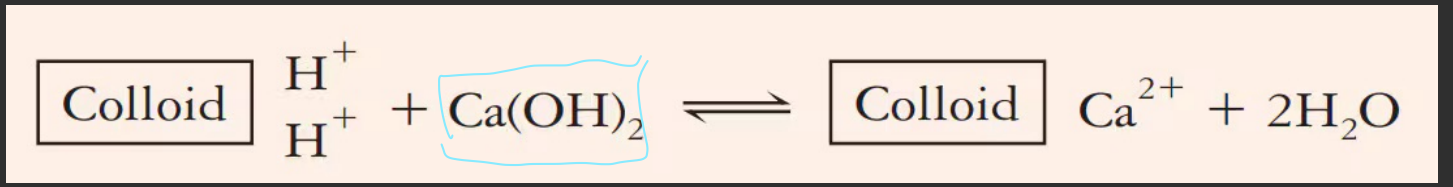
If 1 cmol of adsorbed Na+ ions per kilogram of soil were replaced by H+ ions in this reaction, how many grams of Na+ ions would be replaced?

1 mol Na = 23 g

1 cmol Na = 0.23 g

1 mol H = 1 g

1 cmol H = 0.01 g



assume that 2 cmolc H+/kg soil is replaced by the Ca(OH)2

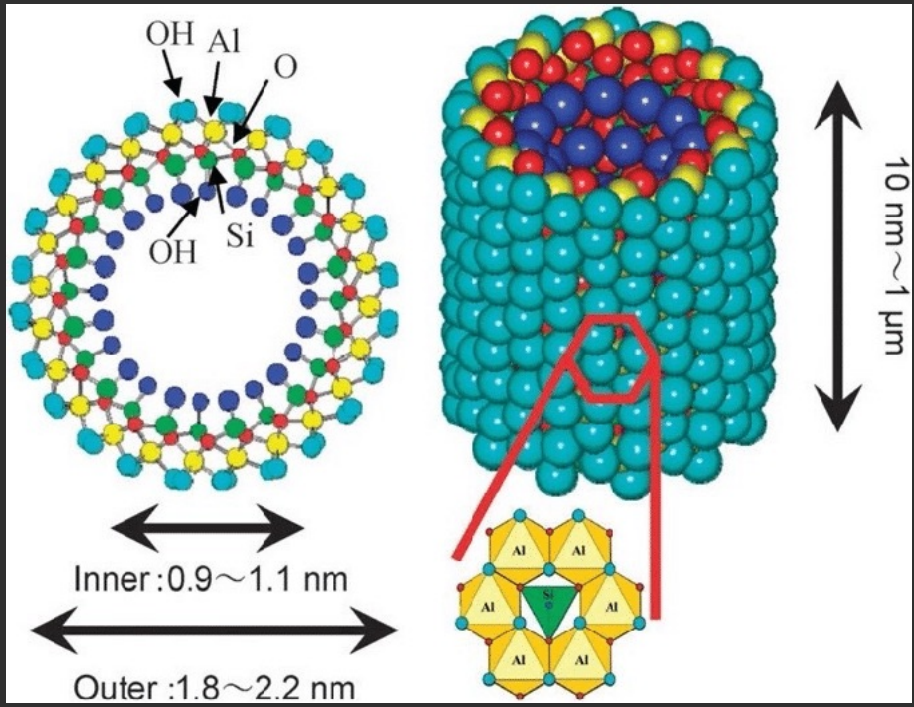
How many grams of Ca^{2+} bond to the colloid?

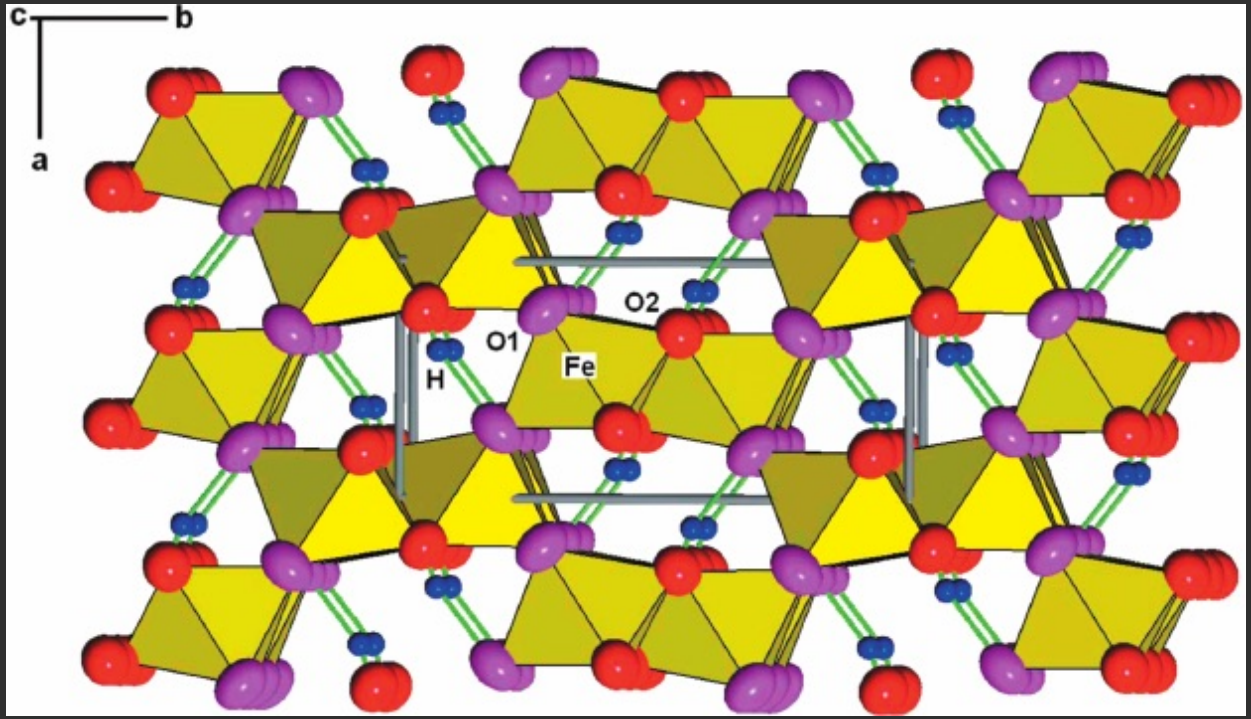
2 cmolc = 0.2

$\frac{1\,Ca}{2H}$

Molecular weight $Ca(OH)_2 = \frac{74\,g/mol}{2} = 37\,g$

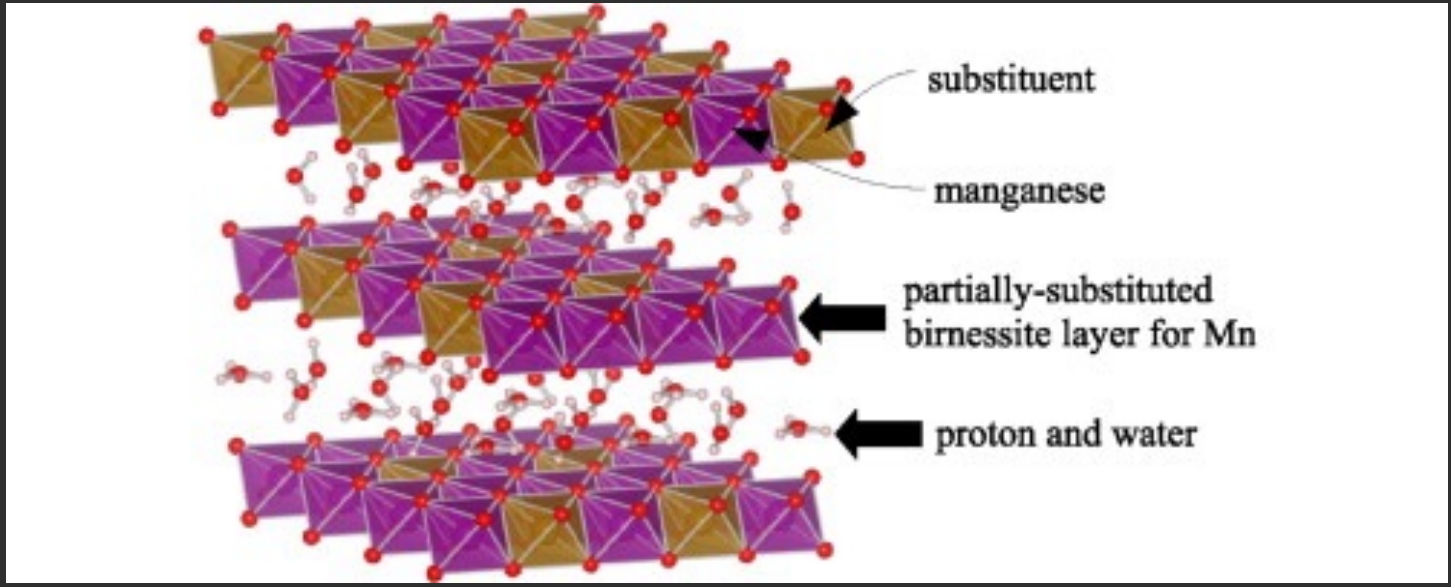
How much $Ca(OH)_2$ to add $= 0.37\,g$


OH
Al
O
OH
Si
Inner :0.9～1.1 nm
Outer :1.8～2.2 nm
10 nm～1 μm
Al
Al
Al
Si
Al
Al
Al



↑

Goethite


substituent
manganese
partially-substituted
birnessite layer for Mn
proton and water

Birnessite

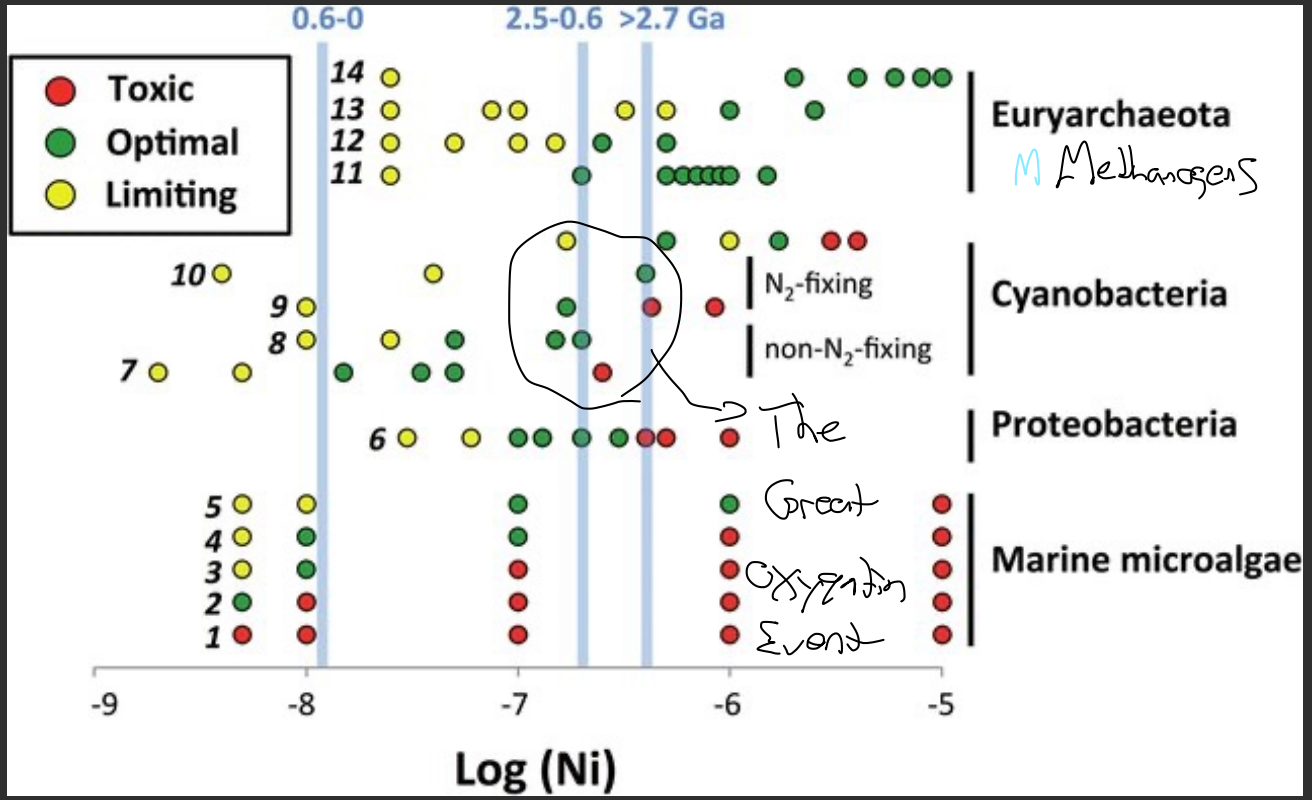


Figure 2.2 Growth response (limiting (yellow), optimal (green), or toxic (red)) of diverse microbial taxa to varying concentrations of total dissolved Ni (circles), and reconstructed maximum marine Ni concentrations through geologic history (blue vertical lines). 5 Marine microalgae (grown on urea): 1. Pavlova lutheri, Chaetoceros gracilis, Olisthodiscus luteus; 55 2. Prymnesium parvum; 55 3. Rhodomonas sp., Achnanthes brevipes, Amphidinium carterae, Skeletonema costatum, Hymenomonas elongata, Porphyridium cruentum; 55 4. Thalassiosira spp.; 53-55 5. Cyclotella cryptica; 56 Proteobacterium: 6. Cupriavidus necator; 118,119 Cyanobacteria: 7. Synechococcus spp. (non-N 2-fixing, marine); 58 8. Oscillatoria sp. 3NT (non-N 2-fixing, marine); 90 9. Nostoc muscorum (N 2-fixing, freshwater); 89 10. Trichodesmium erythraeum (N 2-fixing, marine); 71 Euryarchaeota: 11. Methanococcus voltae; 120 12. Methanococcoides methylutens; 121 13. Methanobacterium thermoautotrophicum; 87,122,123 14. Methanothrix soehngenii; 91 Ga: giga-annum (billions of years ago).