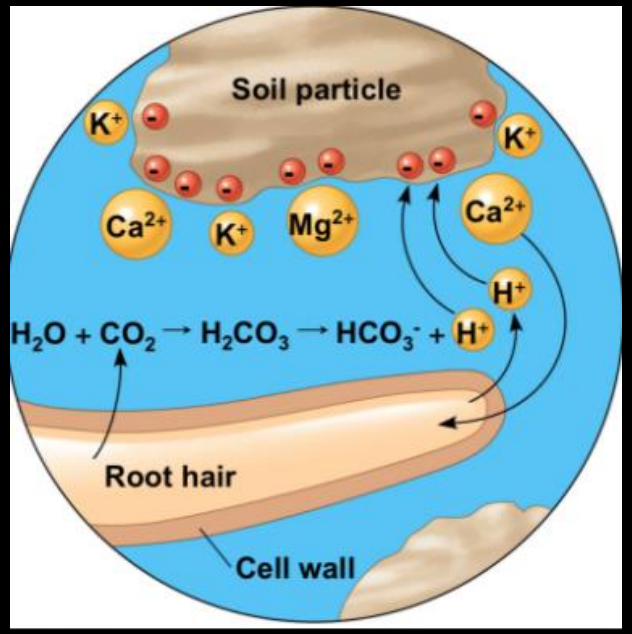
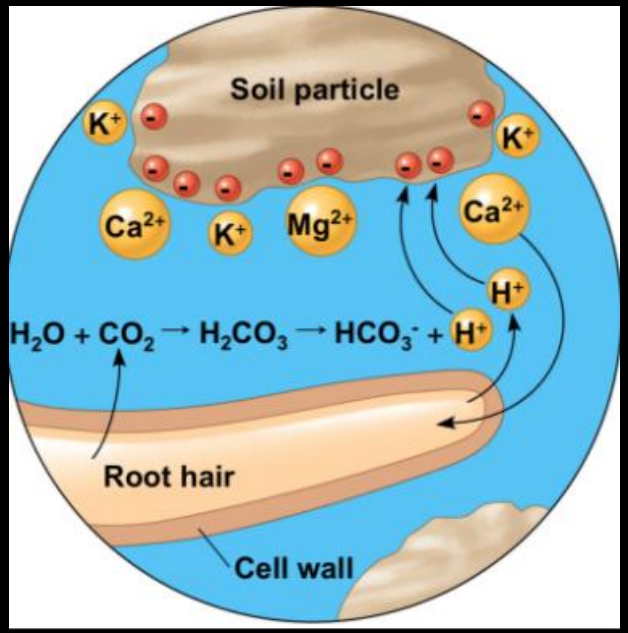
LECTURE IN SOIL SCIENCE



‘’SOIL HAS A CHEMISTRY”

Soil Chemical Characteristics



Prof. Dr. Oğuz Can TURGAY
Soil Science Department
Faculty of Agriculture, Ankara University

Soil Chemical Characteristics

- Soil pH
- Mineral nutrients in soil
- Colloids (clay and organic matter)
- CEC (cation exchange capacity)
- Electrical conductivity
- Soil buffering capacity

Soil pH

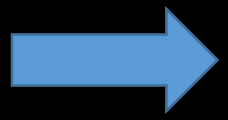
- Soil pH or soil reaction is an indication of the acidity or alkalinity of soil and is measured in pH units.
- Soil pH is defined as the negative logarithm of the hydrogen ion concentration.
- The pH scale goes from 0 to 14 with pH 7 as the neutral point.
- As the amount of hydrogen ions in the soil increases the soil pH decreases thus becoming more acidic.
- From pH 7 to 0 the soil is increasingly more acidic and from pH 7 to 14 the soil is increasingly more alkaline or basic.

https://www.esf.edu/pubprog/brochure/soilph/soilph.htm

Soil pH

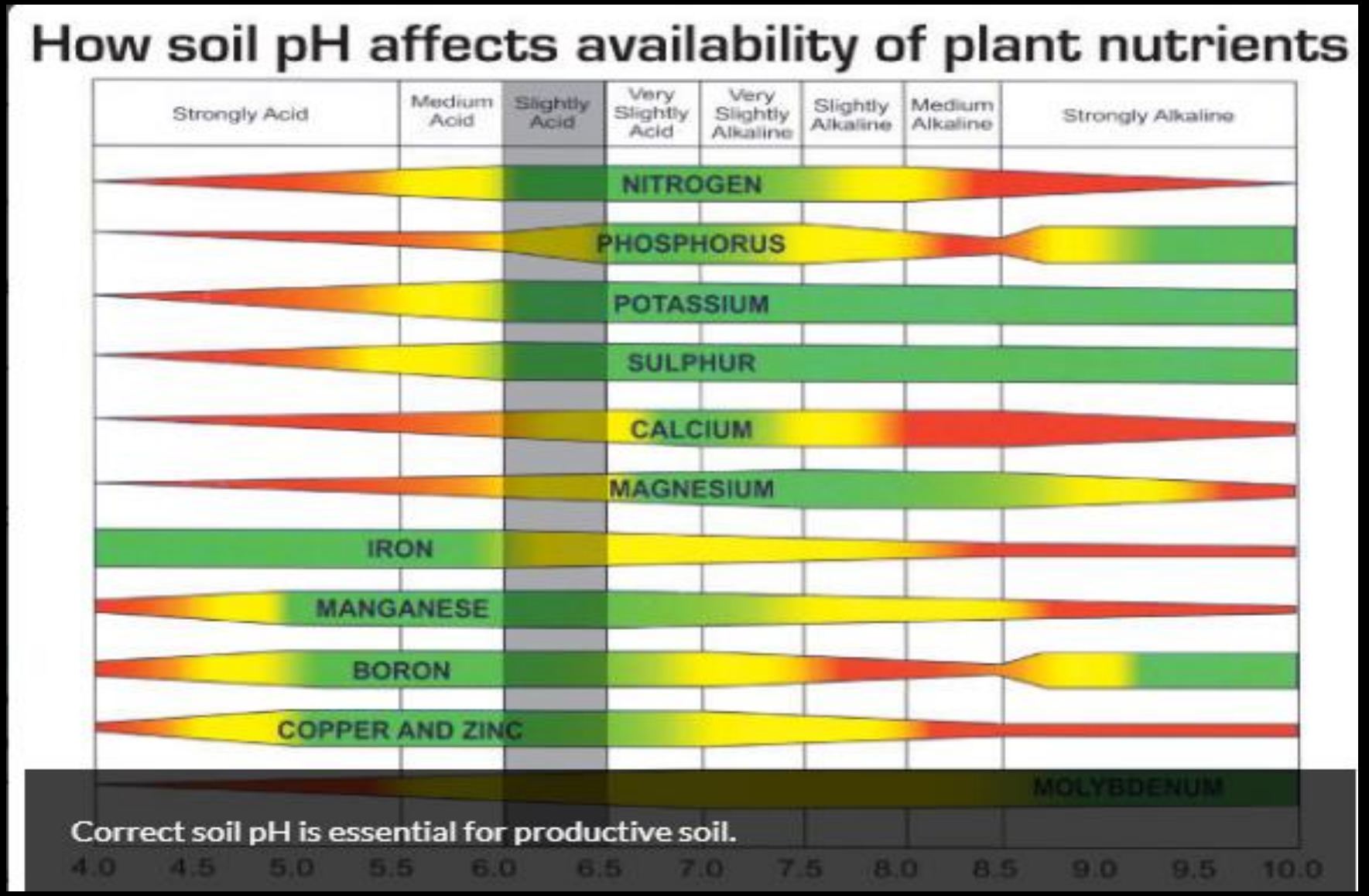
Denomination	pH range
Ultra acid	< 3.5
Extremely acid	3.5–4.4
Very strongly acid	4.5–5.0
Strongly acid	5.1–5.5
Moderately acid	5.6–6.0
Slightly acid	6.1–6.5
Neutral	6.6–7.3
Slightly alkaline	7.4–7.8
Moderately alkaline	7.9–8.4
Strongly alkaline	8.5–9.0
Very strongly alkaline	> 9.0

Soil Conservation Service, USA

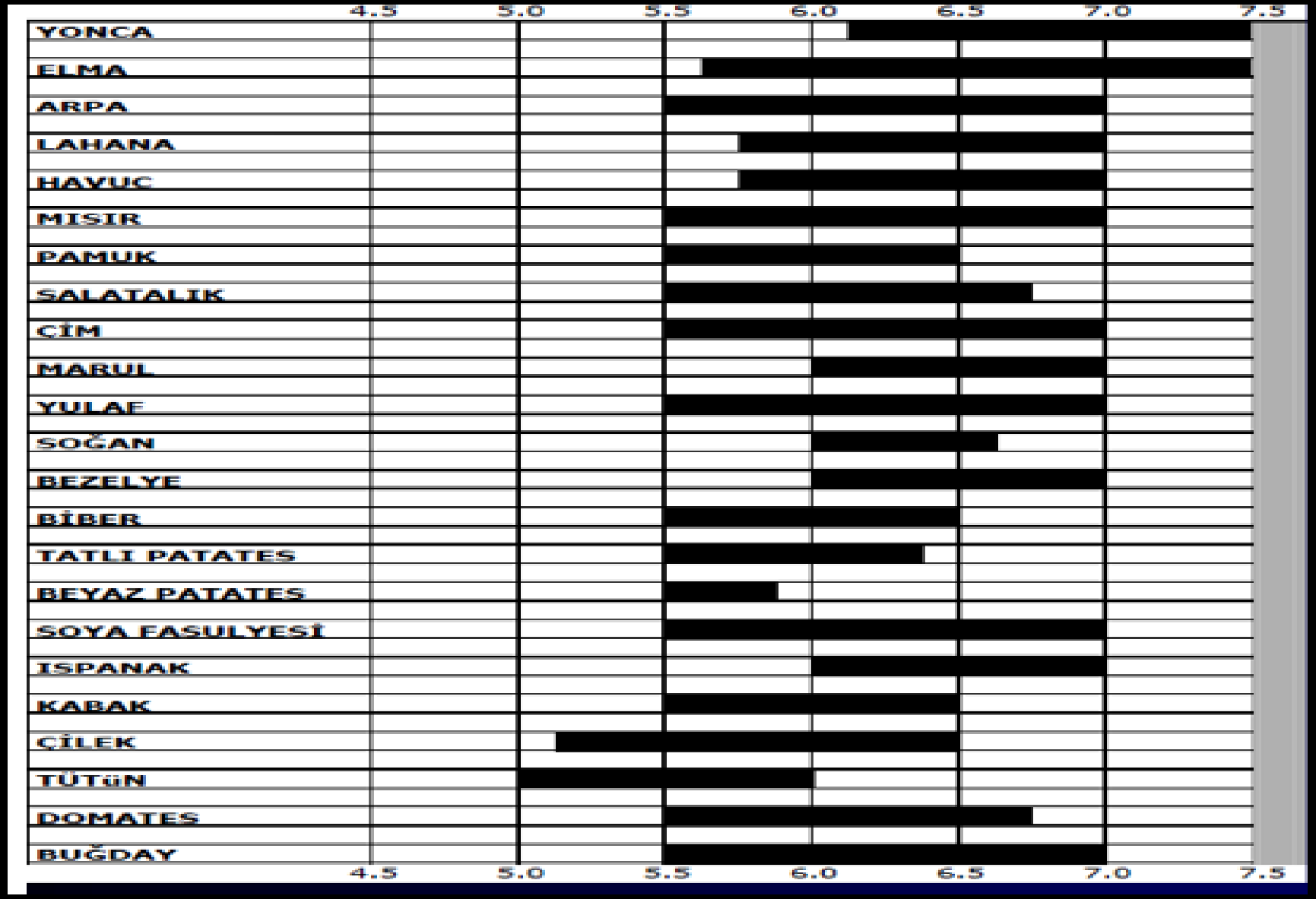


- Acidic soil pH (below 7,0)
- Neutral soil pH (around 7,0)
- Alkaline soil pH (above 7,0)

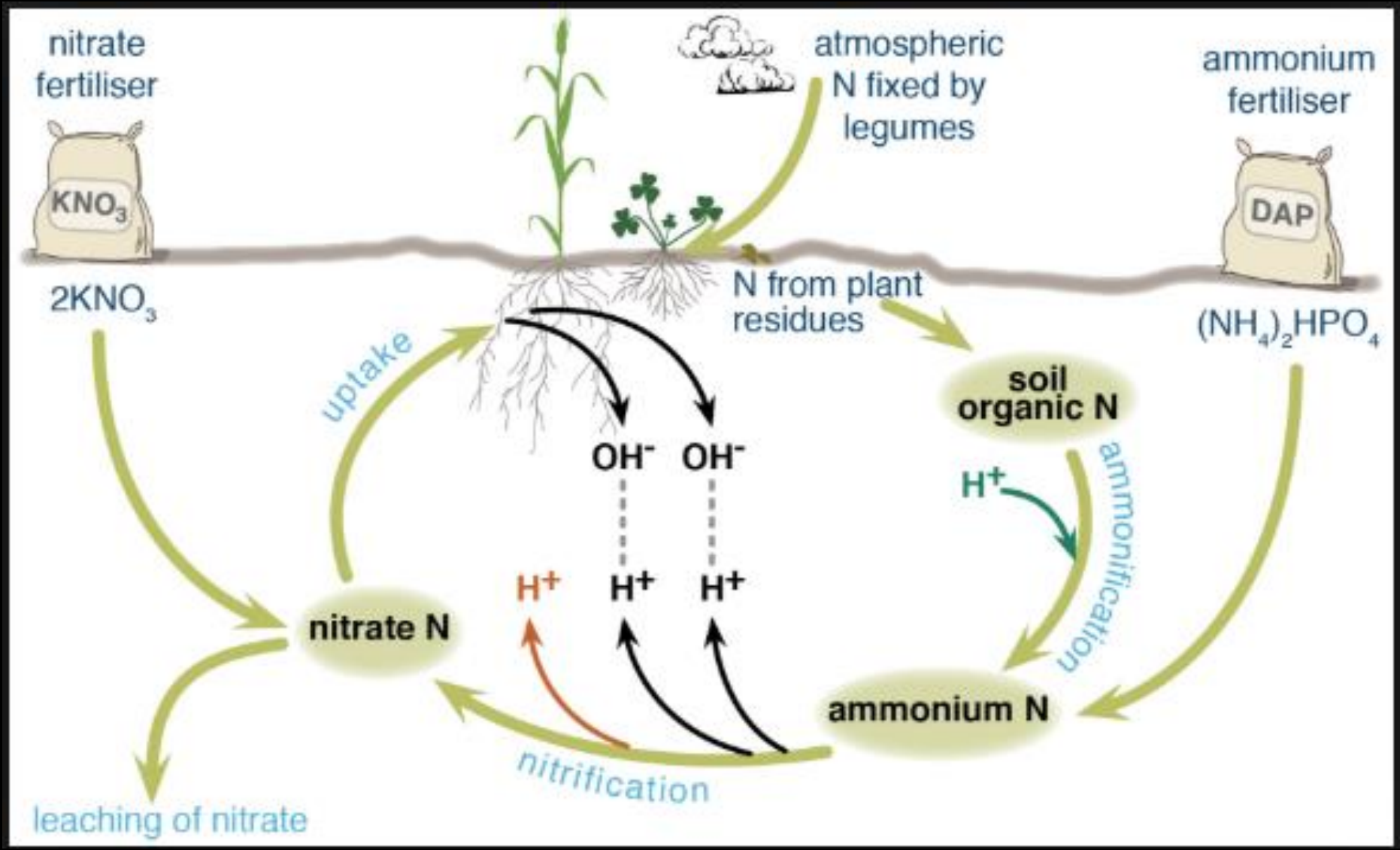
Why soil pH matters??



pH effect on nutrient availability for certain agricultural plants



How can a soil become acidic?



Factors affecting soil pH

- Precipitation (replacement of H with alkaline elements causing acid conditions in soil)
- Geological characteristics of parent material and rocks
- Amount of humus and decomposition level
- Continious and extreme fertilization
- Agriculture with no rotation
- Hydrolysis
- Root respiration
- Plant type (legume acidfy soil)
- Topography and drainage conditions

What can be the potential reasons for the situation below?

What is soil salinity and alkalinity ?

- Soil salinity is a condition that results from the accumulation of Ca, Mg, K and Na.

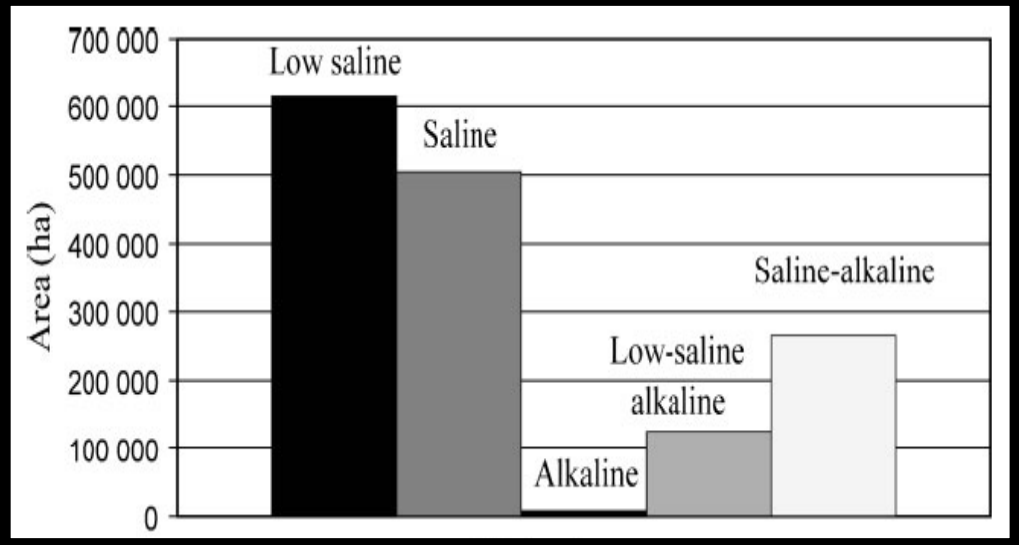
- Soil alkalinity is a type of soil salinity and results from accumulation of Na excessively

- Excessive Na is not good for soil because it increases dispersion of clay and SOM
- Soil gets weaker once it start to clay and SOM as they are responsible for aggregation processes.

- We definitely need to reclamate soil to remove salts from soil

Reasons for Soil Salinity and Alkalinity Problems

- Saline Parent material (calcareous)
- Continental climate (long and hot summers) with low precipitation less than 250mm)
- High evapotranspiration and capillarity in soil
- Misirigation and water quality problems



Salinity degree of Turkish soils (Kendirli et al. 2005)

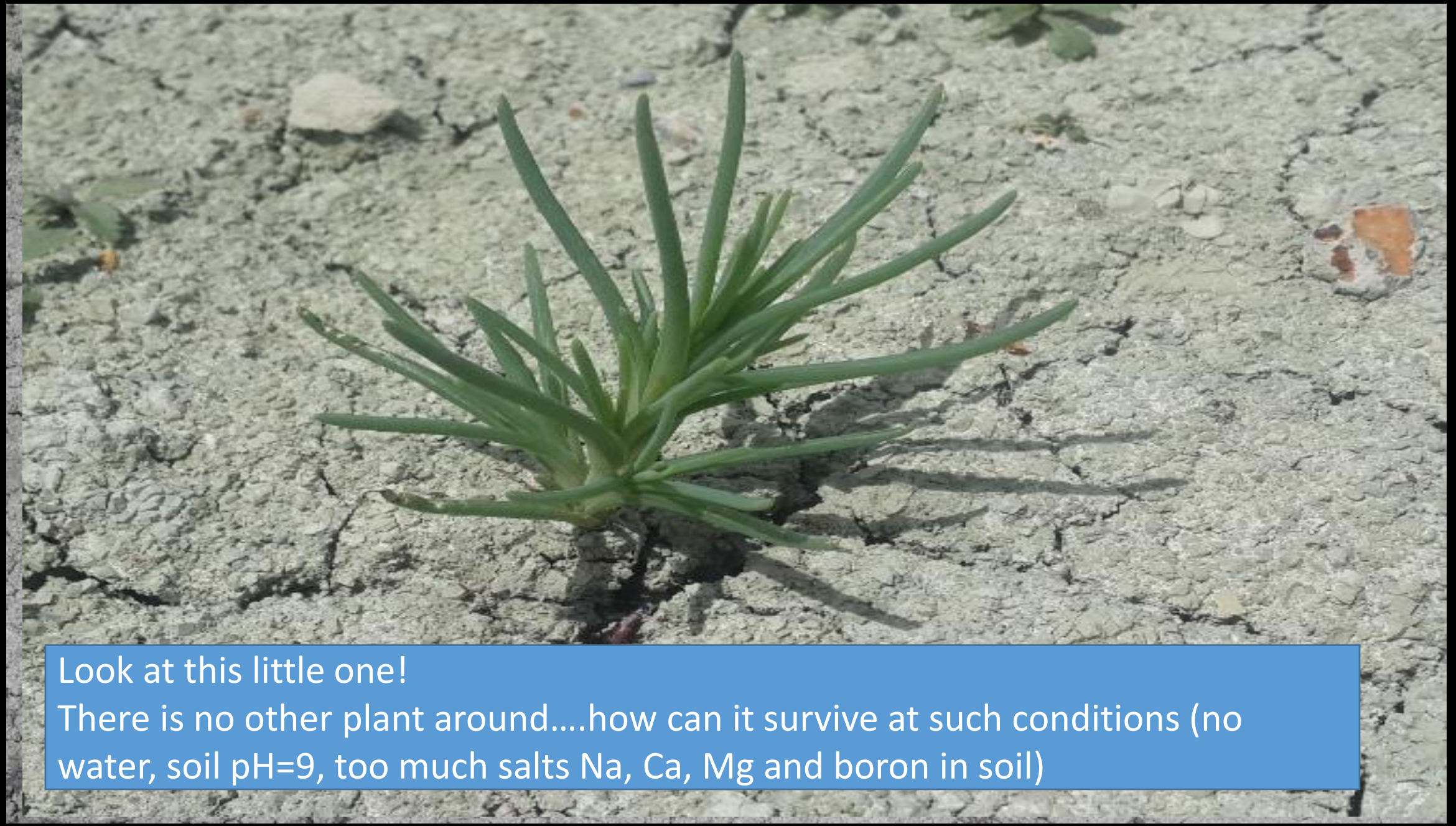
Photos: Central Anatolia, Ankara and Konya R


Ethiopia-Africa
https://www.biosaline.org/news/2018-07-17-6571


NALLIHAN ANKARA REGION (one of the driest place in Turkey, <150mm rainfall

High pH soil = saline/alkaline soil

Why white?



Look at this little one!
There is no other plant around….how can it survive at such conditions (no water, soil pH=9, too much salts Na, Ca, Mg and boron in soil)

Koca soda *(Salsola grandis)*

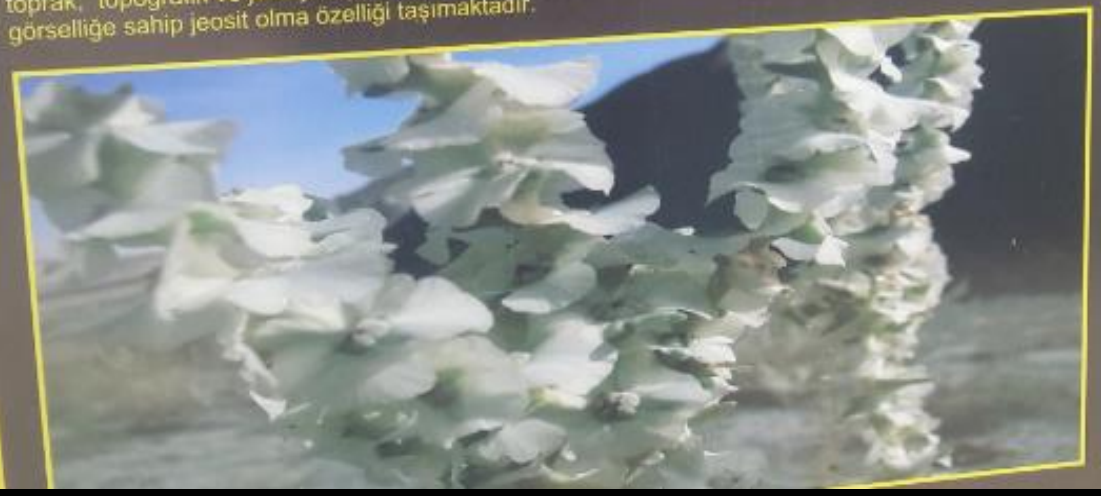
Tehlike Durumu:VAHİM (CR)

Nallıhan, Davutoğlan Kuş Cenneti çevresinde yaşayan kuraklığa ve tuza dayanıklı bu tür 1999 yılında keşfedildi. Horozibiğigiller *(Amaranthaceae)* ailesinden, sadece bu alana özgü, 1,5 m kadar boylanabilen, etli yapraklı, tek yıllık otsu bir bitkidir. Çiçek örtü yaprakları yoktur. Soda otları *(Salsola spp.)* içinde en boylu ve meyve kanatları en büyük olan türdür. Daha çok vadi tabanlarında jipsli, killi ağır topraklarda yayılış gösterir. Hiçbir türün gelişme gösteremediği bu erozyonlu çorak yamaçlarda tutunabilme kabiliyetiyle ön plana çıkmaktadır.

Temmuz ve haziran aylarında çiçeklenir. Gösterişli kanatlı meyveleri ekim ve kasım aylarında olgunlaşır. 4 km2' den daha dar bir alanda yayılış gösterir.

Bilgilendirme Prof. Dr. Mecit Vural tarafından yapılmıştır.

Dar yayılış alanına sahip bu alandaki nadir türler habitatı ile birlikte korunmaya alınmalıdır. Koca sodanın popülasyon dalgalanması kuvvetlidir. Çölleşen dünyada bu bitkilerin genetik materyalleri ileride bizler için hayat kurtarıcı olabilir. Alan toprak, topoğrafik ve jeolojik açıdan da cazip görselliğe sahip jeosit olma özelliği taşımaktadır.

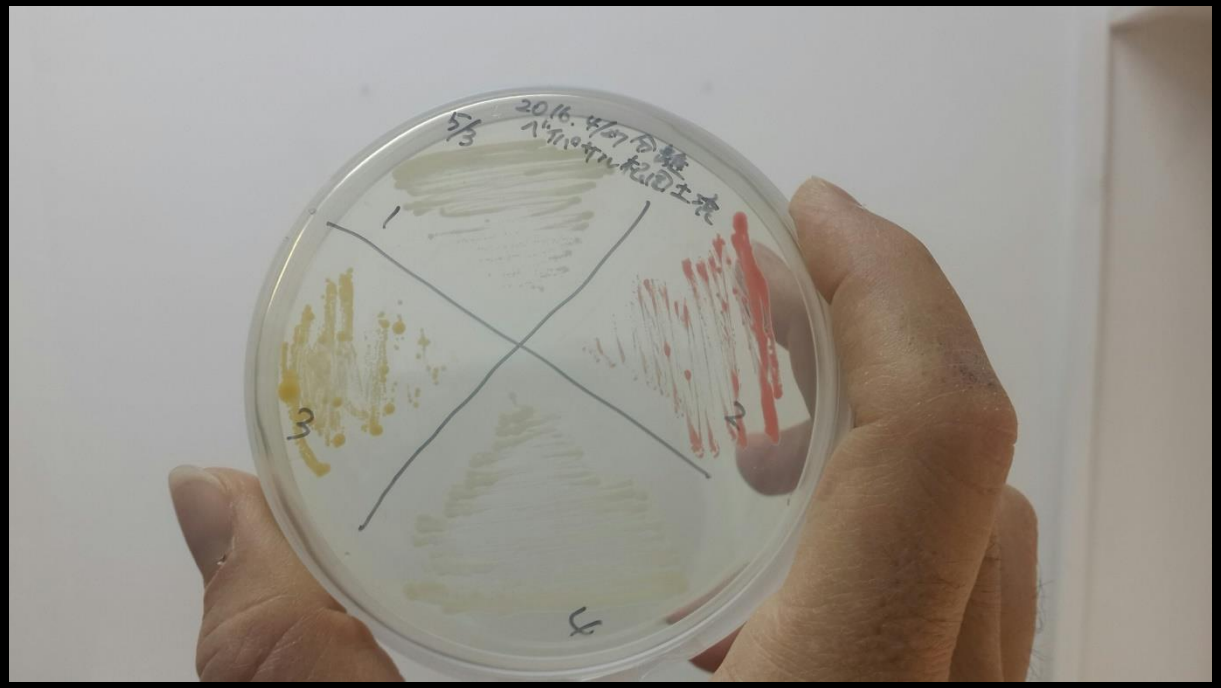


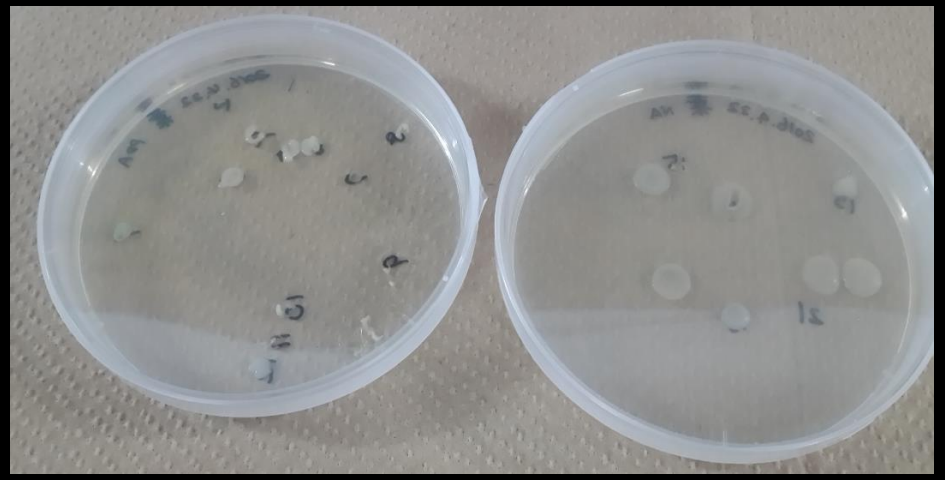
Öldürgen *(Anabasis aphylla)*

Tehlike Durumu:VAHİM (CR)

Öldürgen türü (Anabasis aphylla) 60 cm'ye kadar boylanabilen çok dallanmış bir yarıçalıdır. Kuş Cenneti'ni çevreleyen çorak bataklıklarda yetişen bu tür de Horozibiğigiller (Amaranthaceae) ailesine mensuptur. Ön Asya'nın yarı çöllerinde, Hazar'ın kuzeyindeki çorak ovalarda, Azerbaycan, İran ve Nahçevan'da yetiştiği bilinen bu tür Türkiye'de Nallıhan Kuş Cennetini kendine yurt edinmiştir. 1937'de Iğdır'da yetiştiği rapor edilmesine rağmen bugüne kadar Iğdır'dan gelen başka kayıt yoktur. Sonbaharda meyvelendiği zaman daha gösterişlidir. Meyvesi iki adet kanatla kuşatılır. Çorağa uyum özelliği ve Türkiye'de sadece Nallıhan Kuş Cenneti'nde az bireyle temsil edilmesi ulusal ölçekte korunmasını gerektirmektedir.

Bilgilendirme Prof. Dr. Mecit Vural tarafından yapılmıştır.


5/3
1
3
2
4



Effects of soil salinity

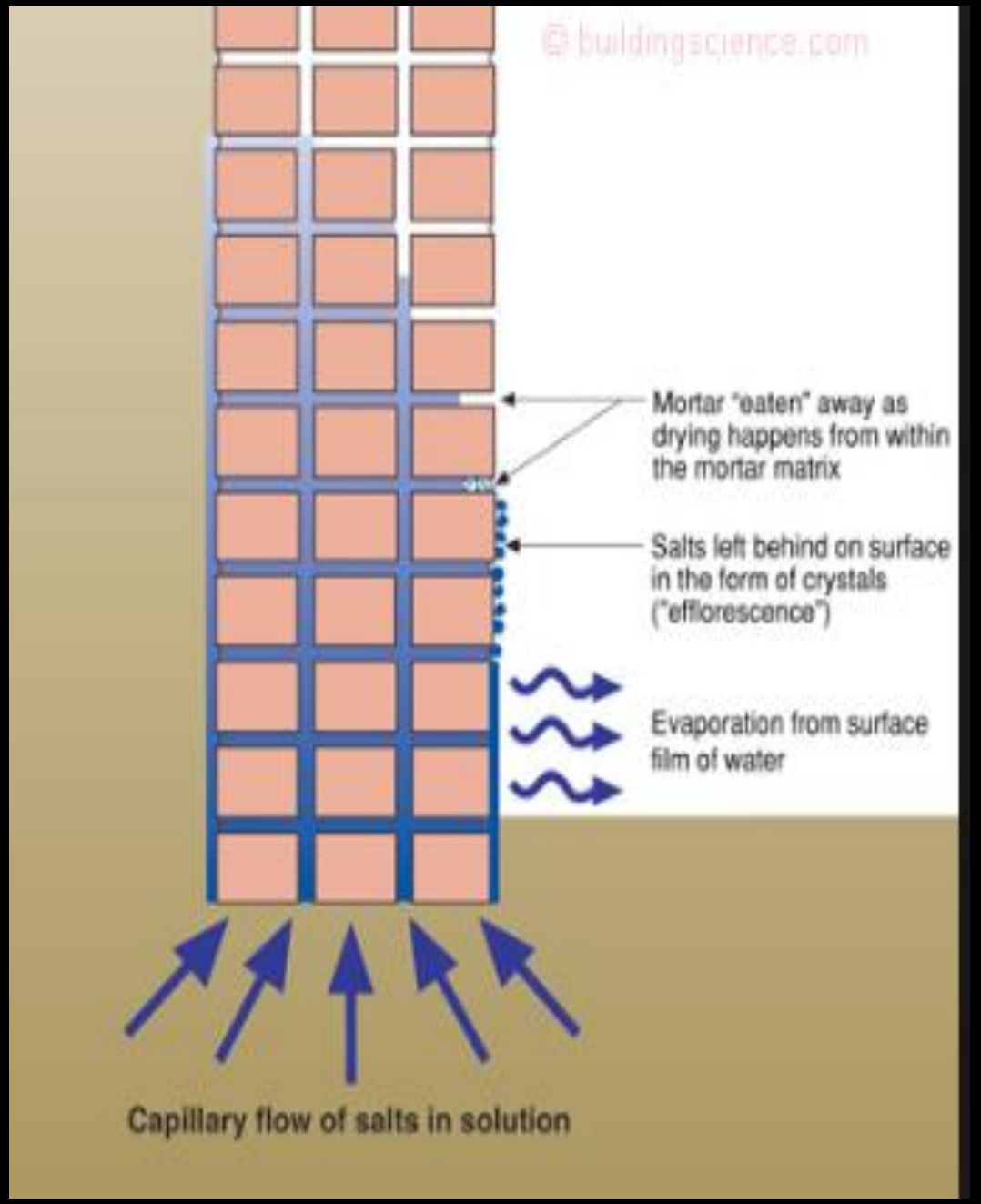
- Excessive amount of salts limits plant growth by toxically and reducing water potential

- Soil capillarity moves salts from deeper soil layers to surface and accumulate them near surface or surface soil

Major Soil Threats in Turkey

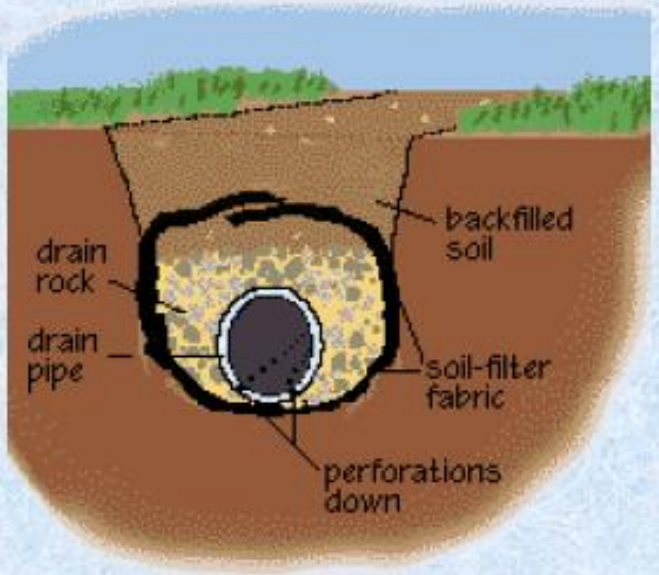
Types of Problems	Area (ha)
Water erosion	66.576.042
Wind erosion	330.000
Alkalinization / Salinization	1.518.749
Hydromorphic soil	2.775.115
Stony or rocky problem	28.484.331
Non agriculture use	894.153

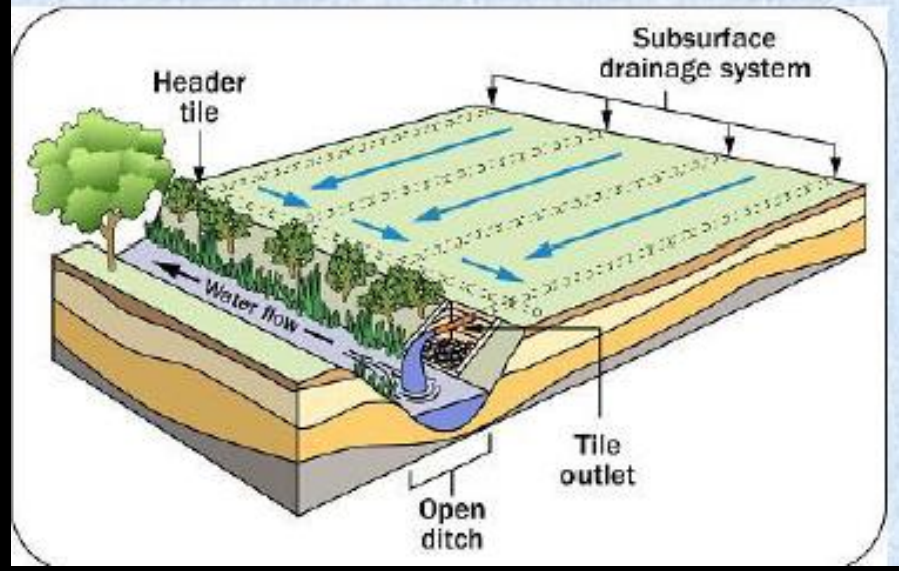
*



How do we combat with soil salinity-Alkalinity Problems

1) Removal of Salt
   - Subsoil drainage
   - Washing
2) Chemical Applications
   -Chemical transformation of alkaline carbonates to alkaline sulphates
3) Salinity Management
- Mulching (for the reduction of evaporation)
- Avoiding wild flooding irrigation methods
- Growing salt tolerant plants (wheat, beet, cotton, barley, millet, rye etc)


backfilled soil
drain rock
drain pipe
soil-filter fabric
perforations down

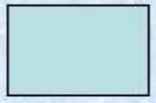

Subsurface drainage system
Header tile
Water flow
Tile outlet
Open ditch

Chemical transformation of alkaline carbonates to alkaline sulphates

Jips ve sülfürik asit uygulaması

- $Na_2CO_3 + CaSO_4 \rightarrow CaCO_3 + Na_2SO_4$ (Yıkanabilir)

Na
Na

$CaSO_4$ ⟶ Ca
Ca

+ Na_2SO_4

Sülfürik asit uygulaması

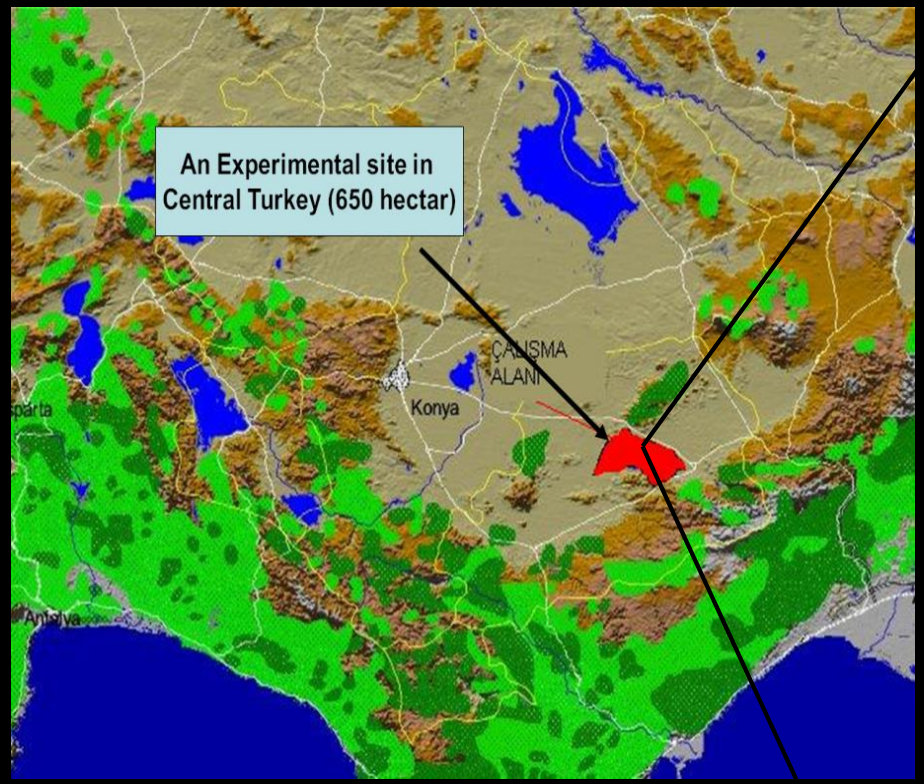
- $Na_2CO_3 + H_2SO_4 \rightarrow CO_2 + H_2O + Na_2SO_4$
- $CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + H_2O + CO_2$

Na
Na

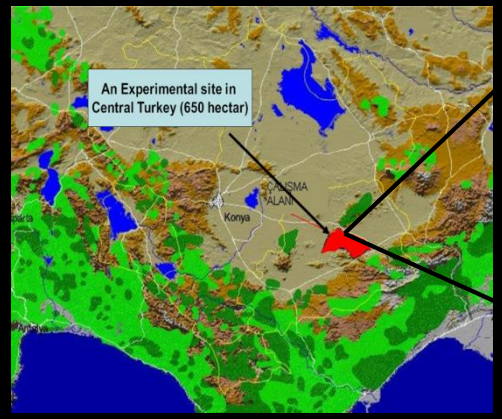
$CaSO_4$ ⟶ Ca
Ca

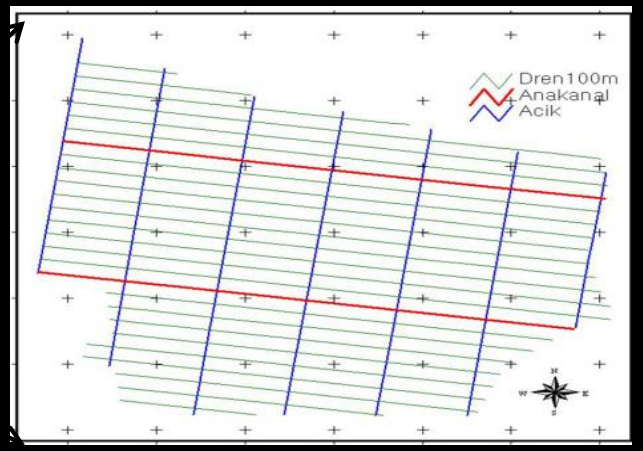
+ Na_2SO_4

A case study, saline-alkaline soil reclamation in Central Turkey (yrs 2003 to 2011)



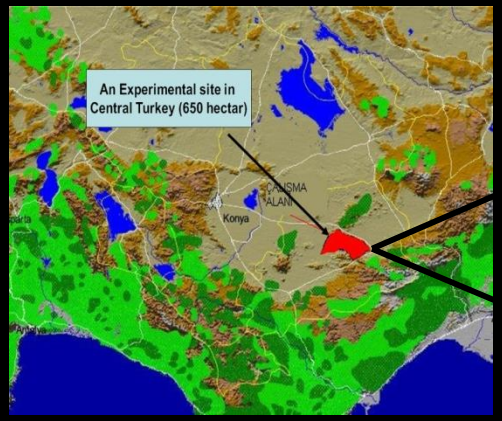
FIELD SETUP..

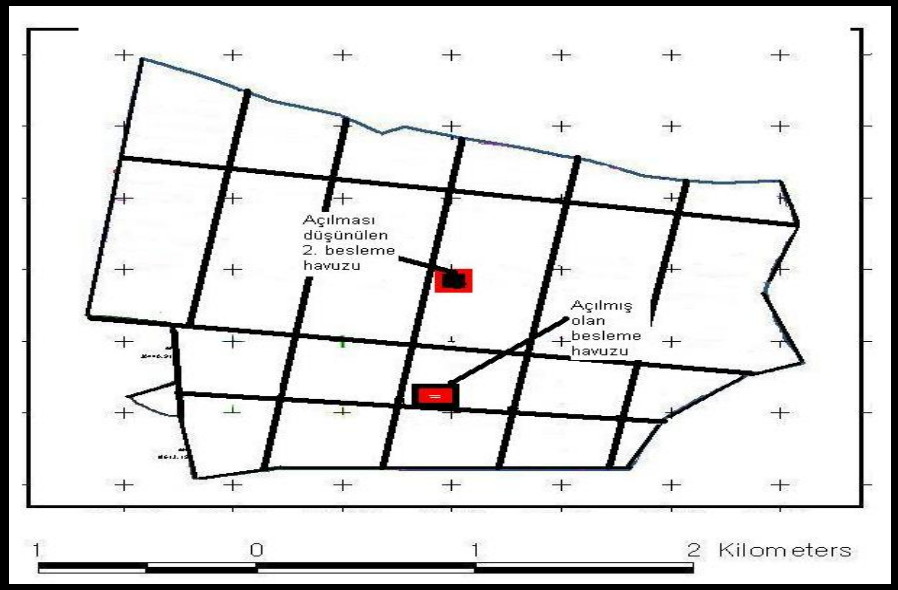




Construction of

- primary and secondary drainage pipe systems
- Temporal water ponds
- Water wells for providing leaching water





MATERIAL and METHODS:

- Hydromorphic saline-alluvial soils rich in clay and lime..

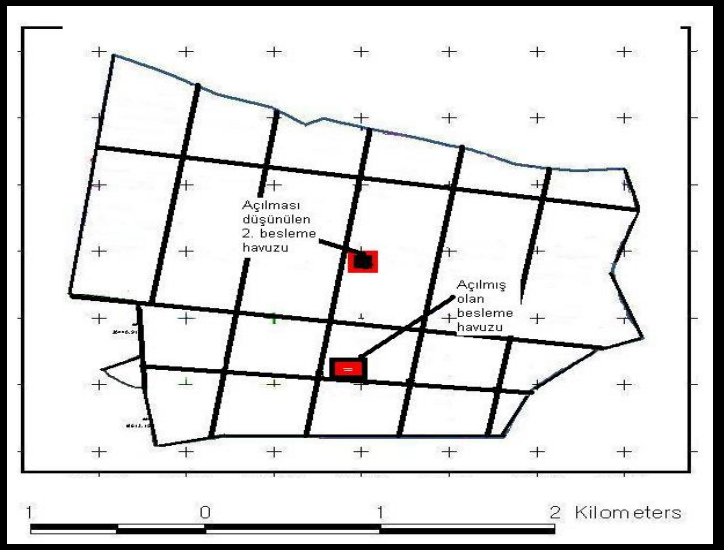
- pH,8.0 - EC, 14.5 dSm^{-1} – lime, 33% - ESP, 49%

- Common salts are Na_2SO_4, Na_2CO_3, NaCl, $CaCl_2$, $MgCl_2$, $MgCO_3$, $MgSO_4$ ve $CaSO_4$

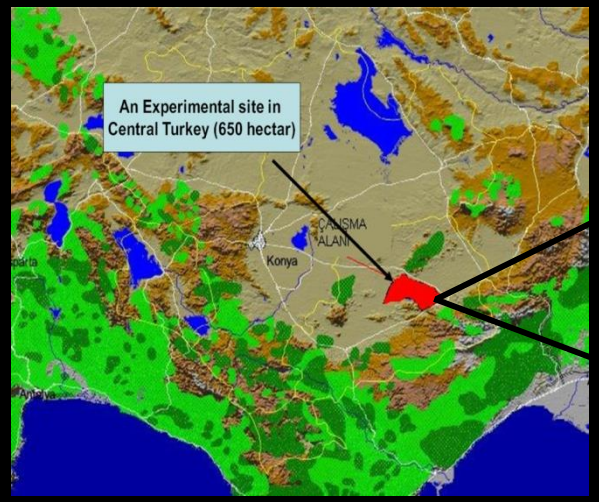
- Reclamation strategy; Drainage (1) intermittent leaching (2), gypsum amelioration (3) and pivot irrigation system were used.

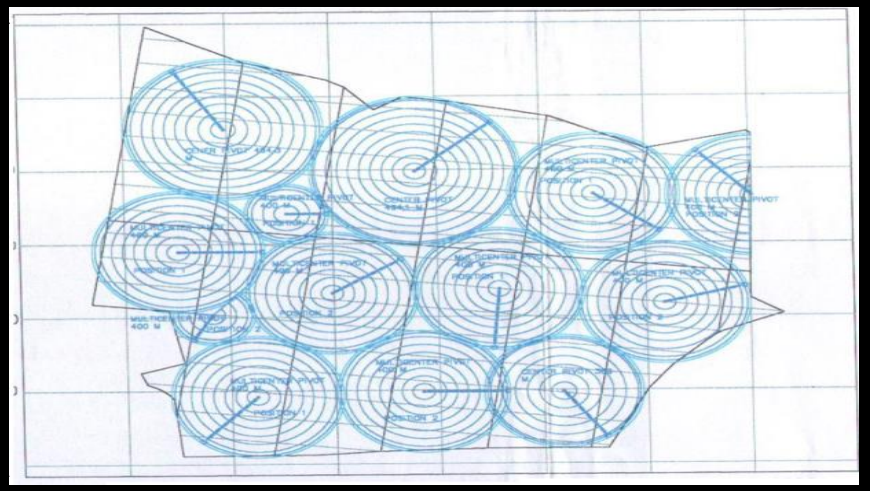
RESULTS:

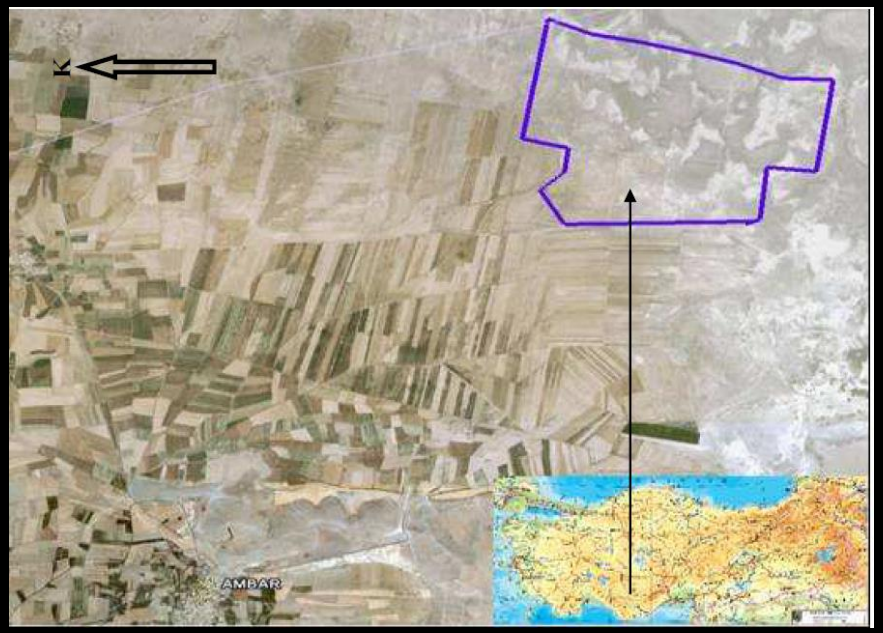
- **150 cm of leaching water applied**
- 60 cm depth of stabilization and 10% ESP were achieved in the end of 7 years application period...



Design for pivot irrigation system at the field



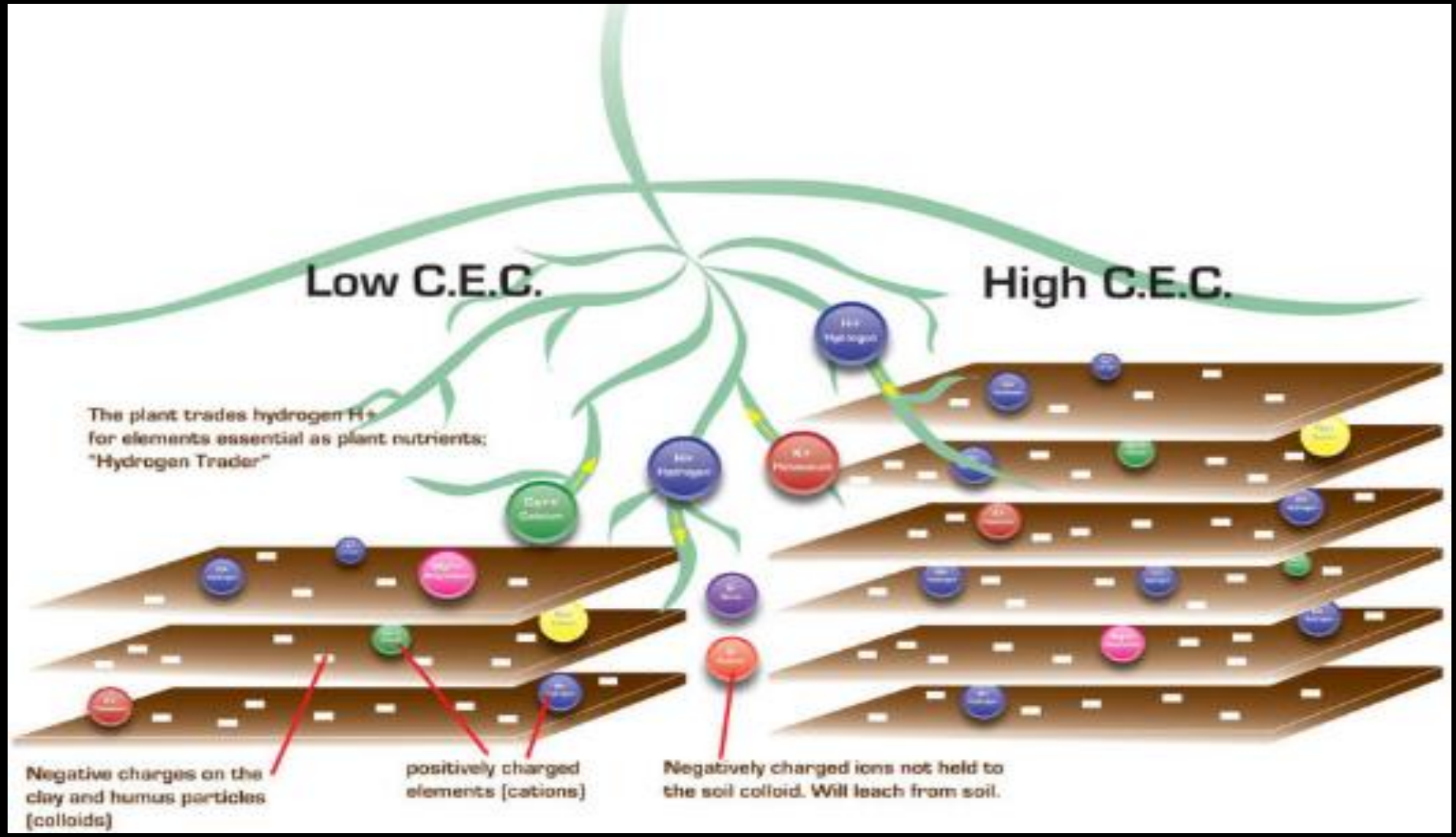




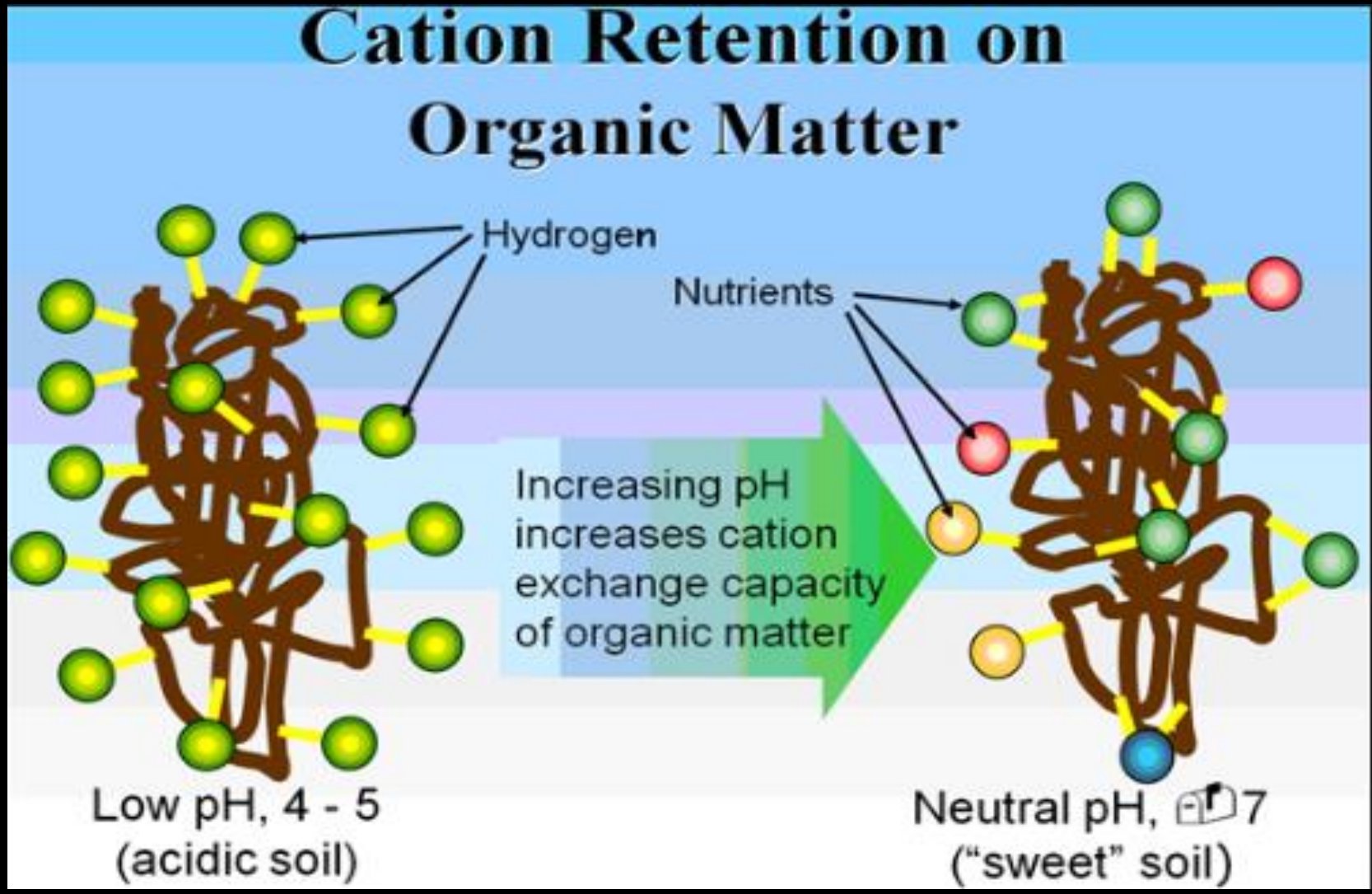
Yr 2003

Yr 2013

Colloids-Nutrients-CEC



Colloids-Nutrients-CEC



What is clay?

A finely-grained natural soil minerals that combines one or more clay minerals with possible trace of (i) quartz (SiO_2) and (ii) metal oxides (Al_2O_3)

Structure of phyllosilicate clays

- İkincil silikat killeri
- Fe – Al Oksi-hidrat killeri

Silikat Killerinin Yapıları

Philosilikat Mineralleri = İnce-levhalı Silikat Mineralleri

Phyllo- (ince levhalı)

SEKONDER SİLİKAT KİLLERİ (Ilıman bölgelerde)

DEMİR VE ALÜMİNYUM OKSİ HİDRAT KİLLERİ (tropik-yarı tropik)

Silikat Killerinin Yapıları

Silikat killeri,

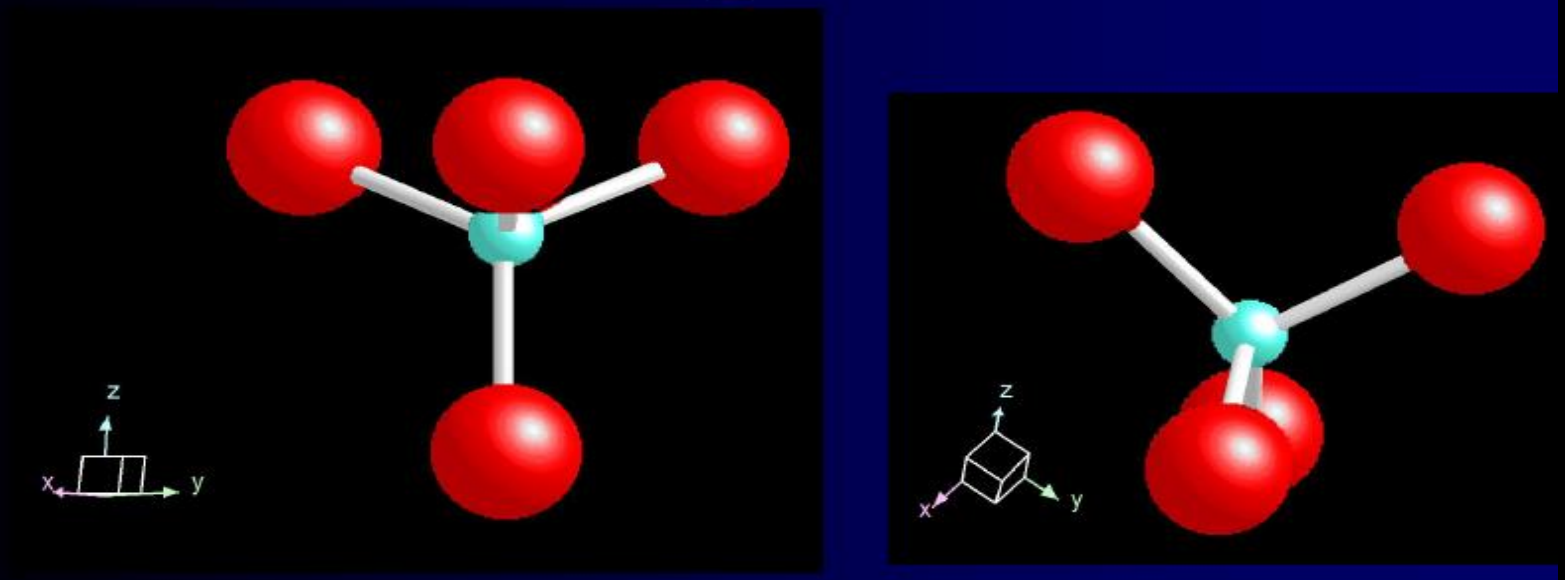
1. "*silis tetra-ederleri*"nin yan yana dizilip bağlanması ile oluşan silis levhaları ile
2. "*aluminyum okta-ederleri*"nin yan yana dizilip bağlanması ile oluşan aluminyum levhalarının 1:1 (Si-Al) ve 2:1 (Si-Al-Si) oranlarında bağlanmaları sonucunda oluşan kristal ünitelerinin, kitap sayfaları gibi üst-üste dizilmeleri ile meydana gelmektedirler.

SİLİKAT KİLLERİN YAPILARI

- Kristal kafeslerinde Si ve Al atomları merkezde, O atomları ve OH grupları tetrahedron ve oktahedron köşelerinde bulunur.
- Tetrahedronların köşelerinde 4 O (Oksijen) atomu merkezde Si atomu Si tabakası)
- Oktahedronların köşelerde 6 O veya OH merkezde Al atomu (Al tabakası)

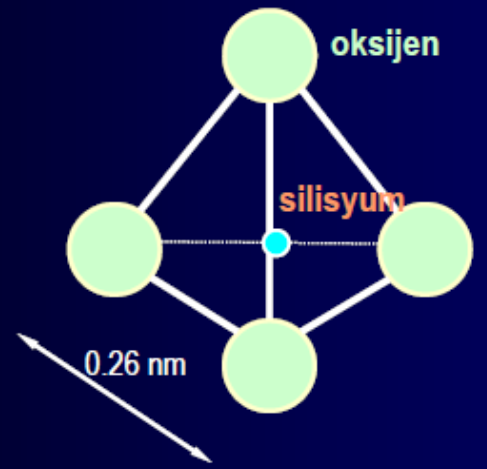
Tetra-eder Levhaların İnşası

SiO_4 tetra-eder

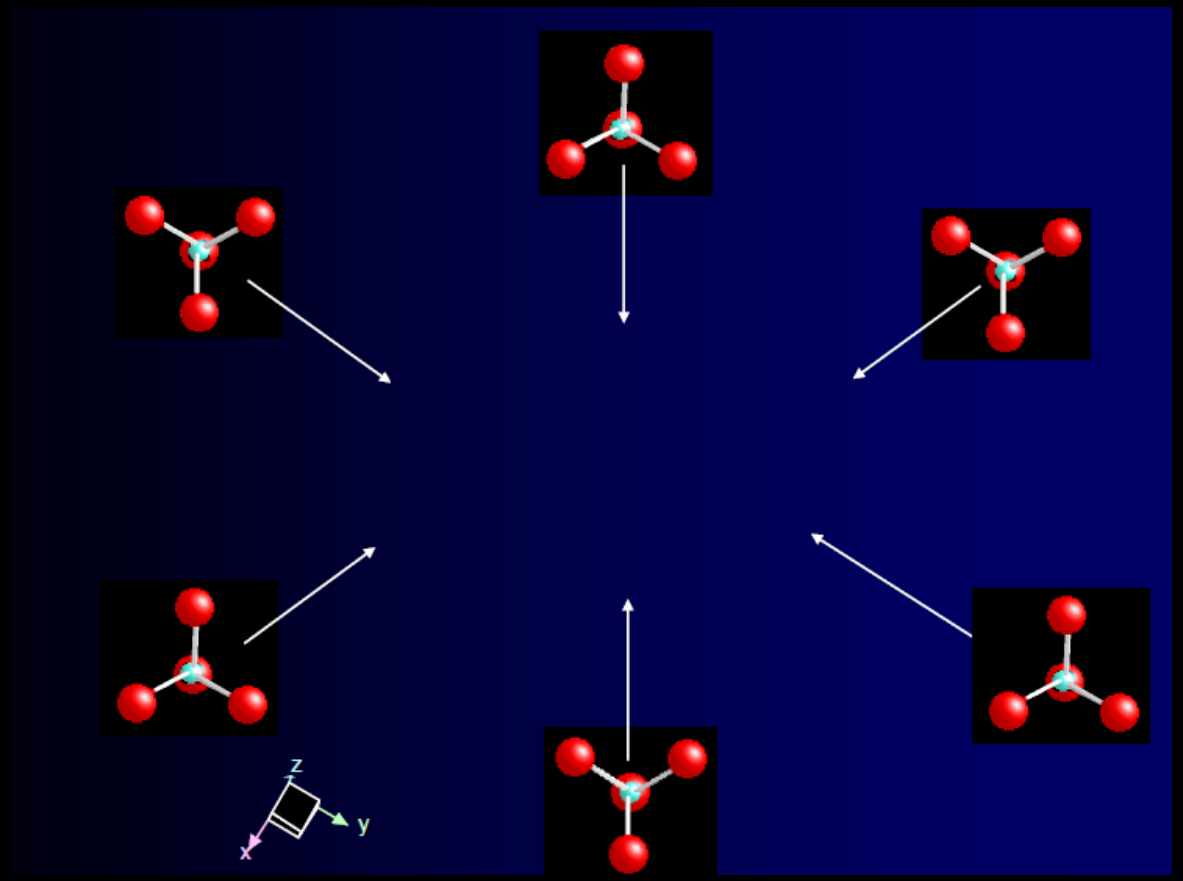


Silisyum (Si) atomları, "*tetra-eder*" şeklinde dizilmiş 4 oksijen (O) atomu içerisindeki boşluğa yerleşmiştir

Temel Yapısal Birim



Silisyum tetra-eder

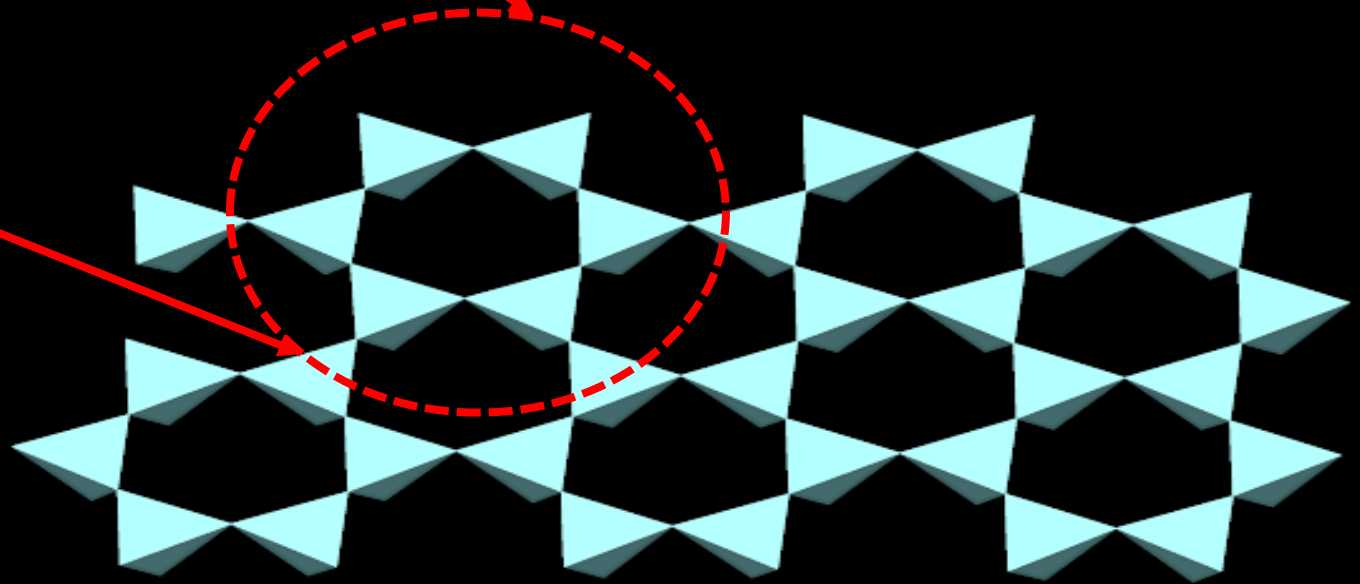


Si_6O_{18}

Tetra-eder Levhalarının Oluşumunda Halkaların Biraraya-gelmesi

Si_6O_{18}

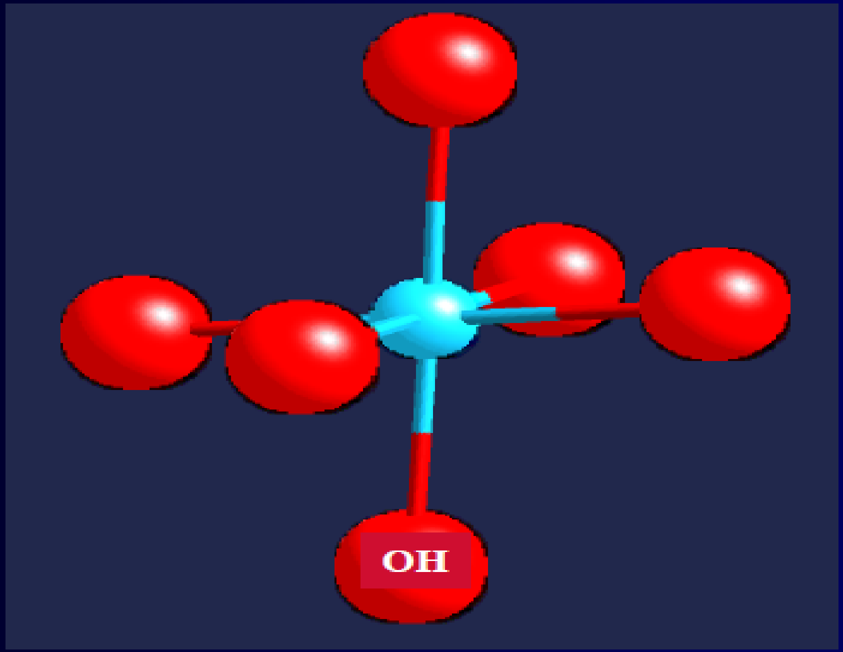
Tetra-eder Levha



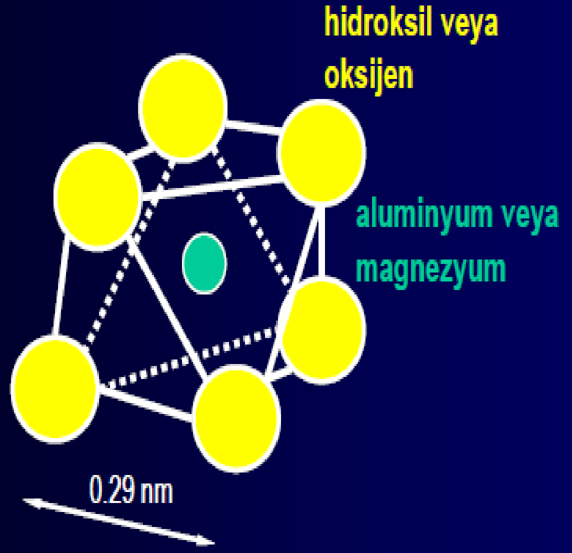
Si:O
2:5

Okta-eder Levhaların İnşası

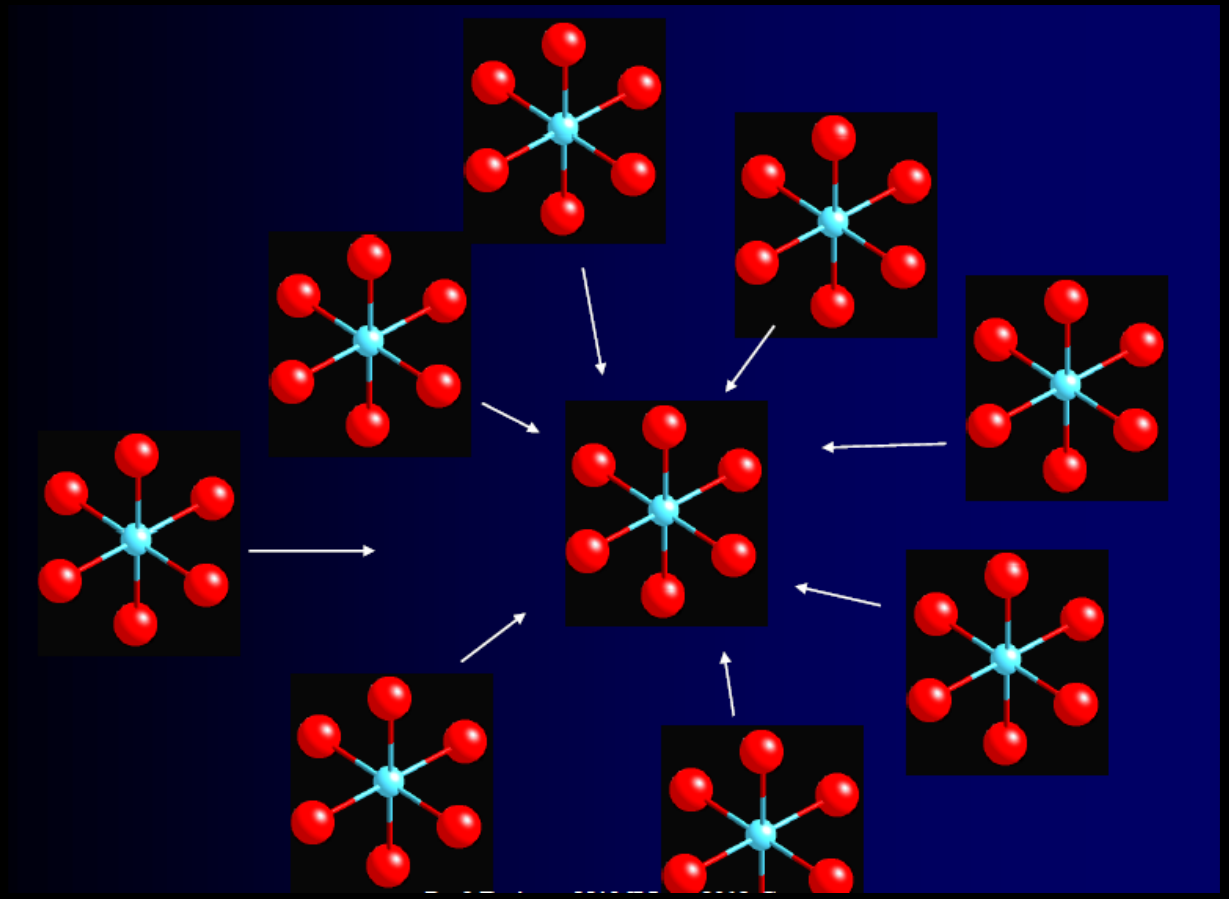
$Al(OH)_6$ veya $Mg\ (OH)_6$ Okta-eder

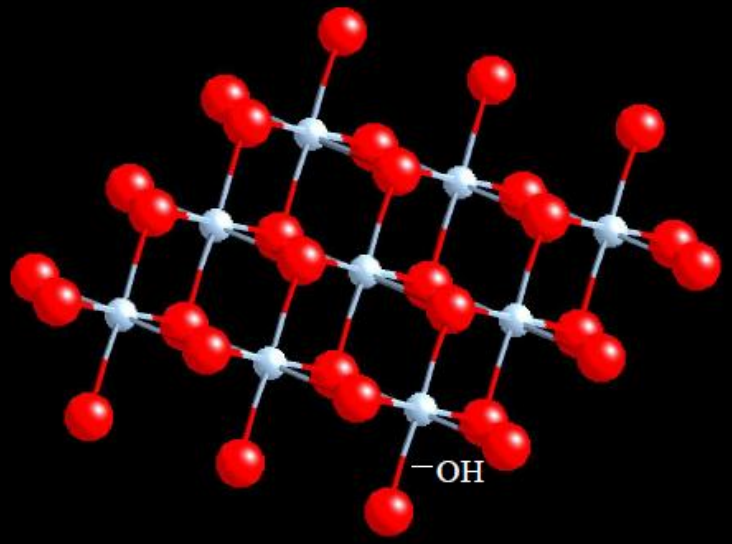


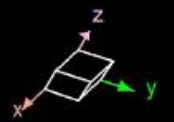
luminyum (Al) atomları, "*okta-eder*" şeklinde dizilmiş 6 hidroksid (OH veya O) atomu içerisindeki boşluğa yerleşmiştir



Aluminyum Okta-eder



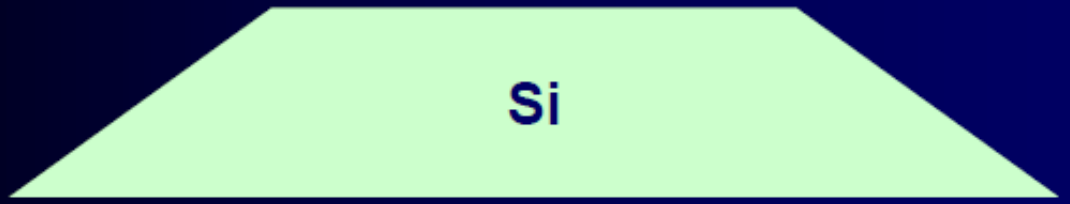

−OH


z
y
x

Oktaeder – Tetraeder Bağlantıları

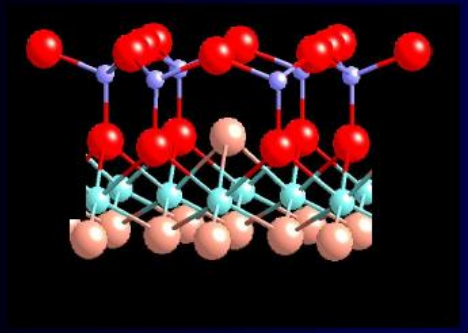
"Oktaeder – Tetraeder" Bağlantıları

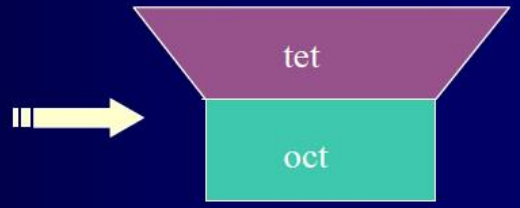
Daha kolay anlaşılır olması için,
silisyum "**tetra-eder levhası**" **ile**:

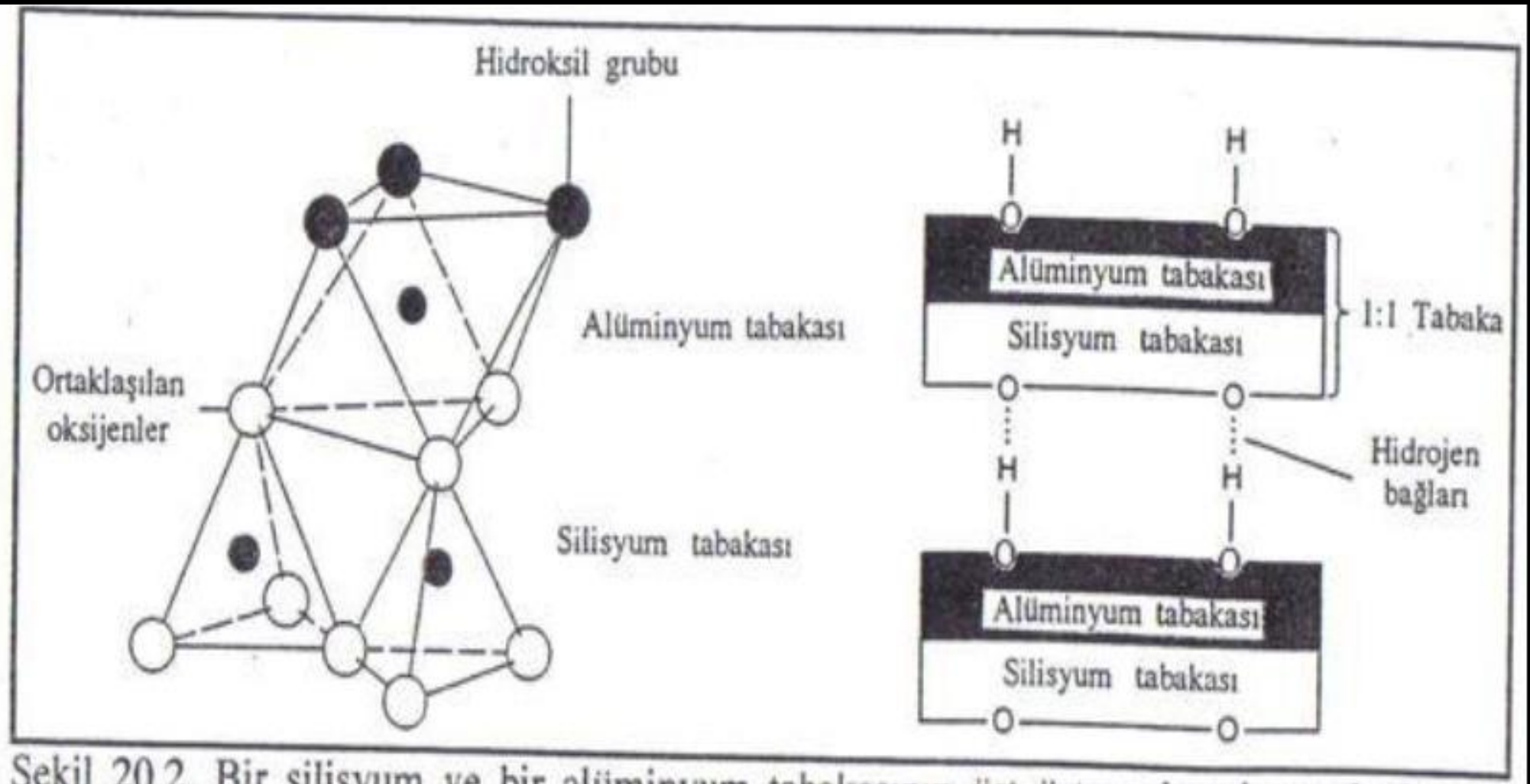


ve aluminyum "**okta-eder levhası**" **da**:

Kolay-çizim Simgeleri = Bloklar



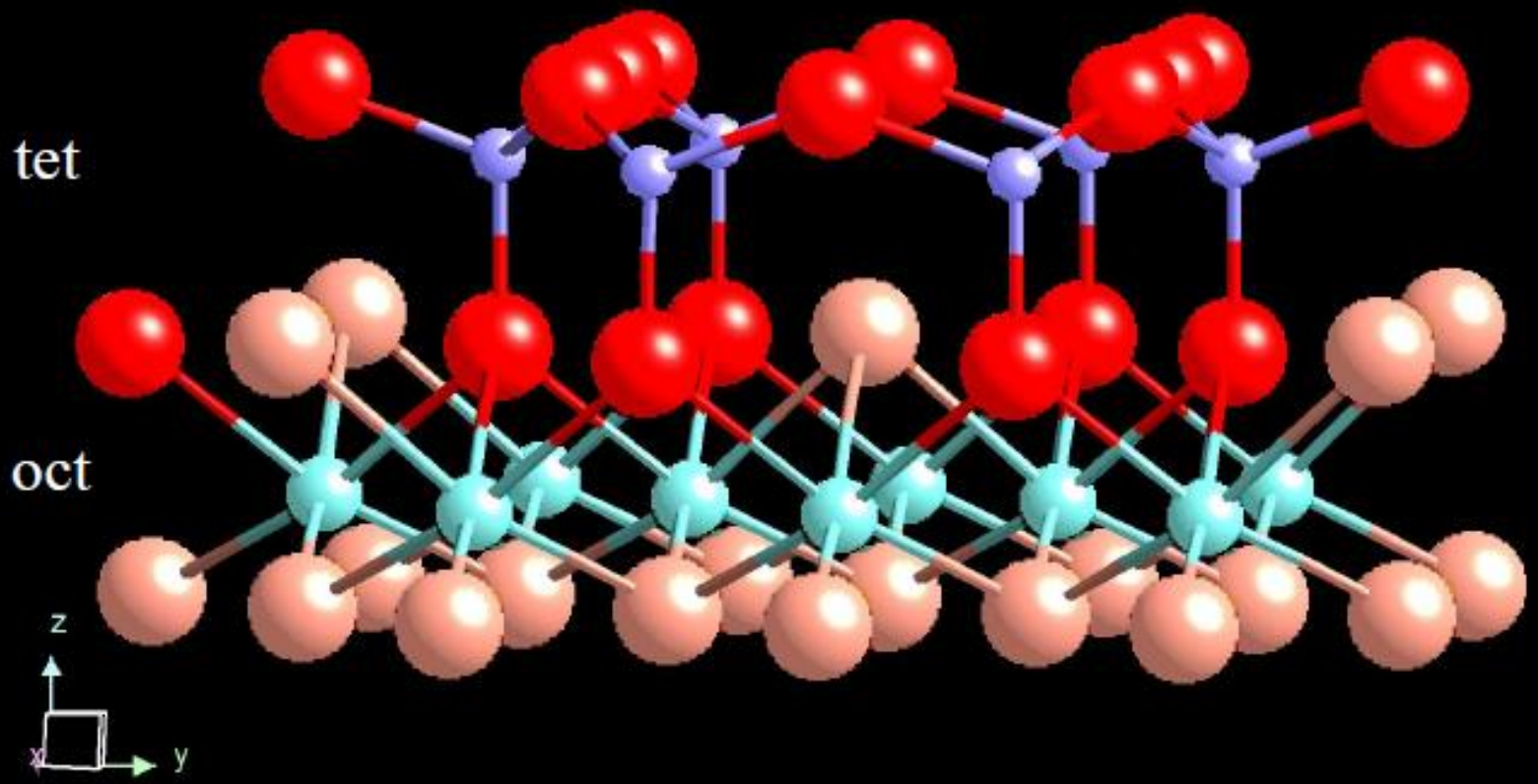


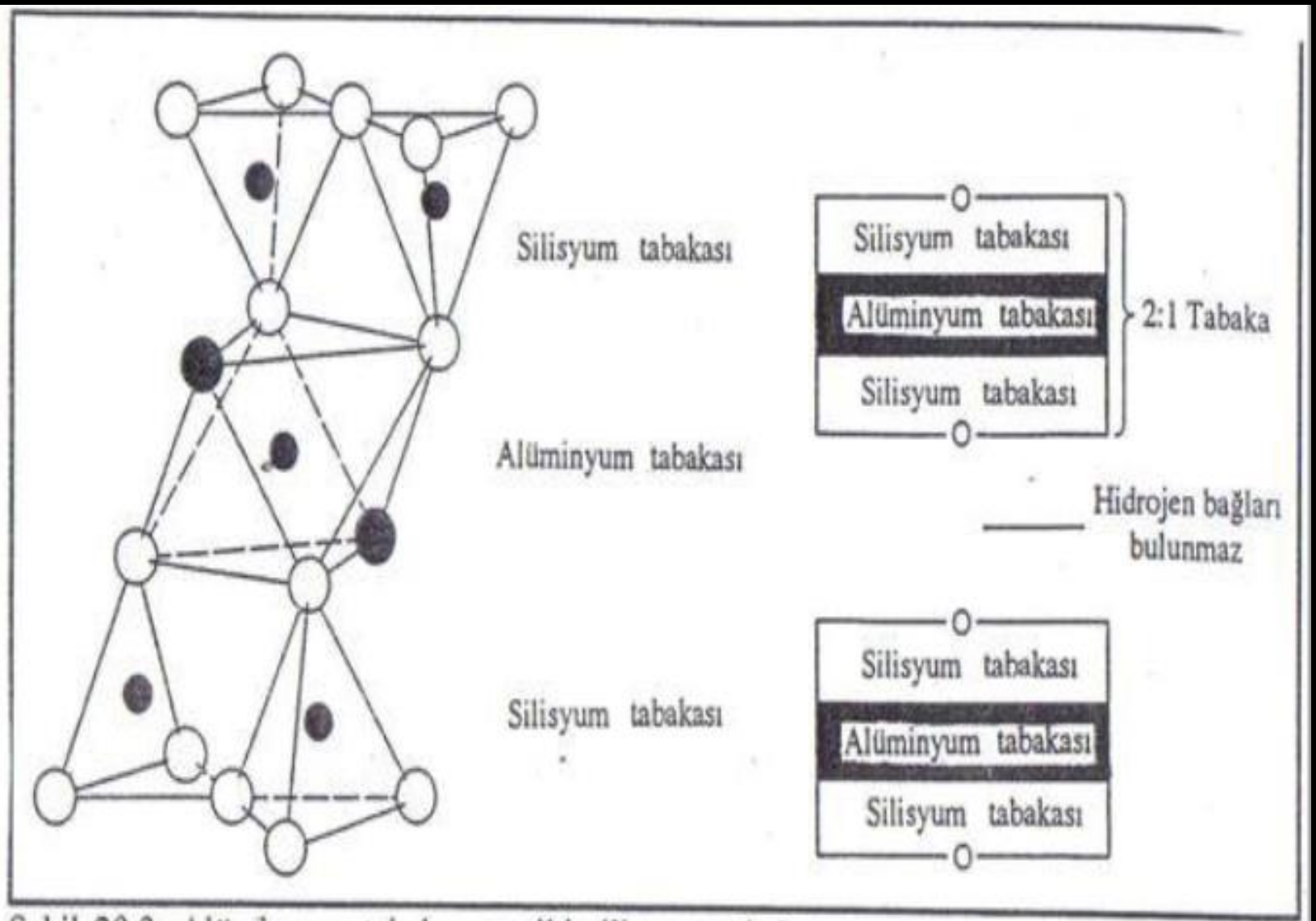


Şekil 20.2. Bir silisyum ve bir alüminyum tabakasının üst üste gelmesi ve oktahedron hidroksilleriyle tetrahedron oksijenlerinden bir sıranın ortaklaşarak bağlanmasıyla oluşan 1:1'lik kristal ünitelerine sahip kil örneği (Plaster 1985)

"Tetra-eder Levhası" Uç-noktalarındaki Oksijenler İle "Okta-eder Levhası" Hidroksillerinin Ortak Kullanımı

Serpentin (1:1 üçokta-eder mineral)

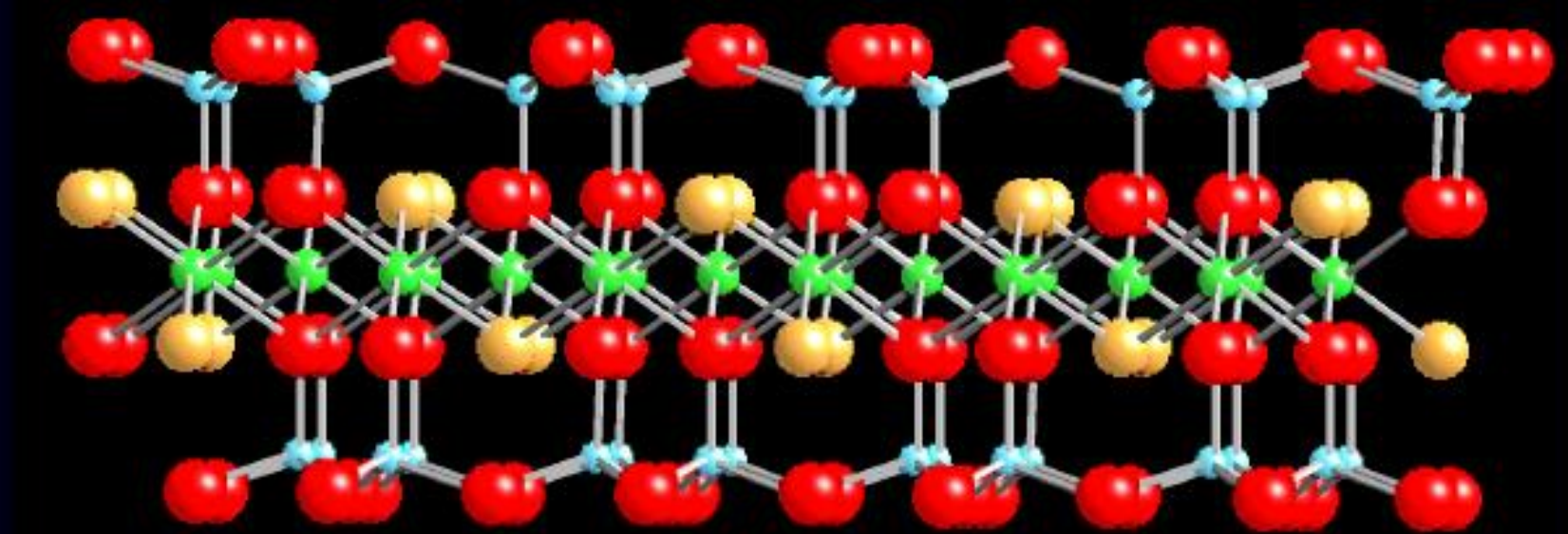


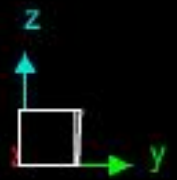


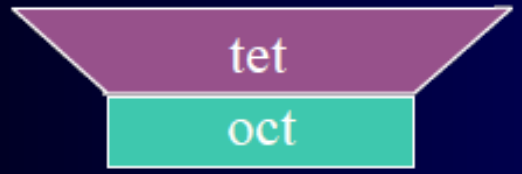
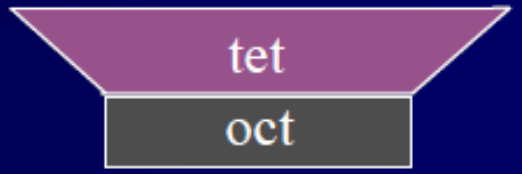
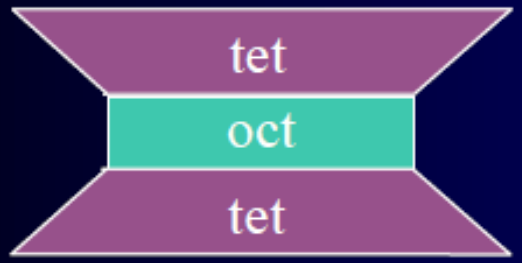
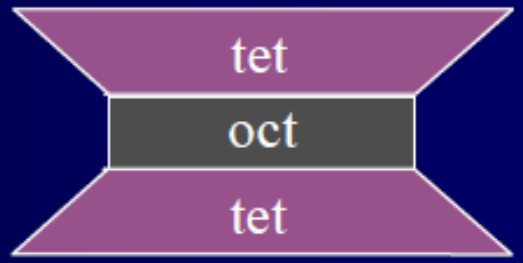
Şekil 20.3. Alüminyum tabakasının iki silisyum tabakası arasına girerek oluşturduğu 2:1 kristal ünitesinin diğer bir üniteyle gevşek O-O köprüsü aracılığıyla meydana getirdiği kil örneği (Plaster 1985)

"Tetra-eder Levhası" Uç-noktalarındaki Oksijenler İle iki "Okta-eder Levhası" Hidroksillerinin Ortak Kullanımı

Talk (2:1 üçokta-eder mineral)



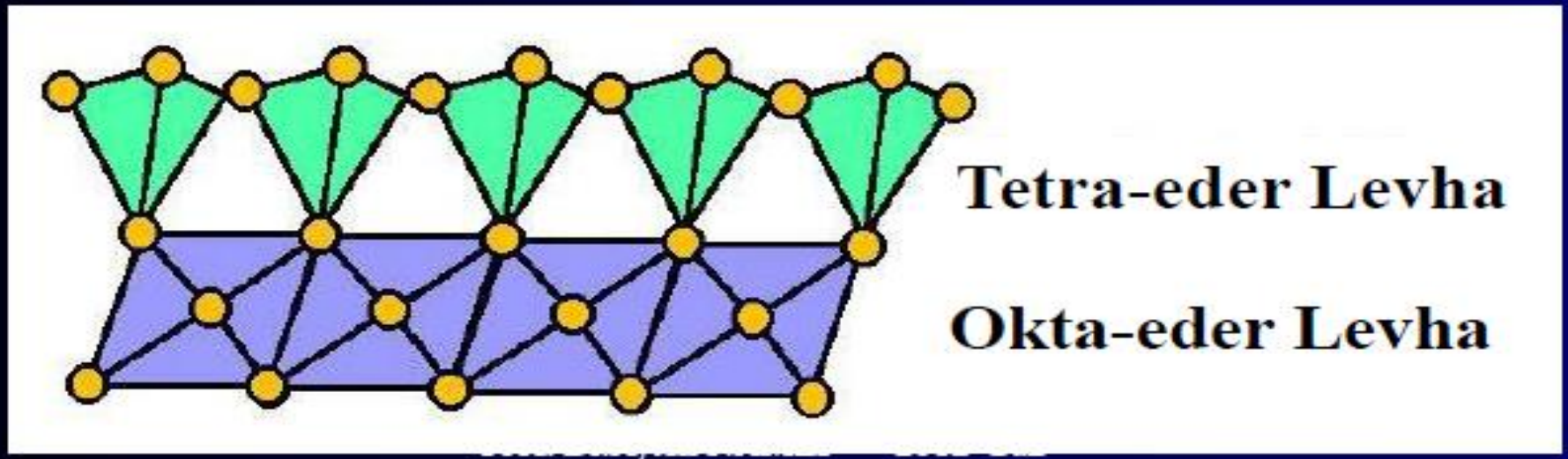


T:O (sınıf)	trioctahedral = üçoktaeder	dioctahedral = ikioktaeder
oktahedra		
	brucite = brusit	gibbsite = jipsit
1:1		
	serpentine = serpentin	kaolinite = kaolinit
2:1		
	talc = talk	pyrophyllite = pirofillit

Farklı Kil Mineralleri

"Tetra-eder Levhaları" ve "Okta-eder Levhaları" nın farklı kombinasyonları farklı kil minerallerini meydana getirir:

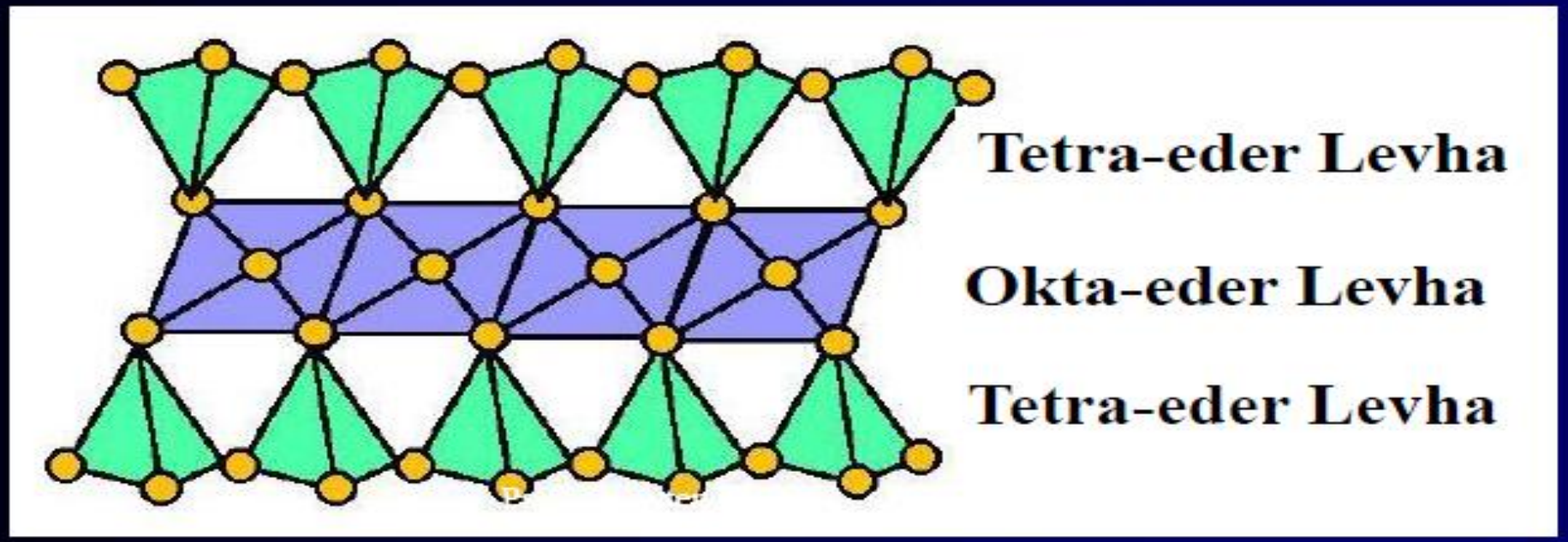
1:1 Kil Minerali (örneğin, kaolinit, halloysit):



Farklı Kil Mineralleri

"Tetra-eder Levhaları" ve "Okta-eder Levhaları" nın farklı kombinasyonları farklı kil minerallerini meydana getirir:

2:1 Kil Minerali (örneğin, montmorillonit, illit)



KİL MİNERALLERİNİN SINIFLANDIRILMASI

I. Amorf olanlar:

- Allofon grubu

ALLOFONLAR:

- AMORF YAPILI (şekilsiz)
- YÜKSEK KDK SAHİP
- VOLKAN KÜLLERİNDEN OLUŞAN TOPRAKLARDA BULUNUR

KİL MİNERALLERİNİN SINIFLANDIRILMASI

II. Kristalin olanlar :

A. İki tabakalı tipler 1:1 tipi

(levha yapılar bir silis tedraeder tabakası ile bir alüminyum oktaeder tabakası)

1. Eşboyutlu olanlar : Kaolin grubu kaolinit, dikit, nakrit.

2. Uzamış olanlar: Halloyisit grubu

B. Üç tabakalı tipler 2:1 tipi

(levhalı yapılar 2 silis tedraederi tabakasıyla I adet merkezi dioktaedral veya trioktaedral tabakadan ibarettir

1. Genişleyen şebeke yapılı olanlar:

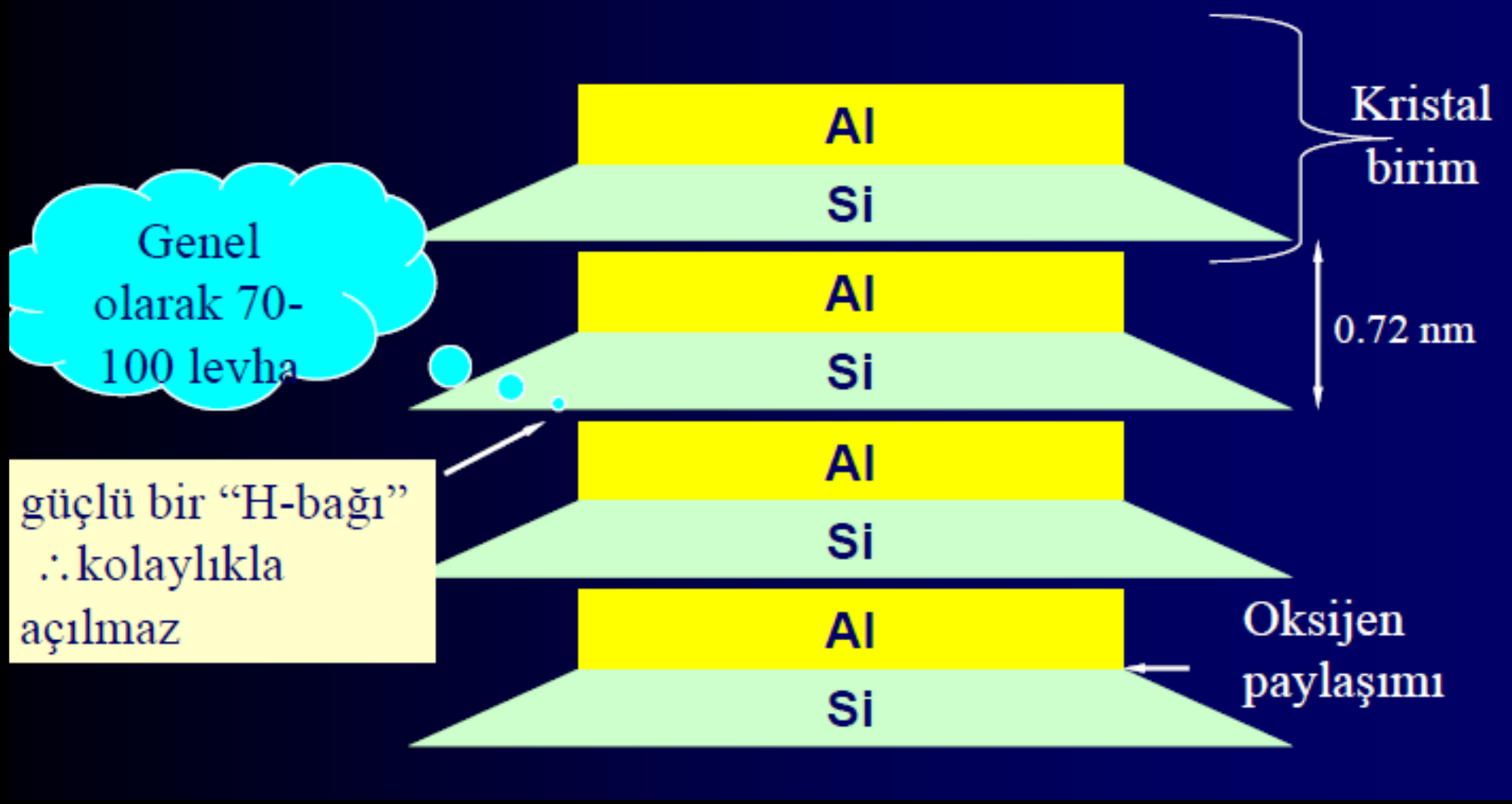
a) Eşboyutlu olanlar: Montmorillonit grubu: montmorillonit, sasonit, vb.

b) Uzamış olanlar: Montmorillonit grubu: montronit, saponit, hektorit.

2. Genişlemeyen şebeke yapılı olanlar:

- İllit grubu

Kaolinit


Al
Si
Al
Si
Al
Si
Al
Si
Kristal birim
0.72 nm
Genel olarak 70-100 levha
güçlü bir "H-bağı"
∴ kolaylıkla açılmaz
Oksijen paylaşımı

KAOLİN (Eş boyutlu/genişlemeyen):

- Sulu alüminyum silikatlardır.
- Bir oktahedral tabakaya bağlı bir tetrahedral tabakadan oluşur. (1:1 tipi tabakalı silikatlar)
- Granit kayaçlardan elde edilen bir kil türüdür.
- **Kaolinit** kaolin mineralleri arasında en yaygın bulunanıdır.
- Hidrojen Köprüsü
- KDK küçük (3-15 me/100 g)
- Kaolinit şişmeyen bir mineraldir.

Kaolinit

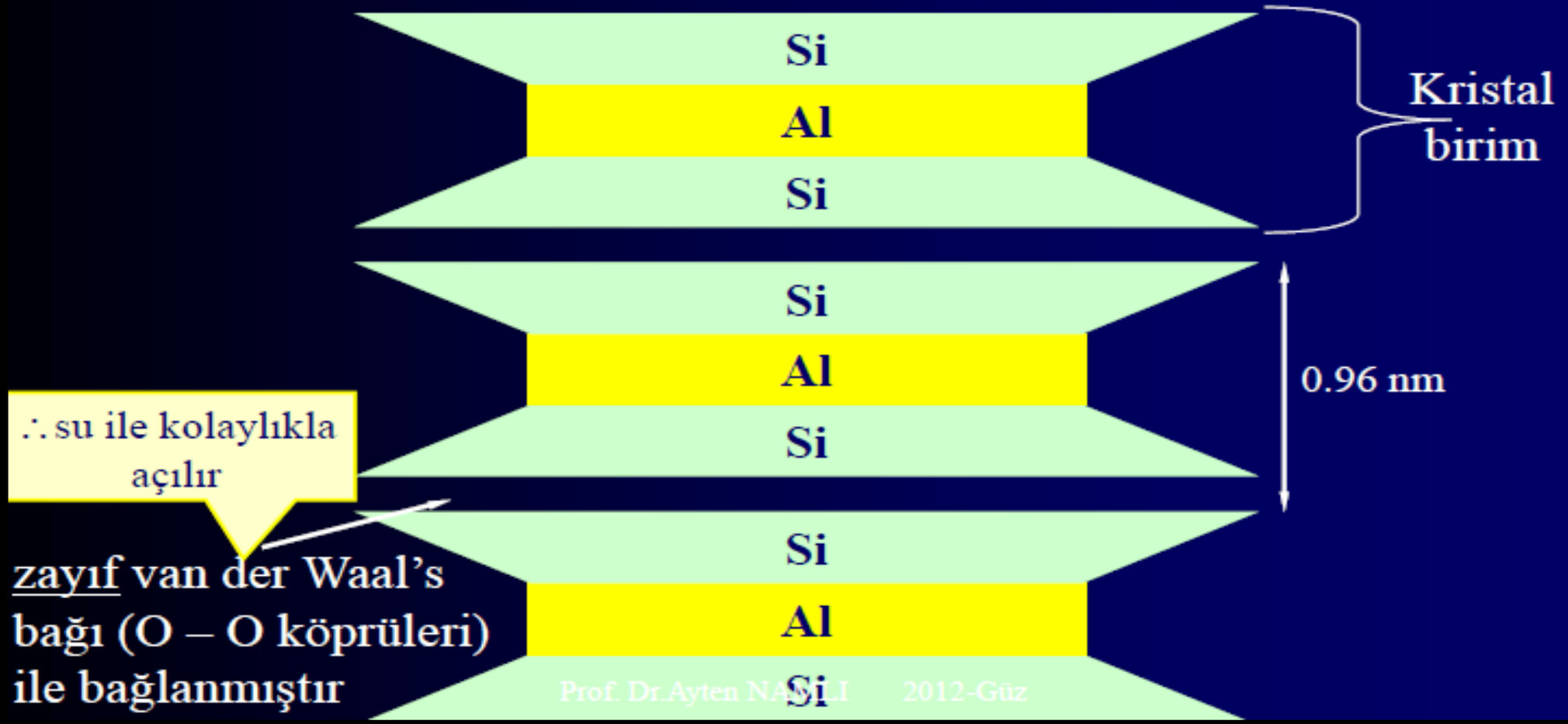
- Seramik, porselen, boyalarda, kağıt ve çömlekçilikte plastik eşya, yapay kauçuk, ilaç, gübre, mürekkep ve kozmetik ürünlerin yapımında kullanılır.
- $(OH)_8Al_4Si_4O_{10}$

Halloysit

- kaolinit ailesi; sulu ve çubuk yapılı kil mineralleri
- $(OH)_8Al_4Si_4O_{10}.4H_2O$

Montmorillonit

- **smektit** olarak da adlandırılır; su ile temasta genişler



Montmorillonit (genişleyen)

- Montmorillonit 2:1 tabaka yapısına sahiptir.
- Bu grup; propillit, talk, vermikulit, sakonit, saponit, nontronit

  ve montmorilloniti kapsayan bir çok mineralden oluşur.
- Tetrahedrallerin tümü Si^{4+} iyonu içerir.
- Ancak oktahedrallerin sekizde biri Al^{3+} iyonu yerine Mg^{2+} iyonu içermektedir.
- Su ile temas ettiğinde, su tabakalar arası boşluğa girer ve kil şişer (gevşek O-O köprüsü)
- Yüksek plastiklik ve kohezyon
- Montmorillonit; su ve iyon adsorbsiyonu için büyük yüzey alanına sahip.
- Bu nedenle çok yüksek katyon değiştirme kapasitesi (80-120 me/100 g).

Montmorillonit

- Yüksek derecede tepkisel (şişebilen) bir kil mineralidir
- $(OH)_4Al_4Si_8O_{20}.nH_2O$

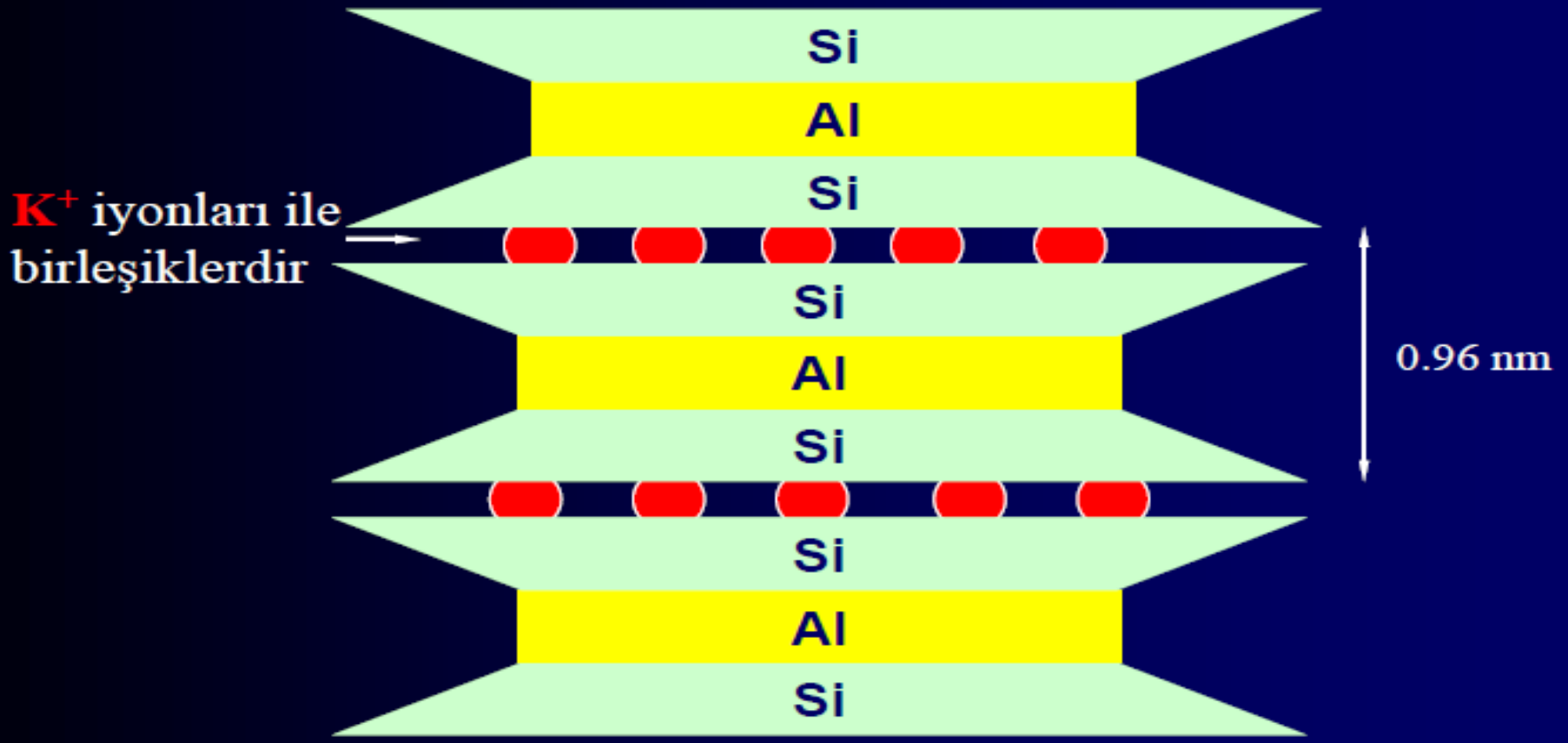
Su ile temasta şişer-genişler

aşırı su çekim eğilimi

Bentonit

- montmorillonit ailesi
- sızıntıları önlemek için, delgi çamuru olarak veya hendek duvar sıvalarında başarıyla kullanılırlar

İllit

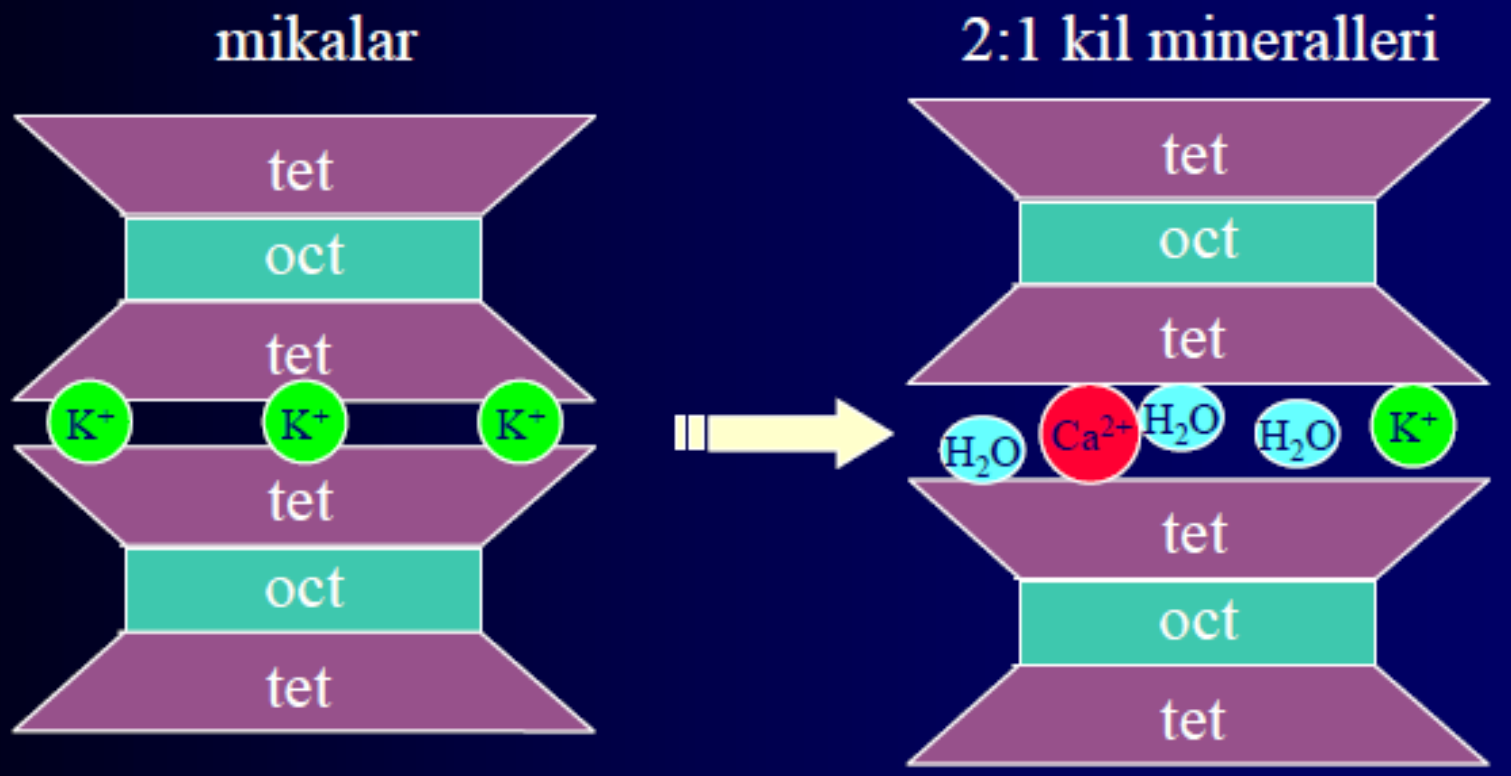


K^+ iyonları büyğklüğü Si-tetra-eder levhalarındaki hekzagonal boşlulara tamamiyle uygundur

İLLİT (genişlemeyen)

- **İllit** minerallerinin yapı özellikleri genellikle mika minerallerinin yapısına benzer.
- Bu yapılar, smektit grubunda olduğu gibi iki silis tetrahedra tabakası arasında yer alan Aluminyum oktahedraları şeklindedir (2:1).
- Potasyum iyonlarının birim tabakaları arasında köprü vazifesi görmesi ve bunları bağlamalarından dolayı genişlemezler.
- **Kristal üniteleri arasına K katyonu** yerleşebilir
- Muskovit ve Biotitten oluşur

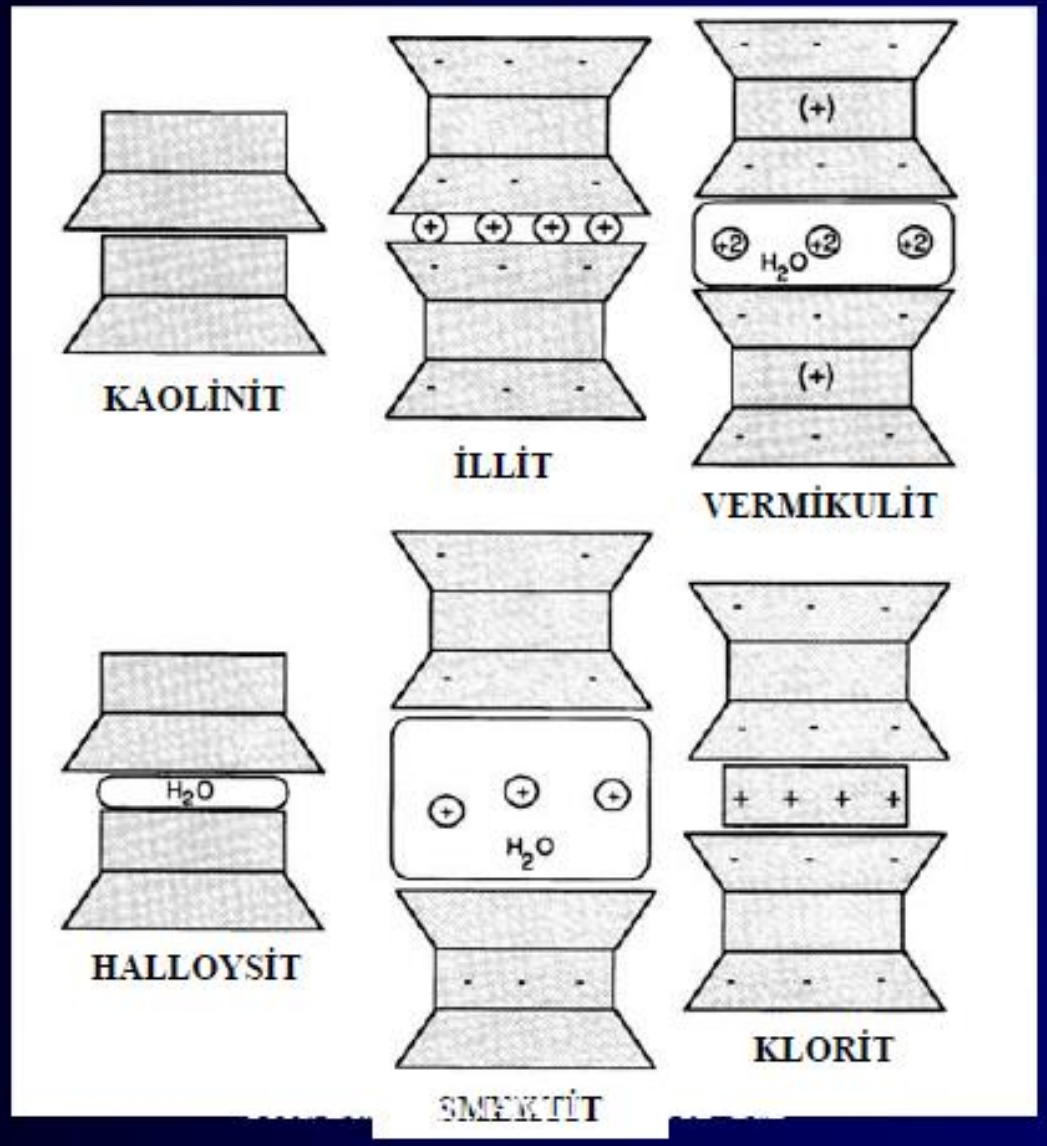
İnce-tabakalı silikatlar: yüklü 2:1 levhaları



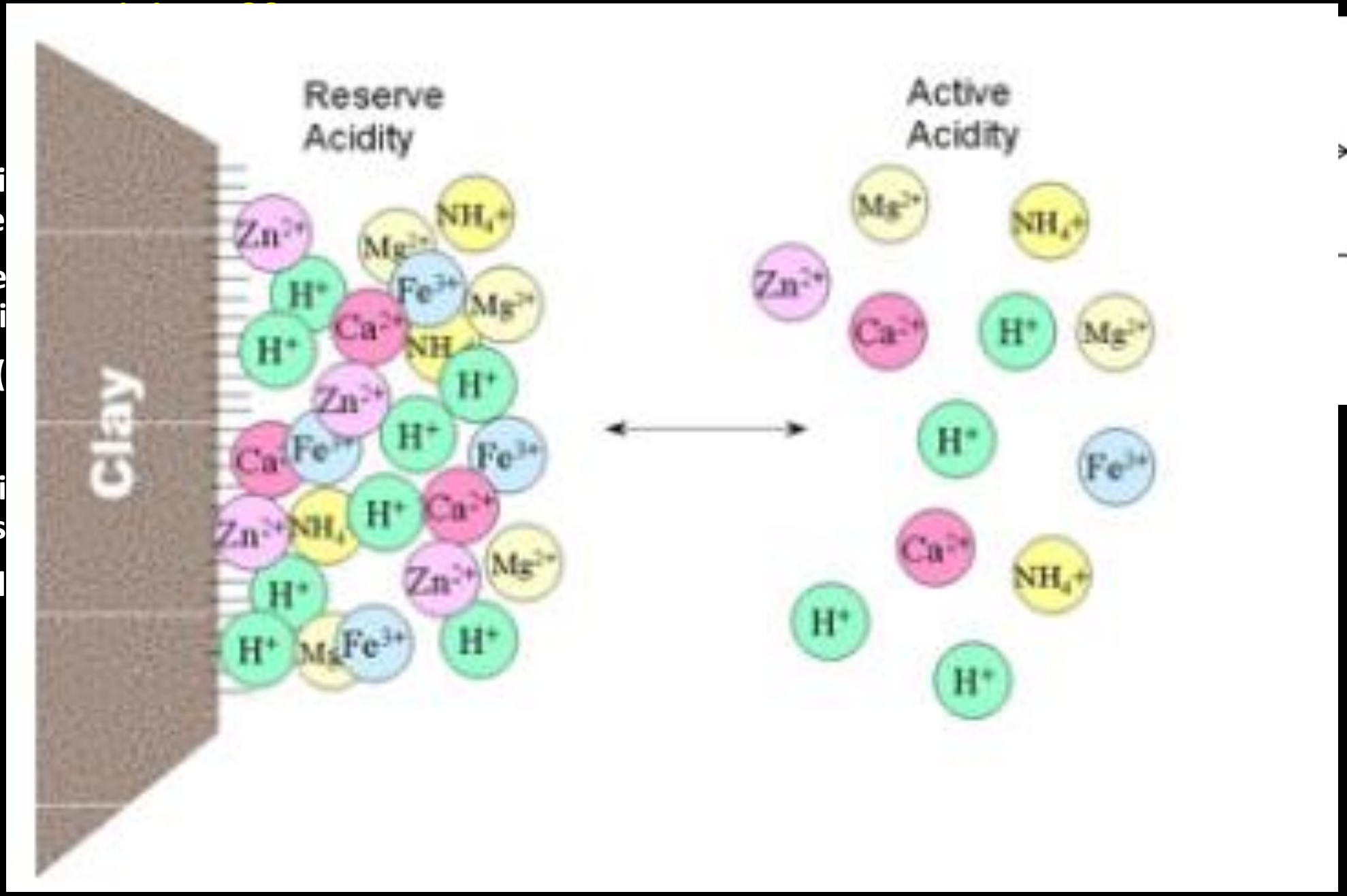
Her bir formül biriminde
1 birim (-) levha yükü

Her bir formül biriminde
< 1 birim (-) levha yükü

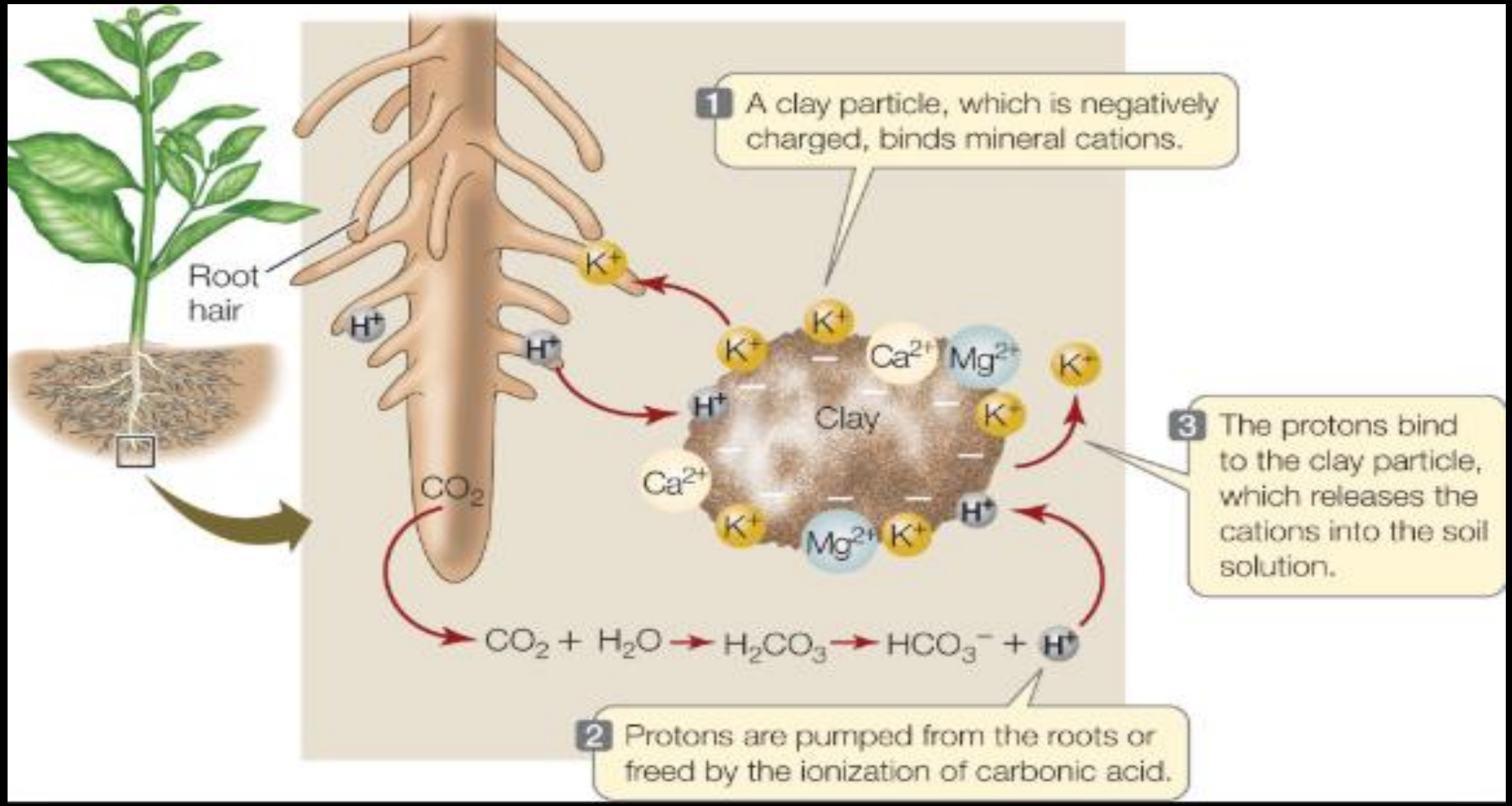
Özet



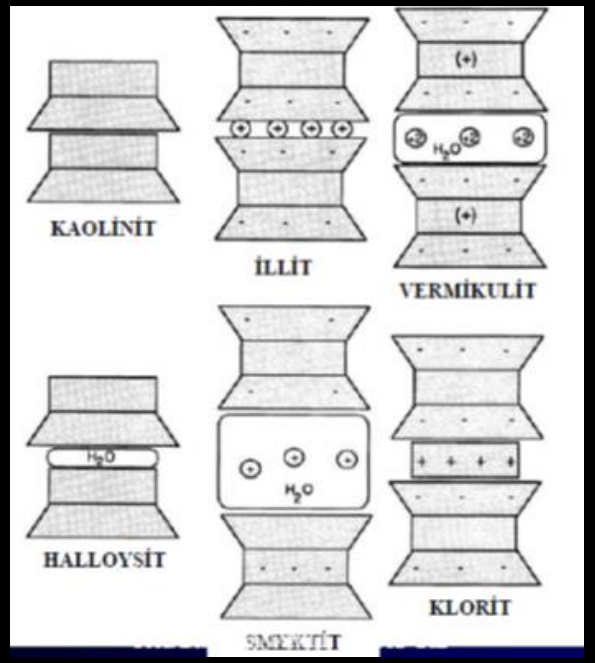
- Changes i
therefore
- Soil there
base addi
(
- Such abili
mechanis
- Soil probl



Ion Exchange in Soil



Cation Exchange Capacity (CEC)



- Ability of soil to hold cations (positively charged ions i.e. Ca-Mg-Na-K)
- Amount of total cations that can be retained on 100 g of soil
- it is greatly related to three factors : ???

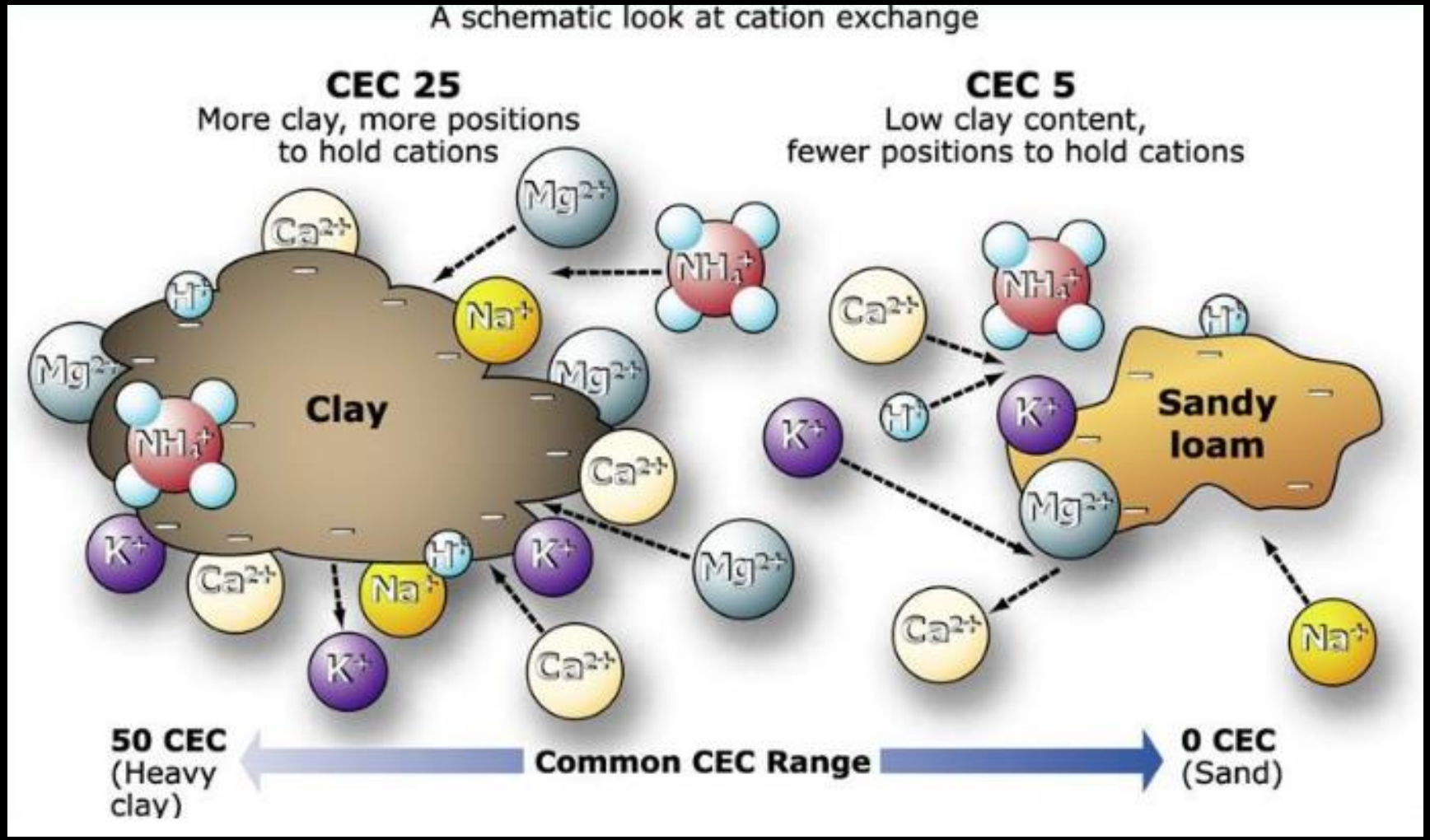
i) Soil particle type (inorganic vs. organic matter)

ii) Soil particle size (i.e. sand vs silt vs clay)

iii) Soil pH (more acidic soils tend to have lower CEC, while neutral soils have higher CECs

the typical range of CEC values for various soil types under neutral pH

Soil & Soil Components	CEC value (meq/100g)
Soil Texture	
Pure Sand	1-5
Fine Sandy Loam	5-10
Loam	5-15
Clay Loam	15-30
Organic Rich Soils	50-100
Pure Organic Matter	200-400
Clay Type	
Kaolinite	3-15
Illite	15-40
Montmorillonite	80-100


A schematic look at cation exchange
CEC 25
More clay, more positions to hold cations
CEC 5
Low clay content, fewer positions to hold cations
Clay
Sandy loam
50 CEC (Heavy clay)
Common CEC Range
0 CEC (Sand)

Soil Electrical Conductivity

- Soil electrical conductivity (EC) is a measure of the amount of salts in soil (salinity of soil).
- It affects crop yields, crop suitability, plant nutrient availability, and activity of soil microbes, which influence key soil processes including the emission of greenhouse gases
- EC does not provide a direct measurement of specific ions or salt compounds, (correlated to concentrations of nitrates, potassium, sodium, chloride, sulfate, and ammonia)
- Soil EC is affected by cropping, irrigation, land use, and application of fertilizer, manure, and compost.
- Irrigation water salinity must also be measured when managing for salinity on irrigated land.
- Irrigating in amounts too low to leach salts, or with water high in salts, allows salts to accumulate in the root zone, increasing EC.

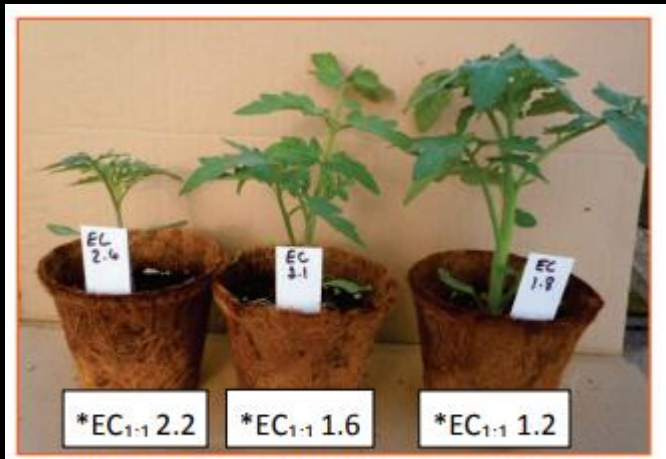


Figure 1. EC1:1 values using compost and tap water for tomatoes (Gage, 2012).

Simple evaluation of soil salinity and alkalinity

	EC (dSm^{-1})	Excheangable Na (%)	pH
Saline soil	**>4**	**<15**	**<8,5**
Alkaline soil	**<4**	**>15**	**>8,5**
Saline-alkaline soil	**>4**	**>15**	**~8,5**