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Midwest Soil Improvement Symposium: 2013

Research and Practical Insights into Using Gypsum

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The Effect of Calcium on Soil Physical Properties and Air-Water Management

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Air-water balance is the single most important factor limiting agricultural production in the U.S.

According to a study by Mittler (2006), the top two causes of economic loss to U.S. agriculture between 1980 and 2004 (major events of $1B loss or more) were:

1. Combined heat and drought stress ($130B)

2. Flooding and water-logging ($50B)

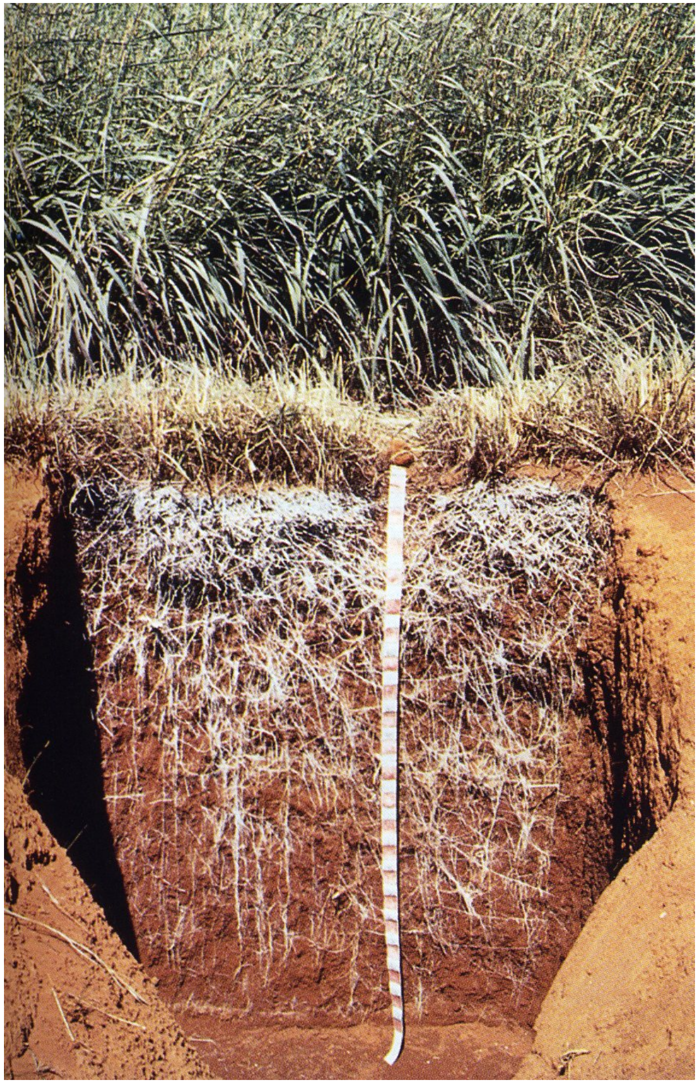


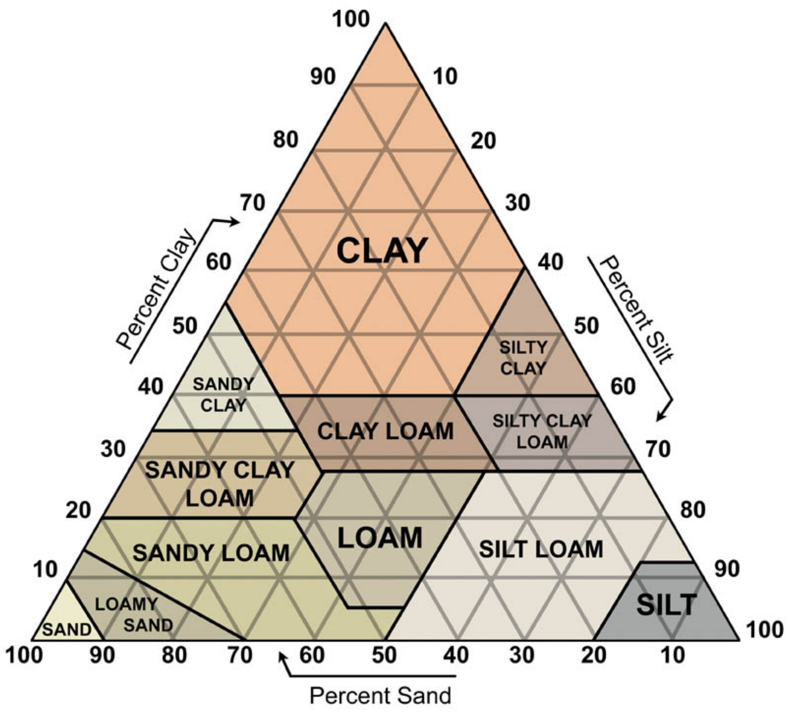
Photo courtesy of S.W. Buol

The ultimate goal of air & water management is to create an environment where the plant root system can reach its full genetic potential for respiration, nutrient uptake, and water transmission. Usually, this means exploiting the largest possible soil volume.

Soil Physical Properties

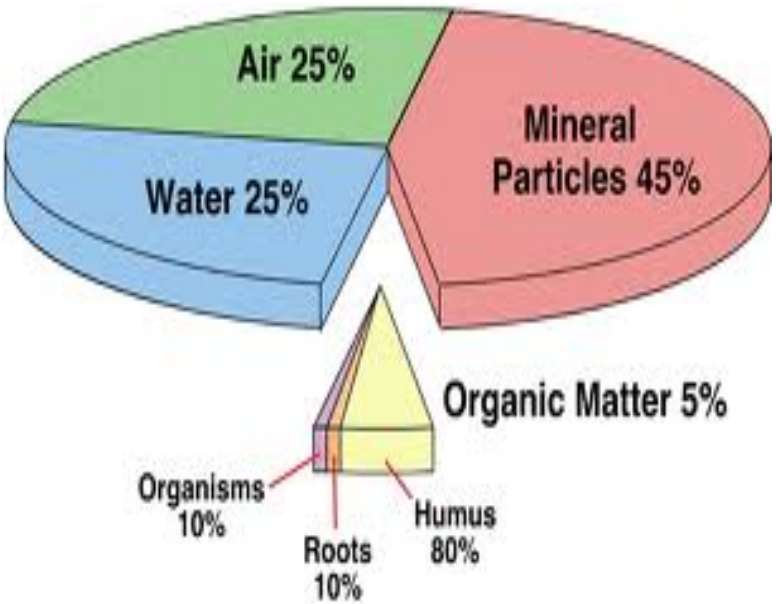
Some are invariant

- Particle Size Distribution (Texture)
- Mineralogy



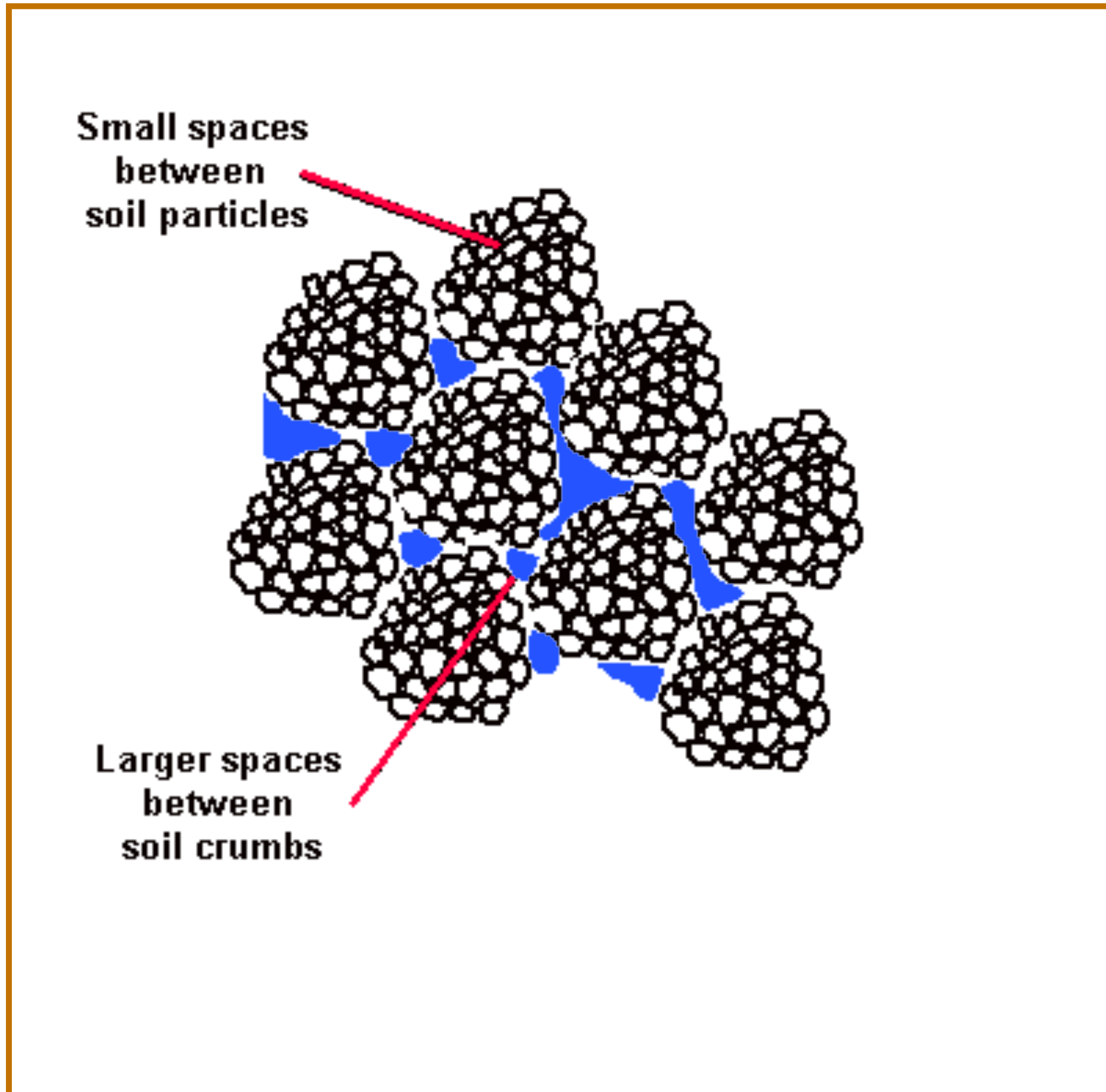
Others are sensitive to mgt.

- Structure (Type, Size, Stability)
- Porosity (Amount, Size, Continuity)



Several dynamic soil properties are impacted by the creation of water stable aggregates

- Infiltration
- Percolation (K_{sat})
- Available water
- Gas exchange



Aggregation and soil structure are enhanced by:

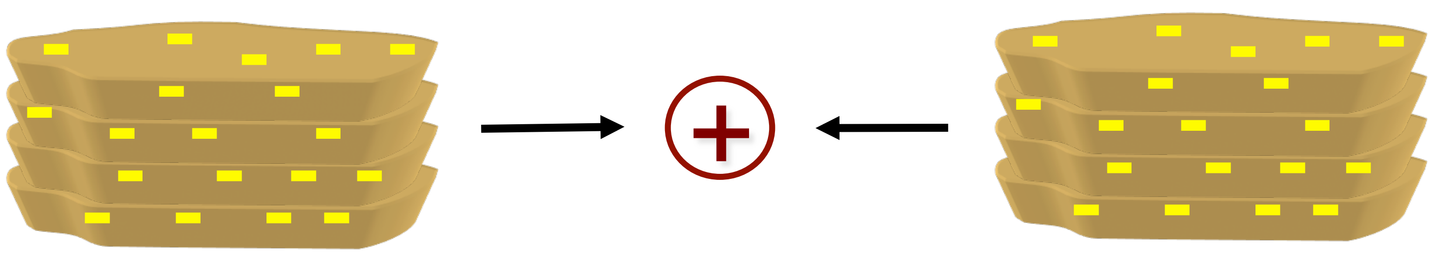
- root & faunal activity
- soil organic matter
- microbial exudates
- soluble calcium ions

structureless

strong, granular structure

Calcium (Ca^{2+}) stabilizes decayed soil organic matter (humus) and is one of several cations (positively charged ions or molecules) that may occupy sites on the soil CEC. Others include ammonium (NH_4^+) sodium (Na^+), potassium (K^+), magnesium (Mg^{2+}), and aluminum (Al^{3+}).

These cations influence the tendency of soil colloids (clay particles) to separate (disperse) or aggregate (flocculate).



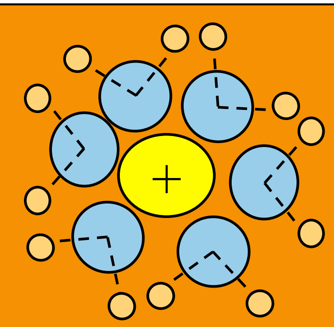
Negatively charged clay particle

Negatively charged clay particle

Graphic from J. Walworth (2006)

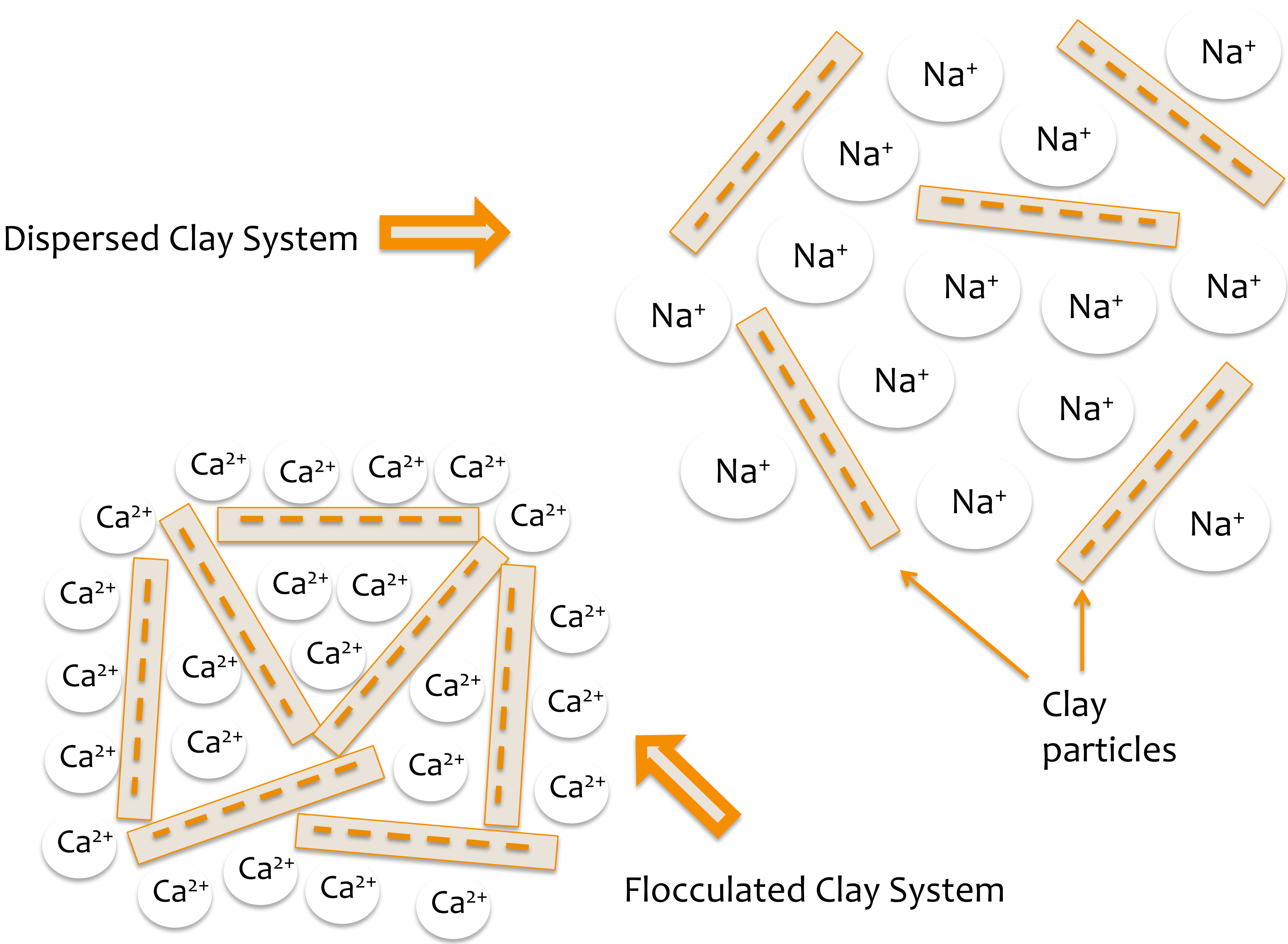
The tendency of a cation to serve as a dispersant or flocculant depends mostly on its charge and hydrated radius within the soil system.

Hydrated cation

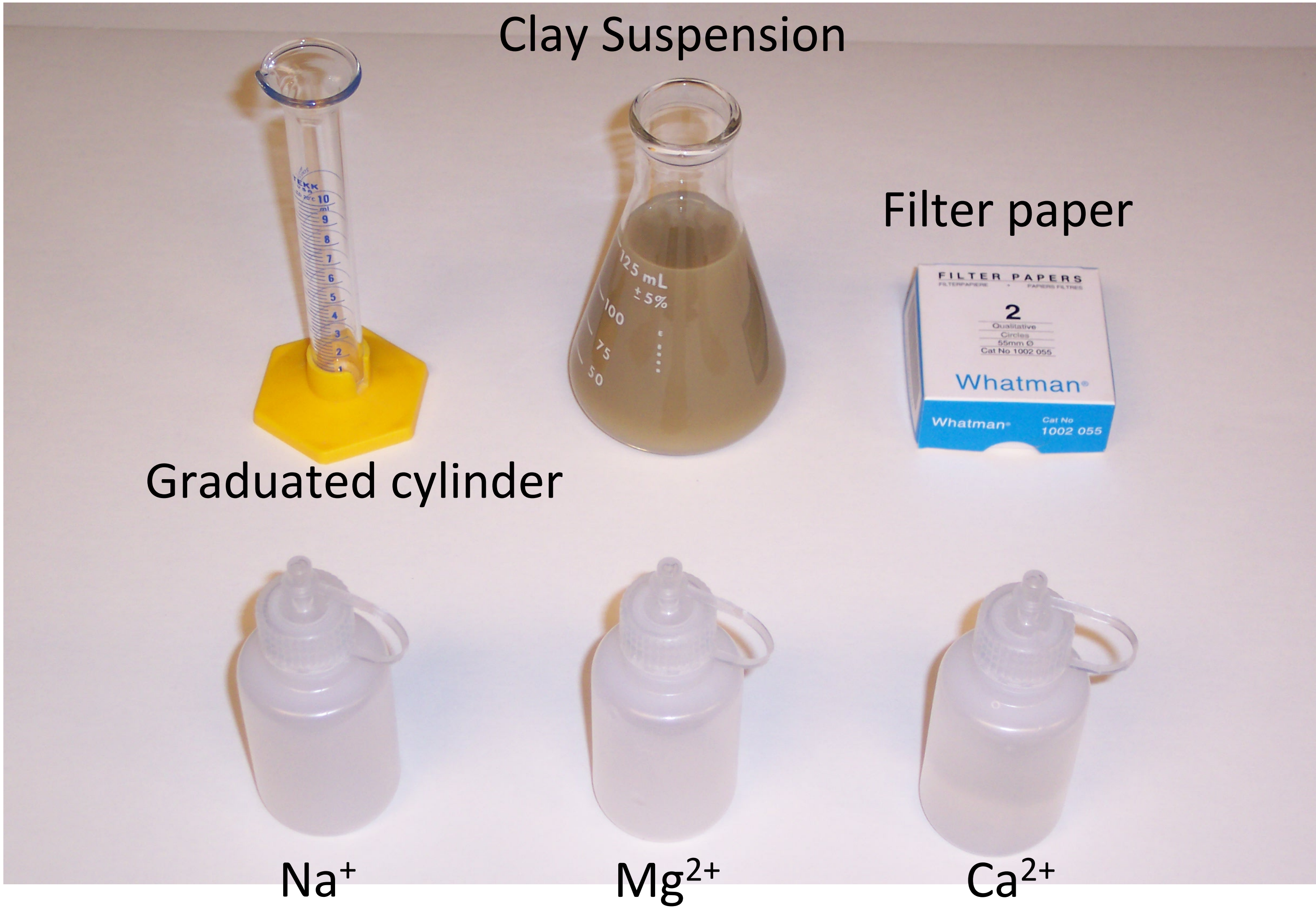


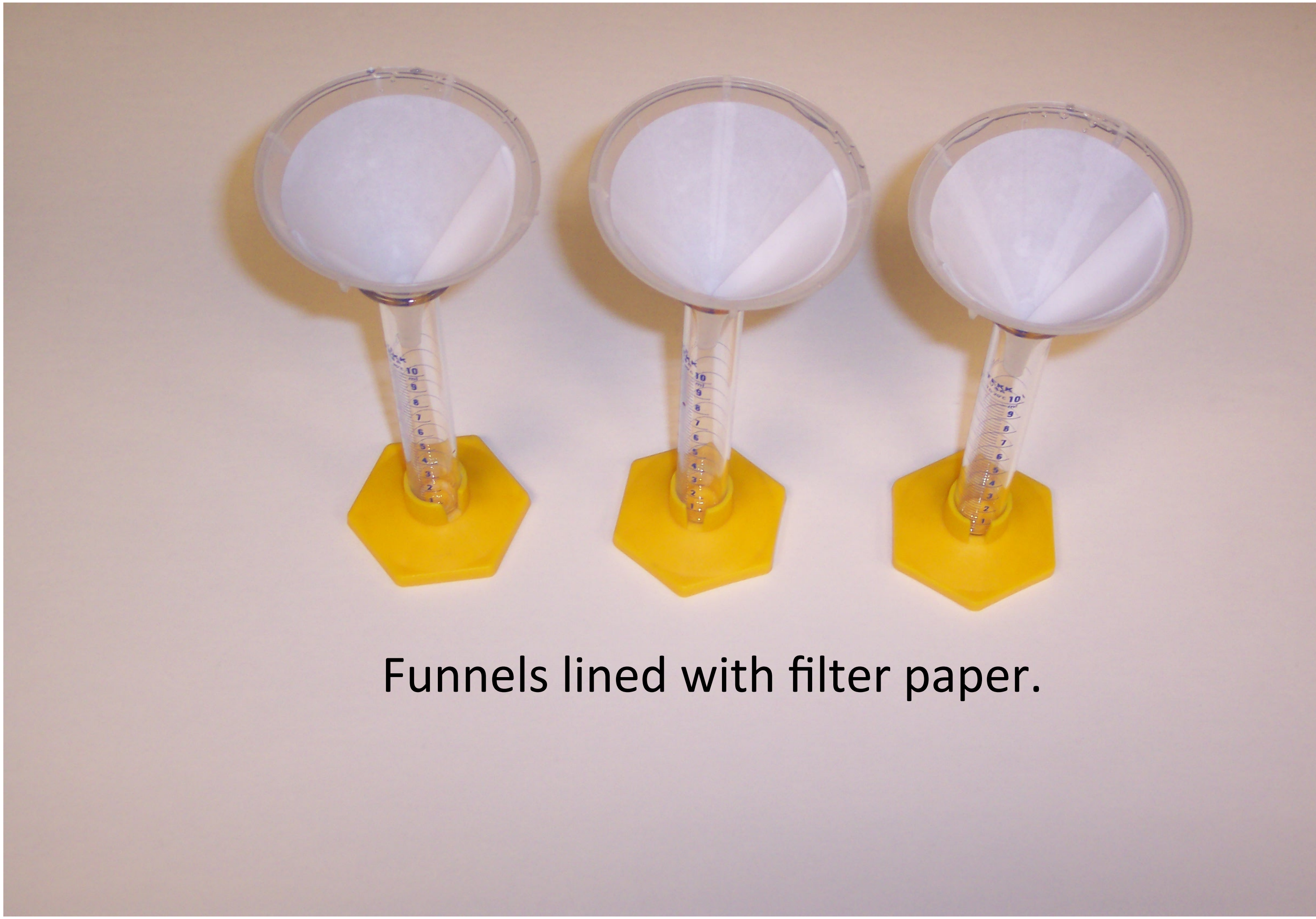
Cation	Charge per ion	Hydrated radius per unit charge* (Å)	Relative flocculating power**
Sodium (Na)	1	3.6	1.0
Potassium (K)	1	3.3	1.7
Magnesium (Mg)	2	2.2	27.0
Calcium (Ca	2	2.0	43.0

*Conway (1981)
** Rengasamy & Sumner (1998)


Dispersed Clay System
Na+
Clay particles
Ca2+
Flocculated Clay System

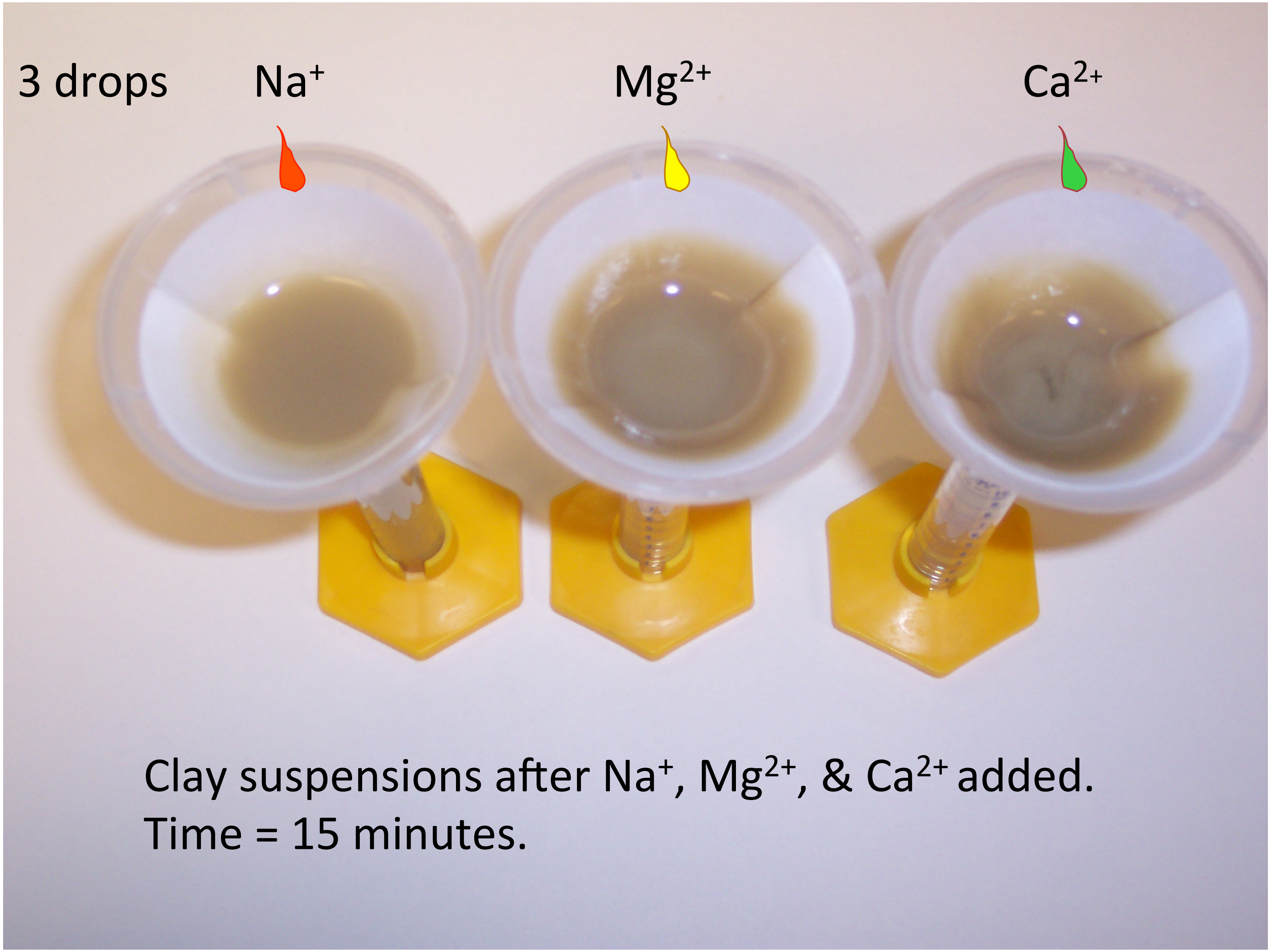
Flocculation/Dispersion Demonstration



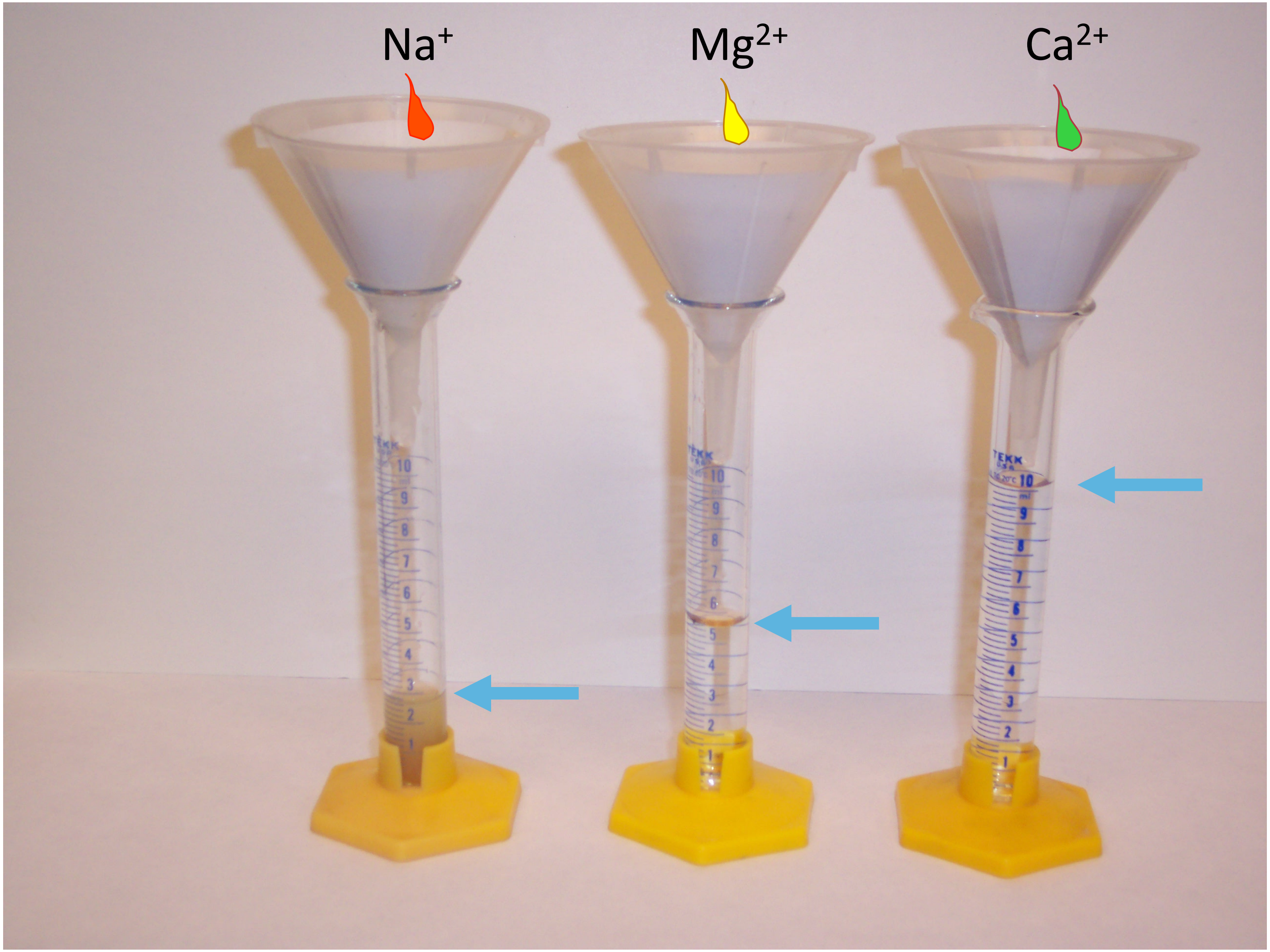


Funnels lined with filter paper.

Clay suspension added to funnels.
Time = 0 minutes.

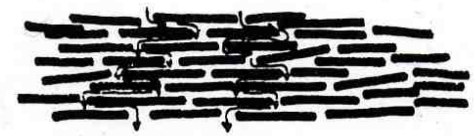


Clay suspensions after Na^{+}, Mg^{2+}, & Ca^{2+} added.
Time = 15 minutes.

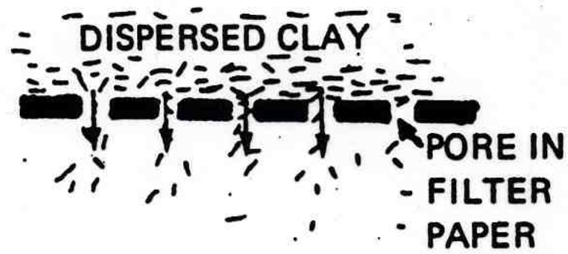


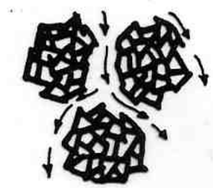
Filtrates after Na^+, Mg^{2+}, and Ca^{2+} added. Time = 15 minutes.

What is happening?

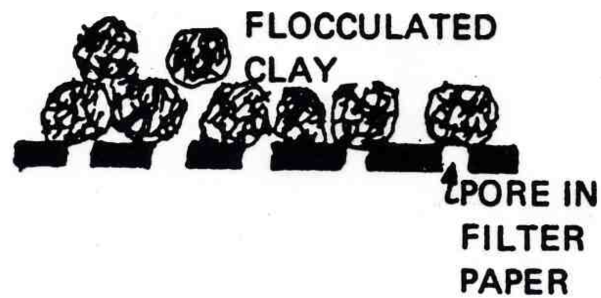


Na^{+}



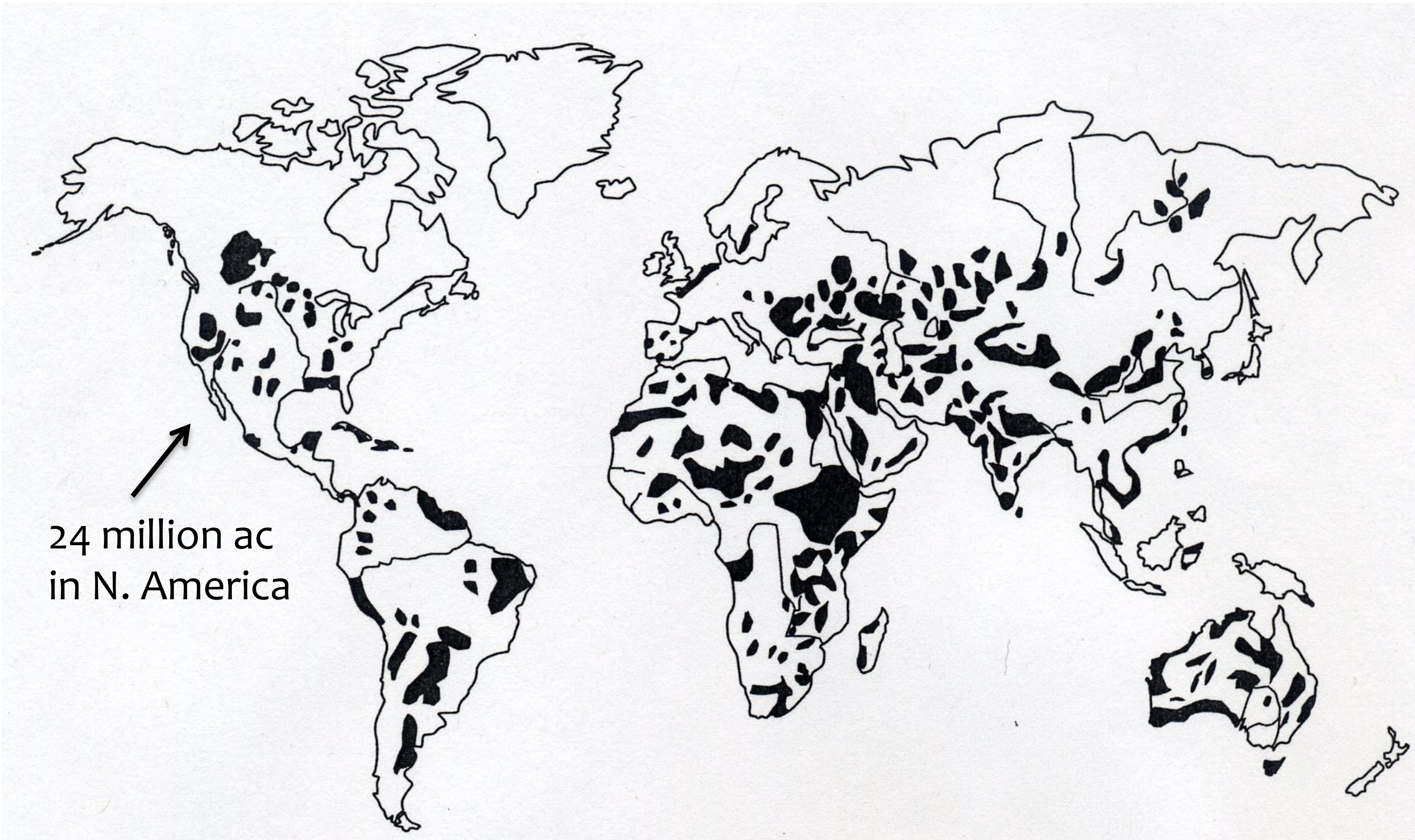


Ca^{2+}



Global Distribution of Na-affected Soils

(from Sparks, Environmental Soil Chemistry, 2nd Ed (2003)



24 million ac
in N. America

Sodic (sodium affected) soils: have exchangeable Na $\geq$ 15 % of the CEC, *and* exchangeable Na + Mg exceeds exchangeable Ca (USDA Hndbk 436, 1st ed, 1976).

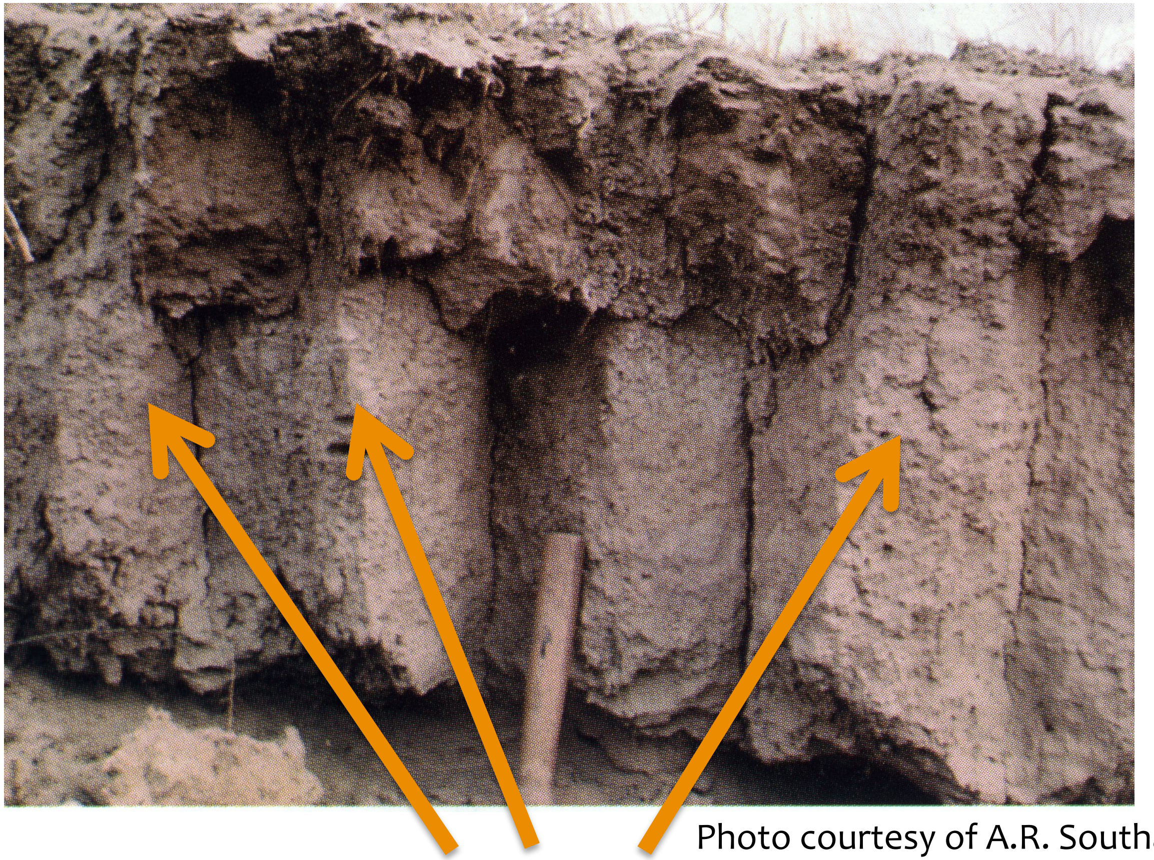


Photo courtesy of A.R. Southard

Note the large, internally massive prisms occurring in the subsoil.

Deep tillage in southern CA to improve permeability of a sodic (high sodium) soil.

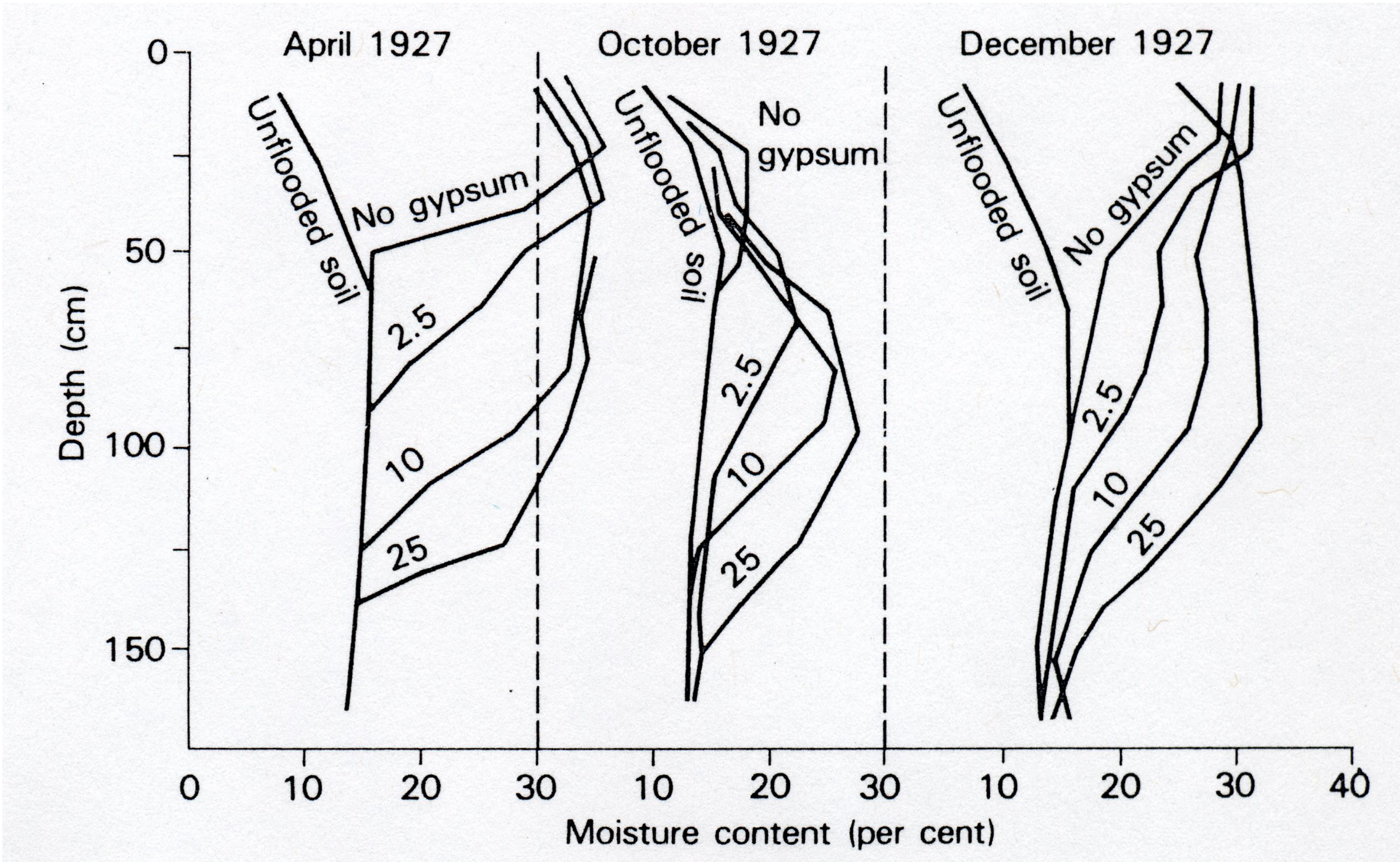
Photos courtesy of Blake Sanden

Gypsum as a Soil "Conditioner"

Gypsum has been used for many years to improve aggregation (structure) and inhibit or overcome dispersion in sodic (high sodium) soils. Soil dispersion contributes to:

- **surface sealing/crusting**
- **problems with seedling emergence**
- **runoff/erosion**
- **subsoil swelling with decreased water and root penetration**
- **poor air exchange**

Reclamation of an impermeable soil with 10% exchangeable Na using surface applied gypsum at rates of 2.5, 10, and 25 ton/ha

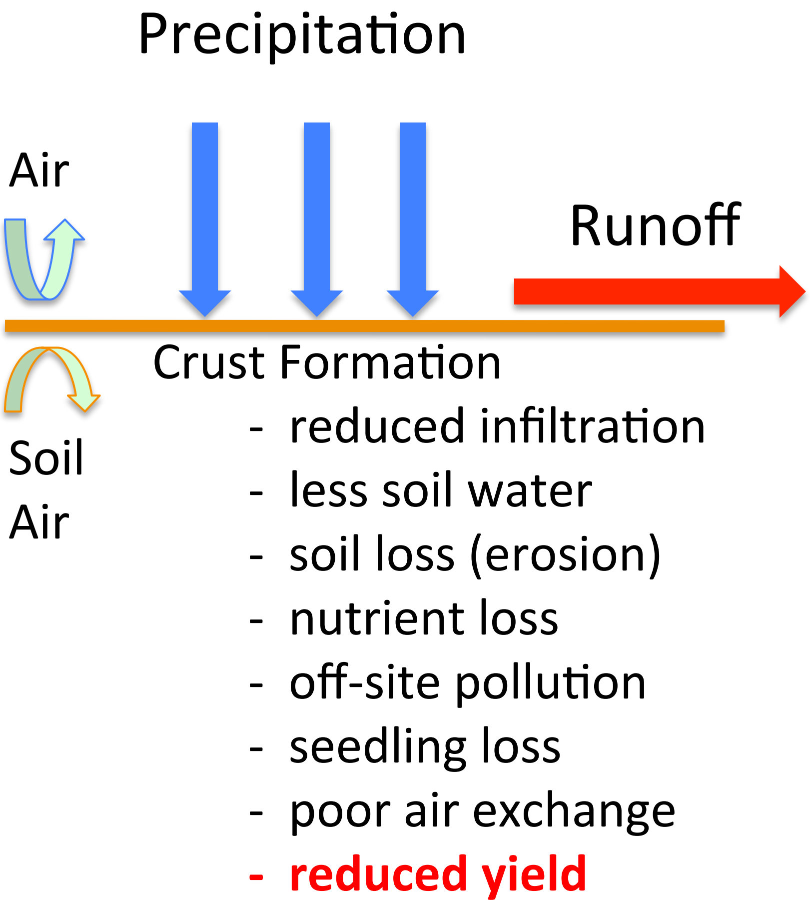


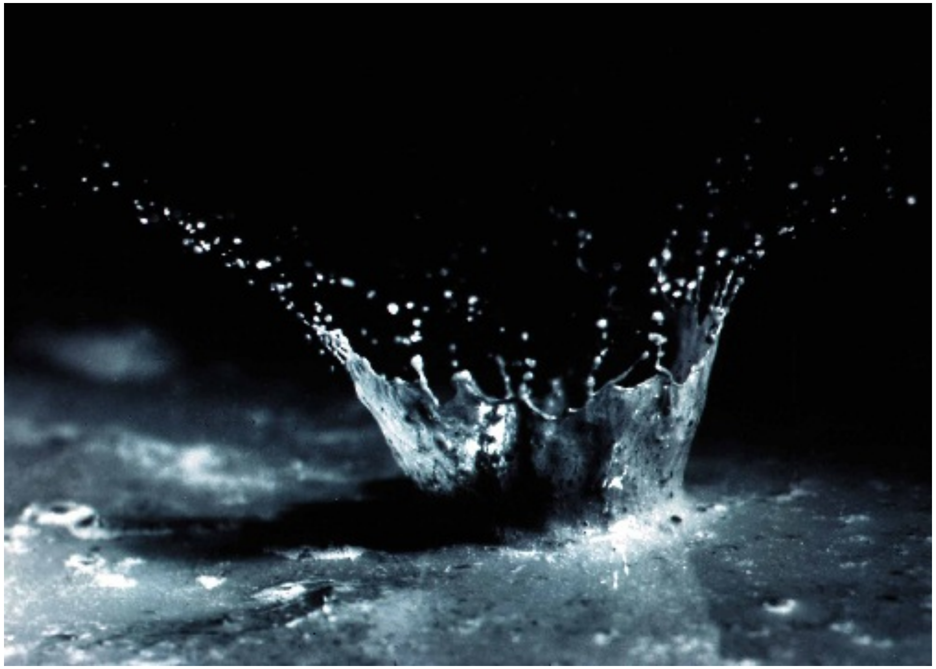
Source: Greene, H.J. J. Agric. Sci. 18:531 (1928)

What about non-sodic soils in the corn belt? Is there really a place for gypsum in a comprehensive management plan?

Clay dispersion and collapse of structure at the soil-air interface is a major contributor to surface sealing (crust formation) in both sodic and non-sodic soils.

photo courtesy of L.D. Norton



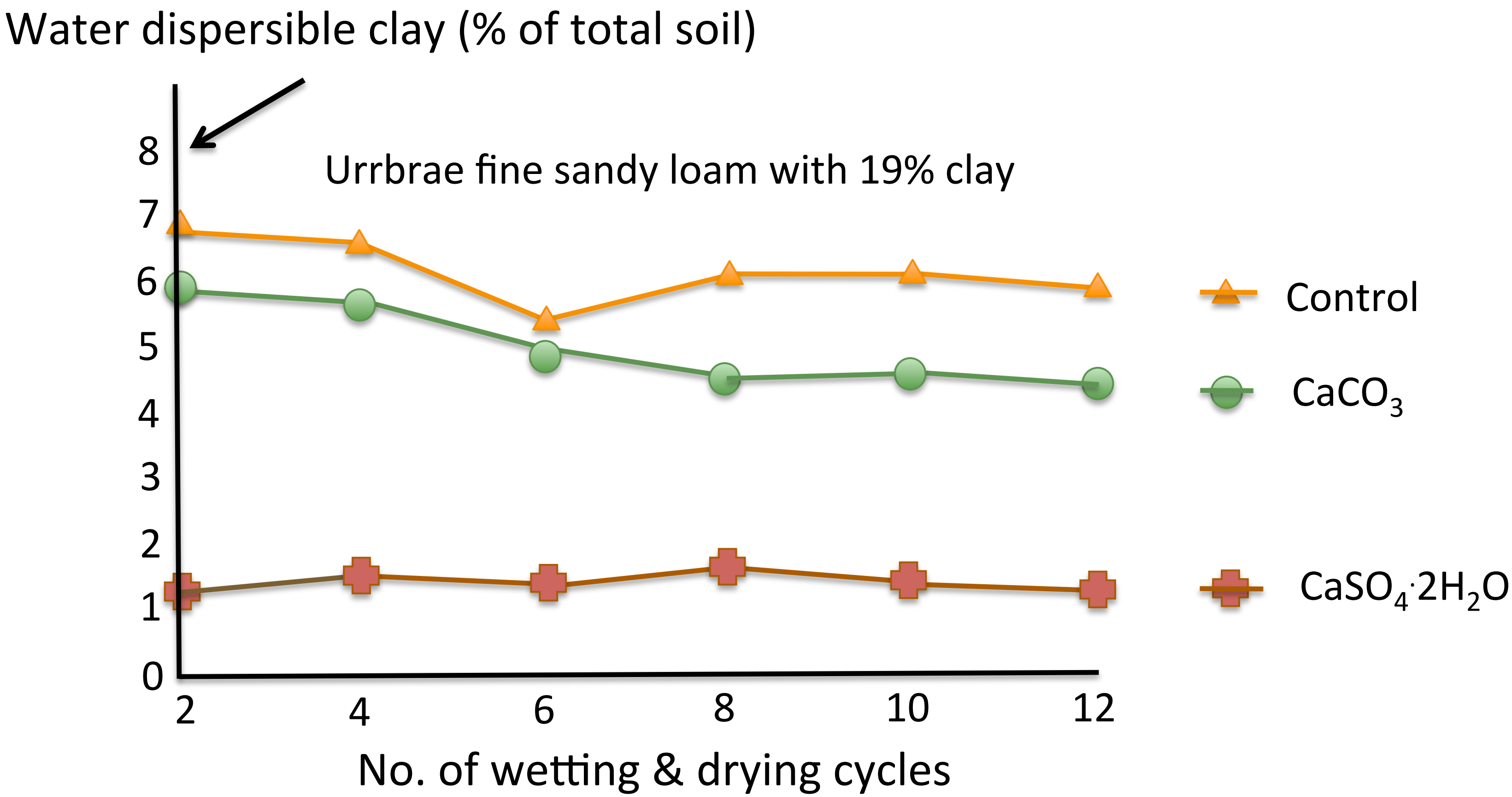


Natural rainwater is dispersive, in part, because of its low electrolyte (salt) content.

Work at the NSEL (Norton et al.) has shown that soil and chemical loss due to crusting, poor infiltration of rainfall, and runoff can be reduced by managing the calcium (Ca) status of the topsoil.

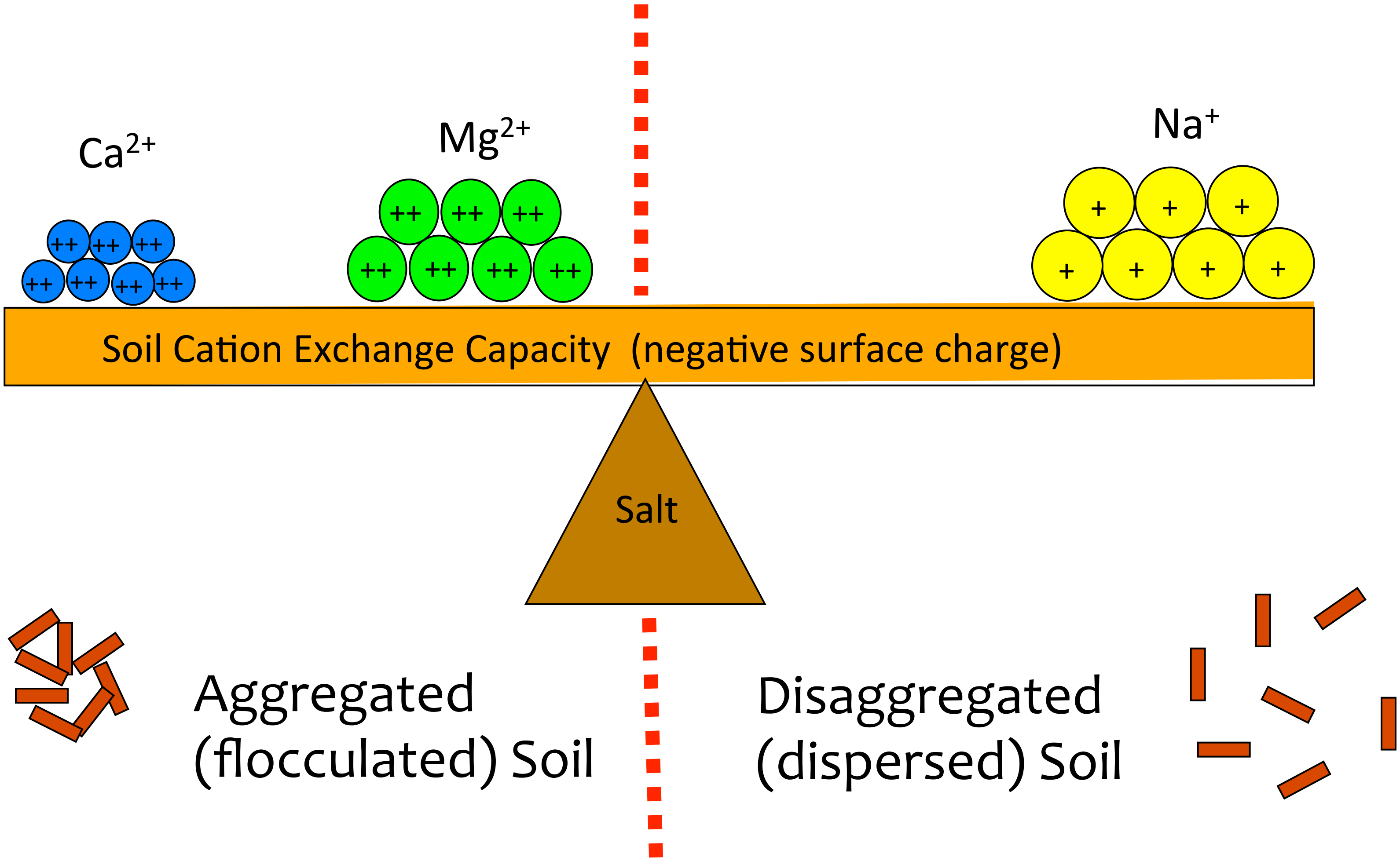
Traditional sources of Ca are:

Compound	Solubility
Limestone ($CaCO_3$)	0.014 g/L
Dolomite [$CaMg(CO_3)_2$]	0.32 g/L
Gypsum ($CaSO_4$)x2H_2O	2.41 g/L

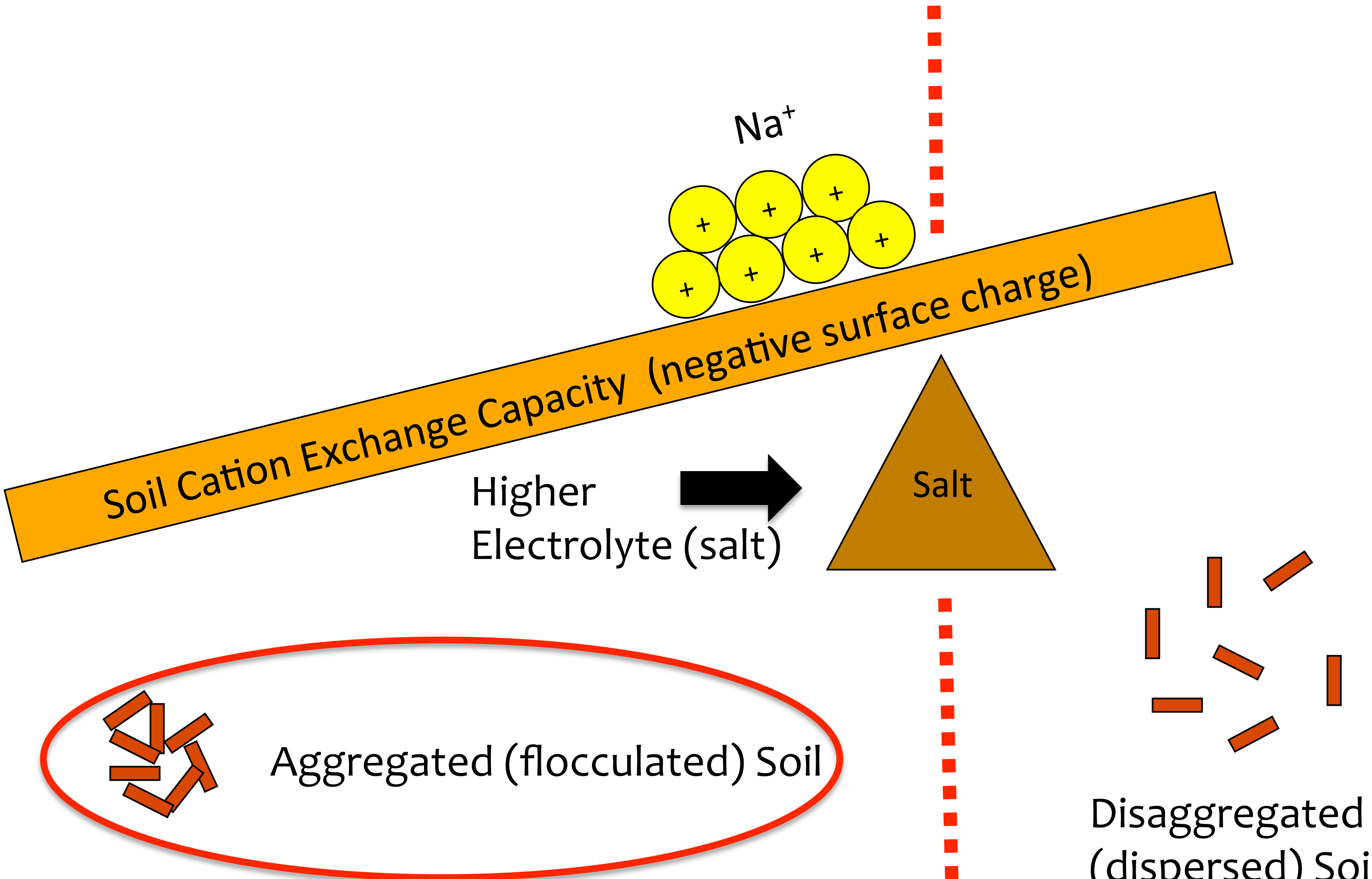


Modified from: Muneer and Oades. 1989.
Aust. J. Soil Res. 27:389-99.

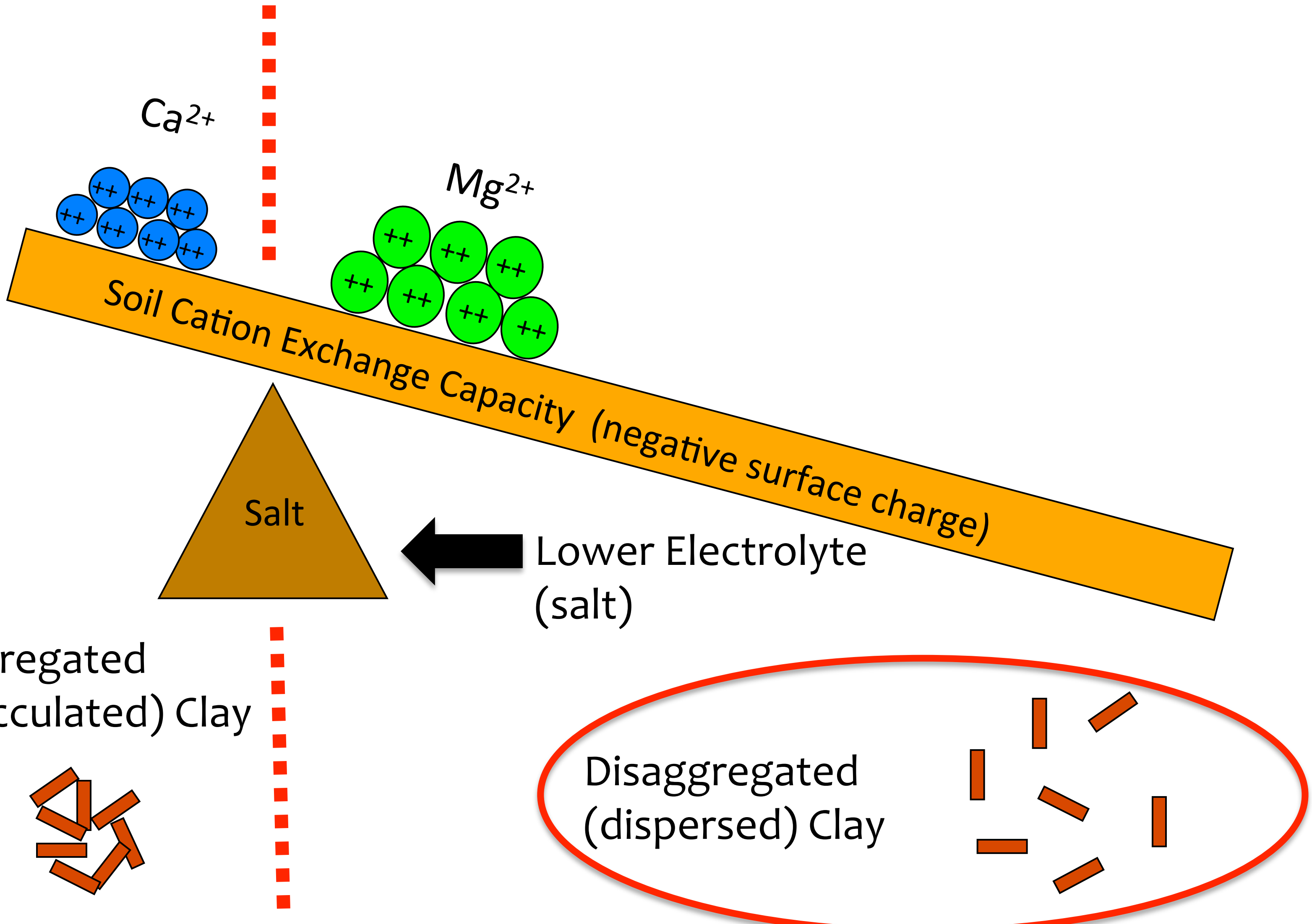
Aggregate stability largely depends on the balance between Exch. Ca^{2+}, Mg^{2+} and Na^{+} as well as the amount of total electrolyte (salt) in the soil soln. Exchangeable Ca^{2+} is a good aggregating (flocculating) agent; Na^{+} is not; **Mg^{2+} is intermediate.**



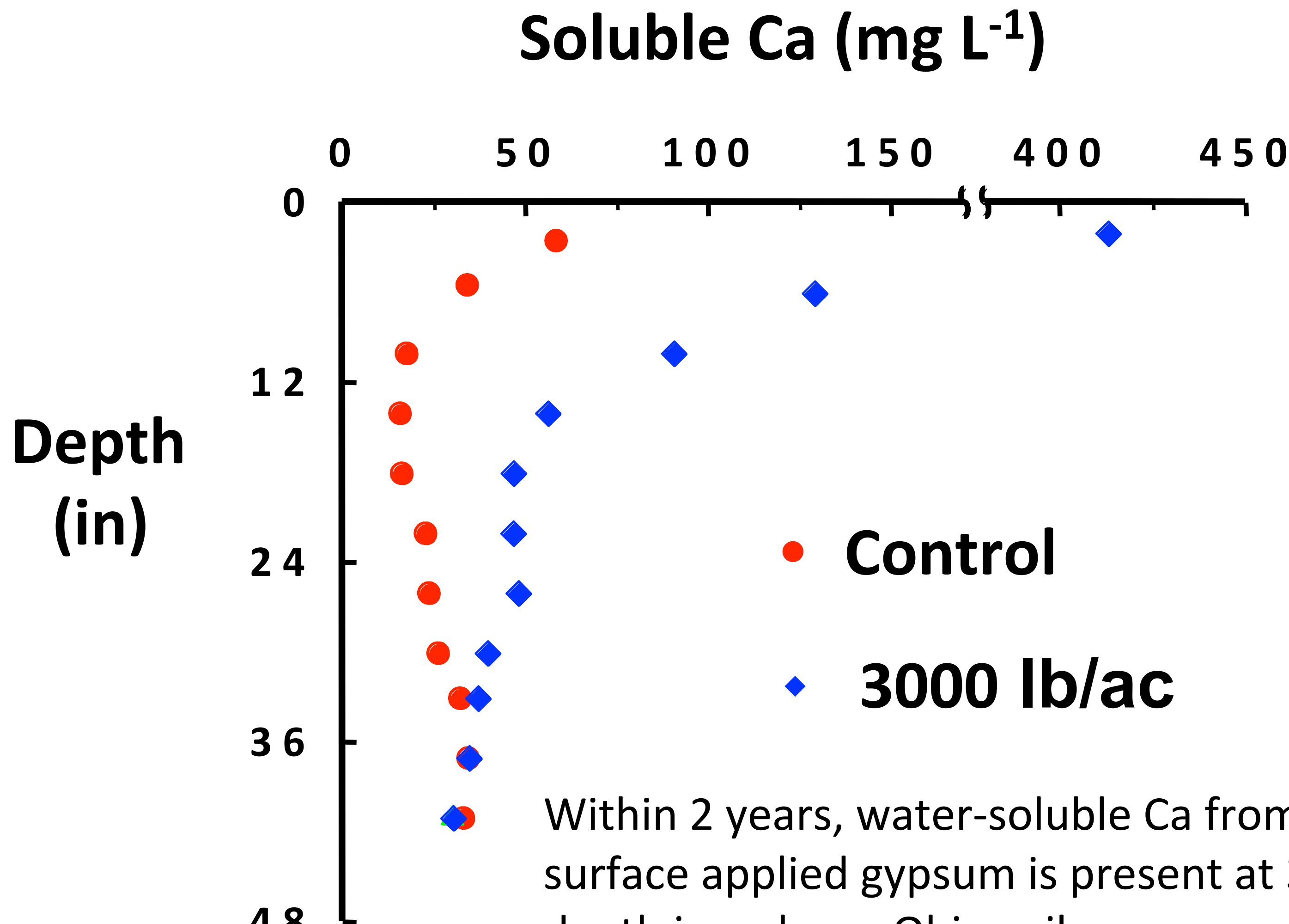
If the electrolyte (salt) content of the soil solution is increased sufficiently, the soil clay will flocculate even when Na^+ is the dominant cation on the CEC.



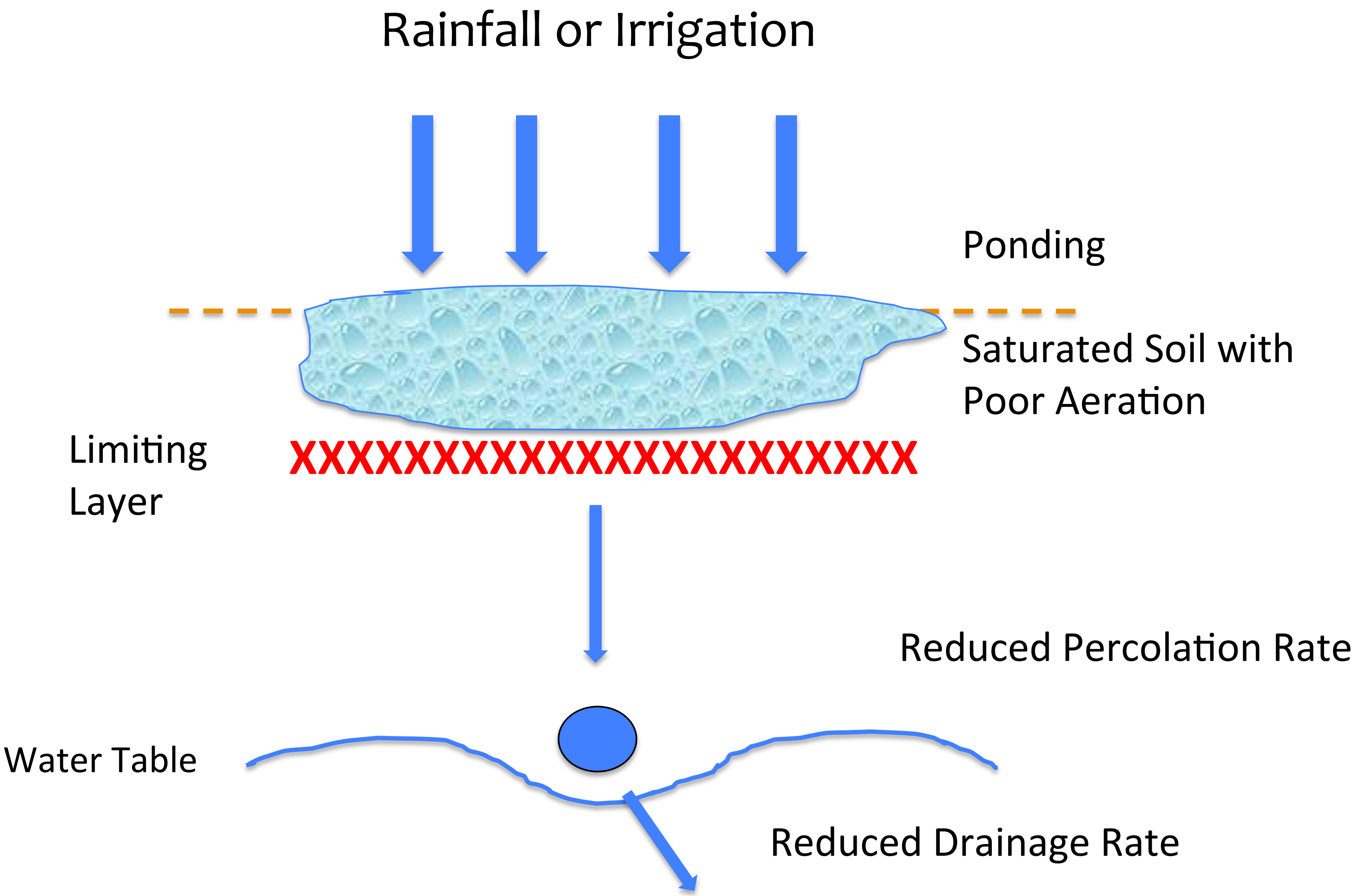
If the electrolyte (salt) content of the soil solution is decreased sufficiently, the soil clay will disperse even when Mg^{2+} (or Ca^{2+}) is the dominant cation on the CEC. The tendency is greater with Mg^{2+}.



Because of its solubility, gypsum can also have a significant, positive impact on subsoil chemistry and structure, even under rainfed agriculture.

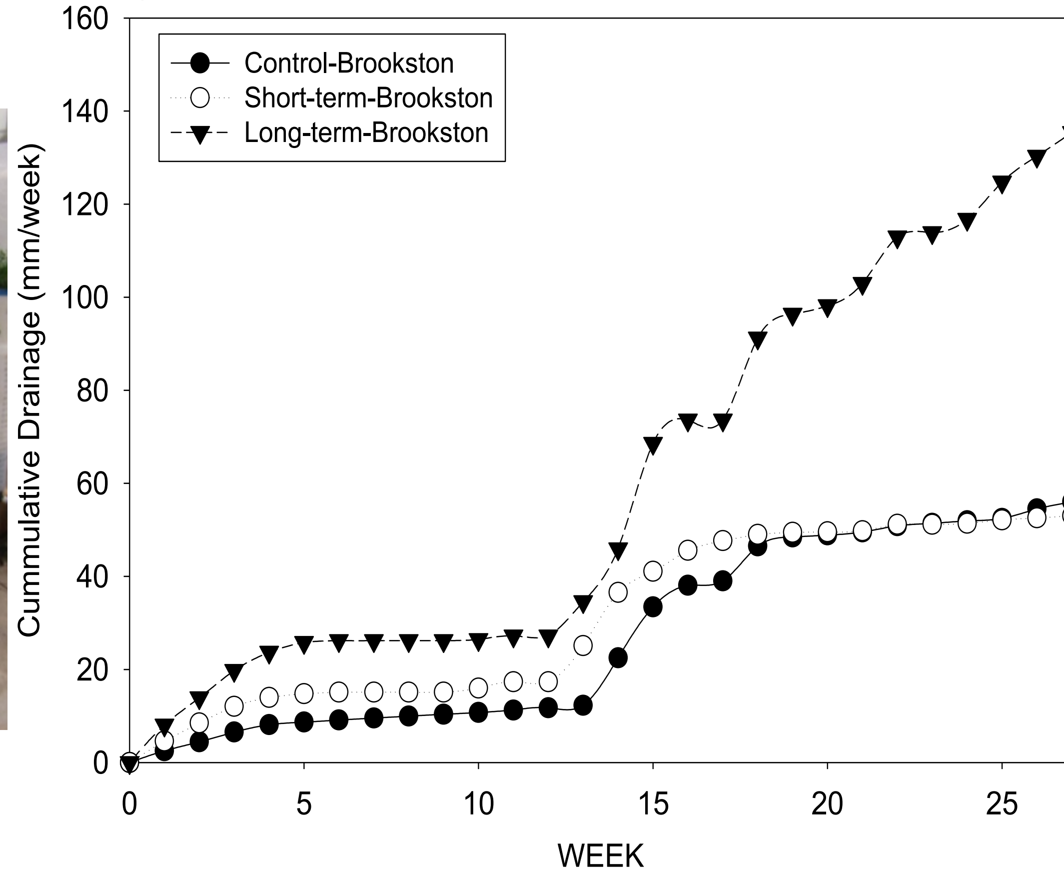


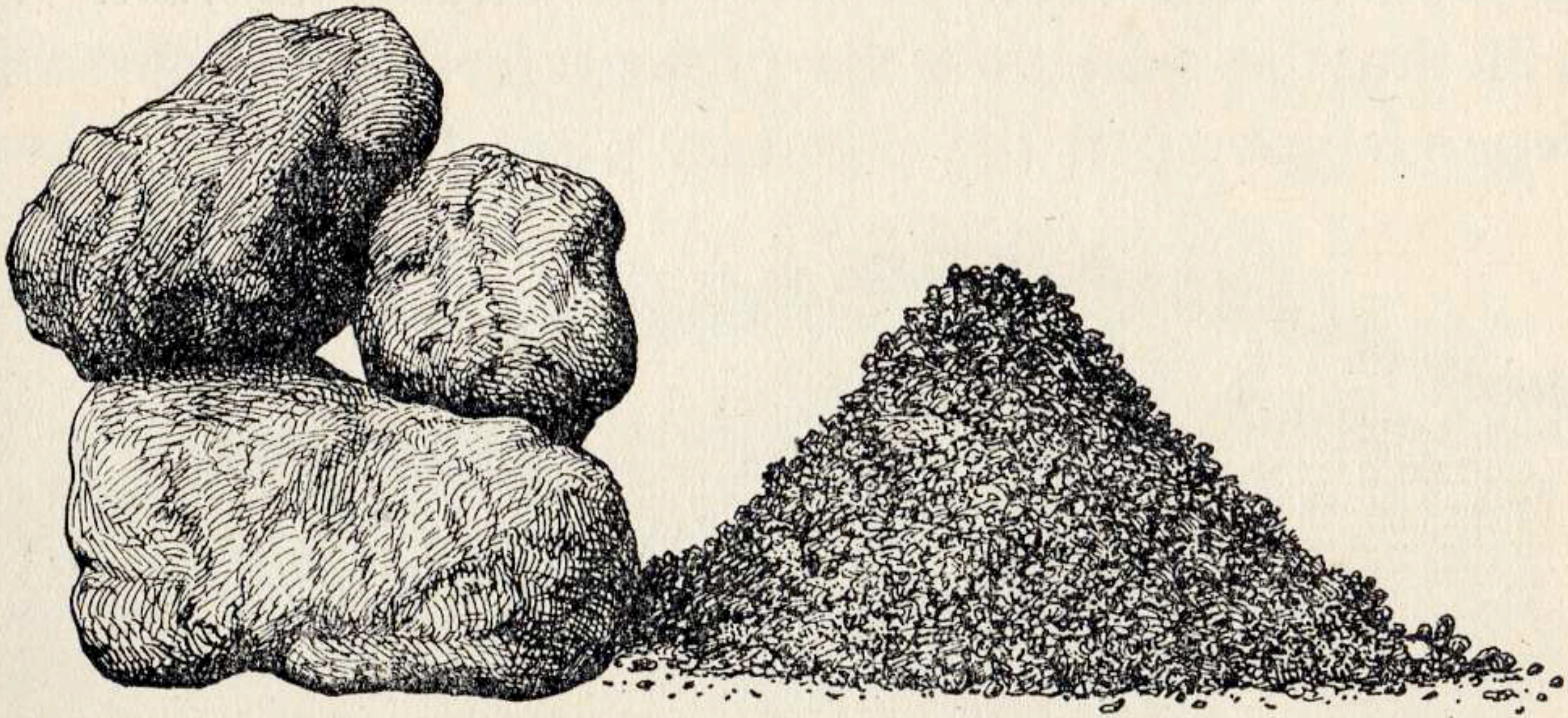
Within 2 years, water-soluble Ca from surface applied gypsum is present at 36 in depth in a clayey Ohio soil.


Rainfall or Irrigation
Ponding
Saturated Soil with
Poor Aeration
Limiting
Layer
Reduced Percolation Rate
Water Table
Reduced Drainage Rate

Cumulative drainage over a 25 week period from intact cores (30.5 x 75 cm) of a Brookston soil after 0, 4, and 12 yr of surface applied gypsum at a rate of 1,500 lb/yr (Tirado-Corbala, 2010).

Drainage (mm)





The physical condition of the soil is as important as its chemical composition. The lumpy soil contains as much plant food as the friable soil, but the plant roots cannot penetrate the hard lumps to obtain it

Alfred Vivian. 1912. "*First Principles* of Soil Fertility"