An Overview of Soil Trace Metal Chemistry

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What are Trace Metals?

- Found in low concentrations in the environment (<0.1 %).
- May be beneficial or detrimental at very low concentrations in man and animals (<1 mg/kg)
- Micronutrients (Fe, Zn, Mn, Cu)
- Heavy metals (>7 g/cm^3) (Cd, Pb, Hg, Cr, Ni)

Sources of Trace Elements

- Rocks and ores
- Primary and secondary minerals
- Atmospheric fallout
- Anthropogenic wastes
- Fertilizers.

Reactions in Soils

- Dissolution/solubilization
- Precipitation
- Hydrolysis/pH
- Exchange/adsorption
- Oxidation-reduction (redox)
- Chelation

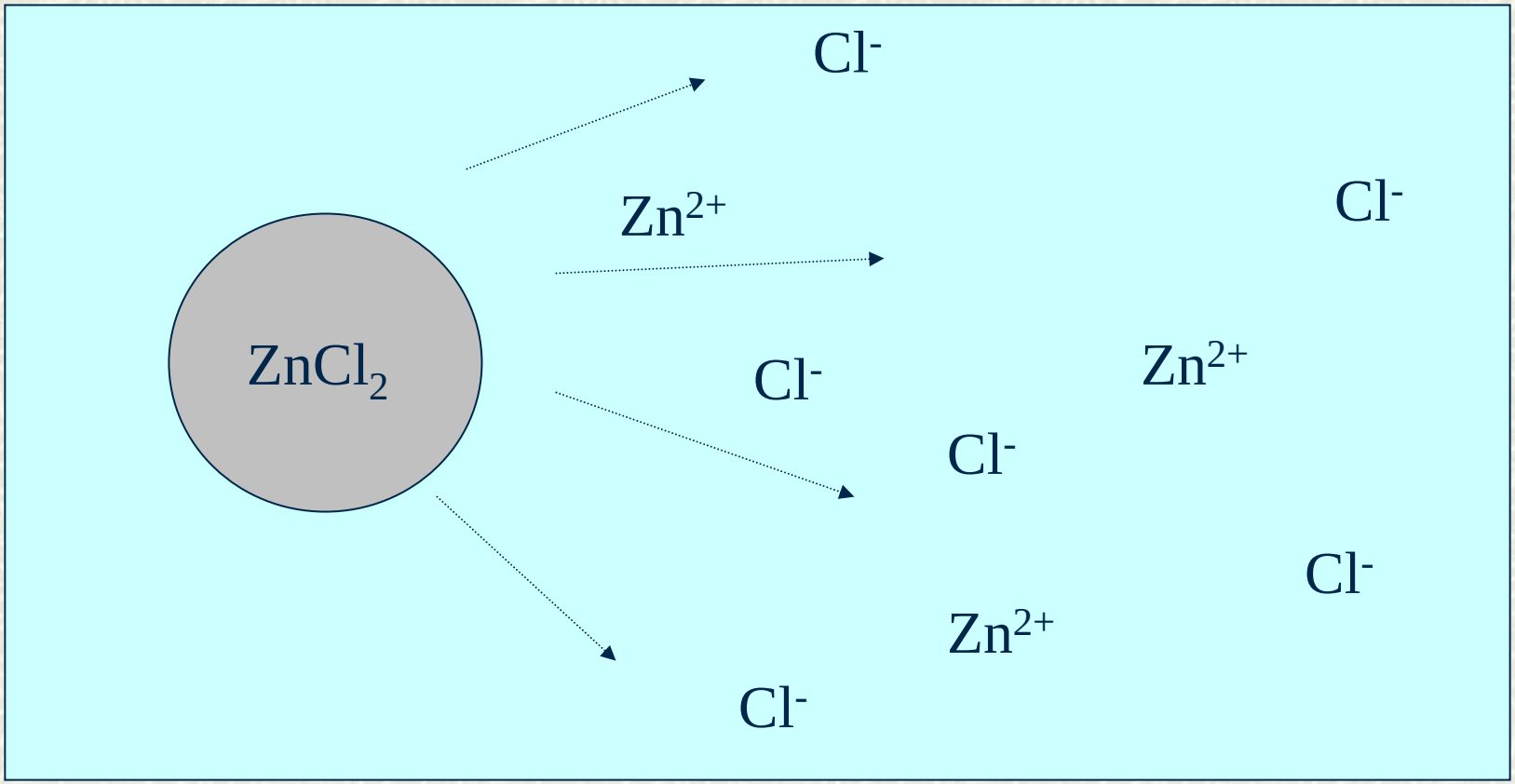
Solubility Reactions

- Reaction with the universal solvent - H_2O.
- Substance dissociates into original (ionic) components.
- Formation of ions in solution
- Ex:

$$ZnCl_2 \xrightleftharpoons{in\ H_2O} Zn^{2+} + 2Cl^-$$

$$\log K° = 7.07$$

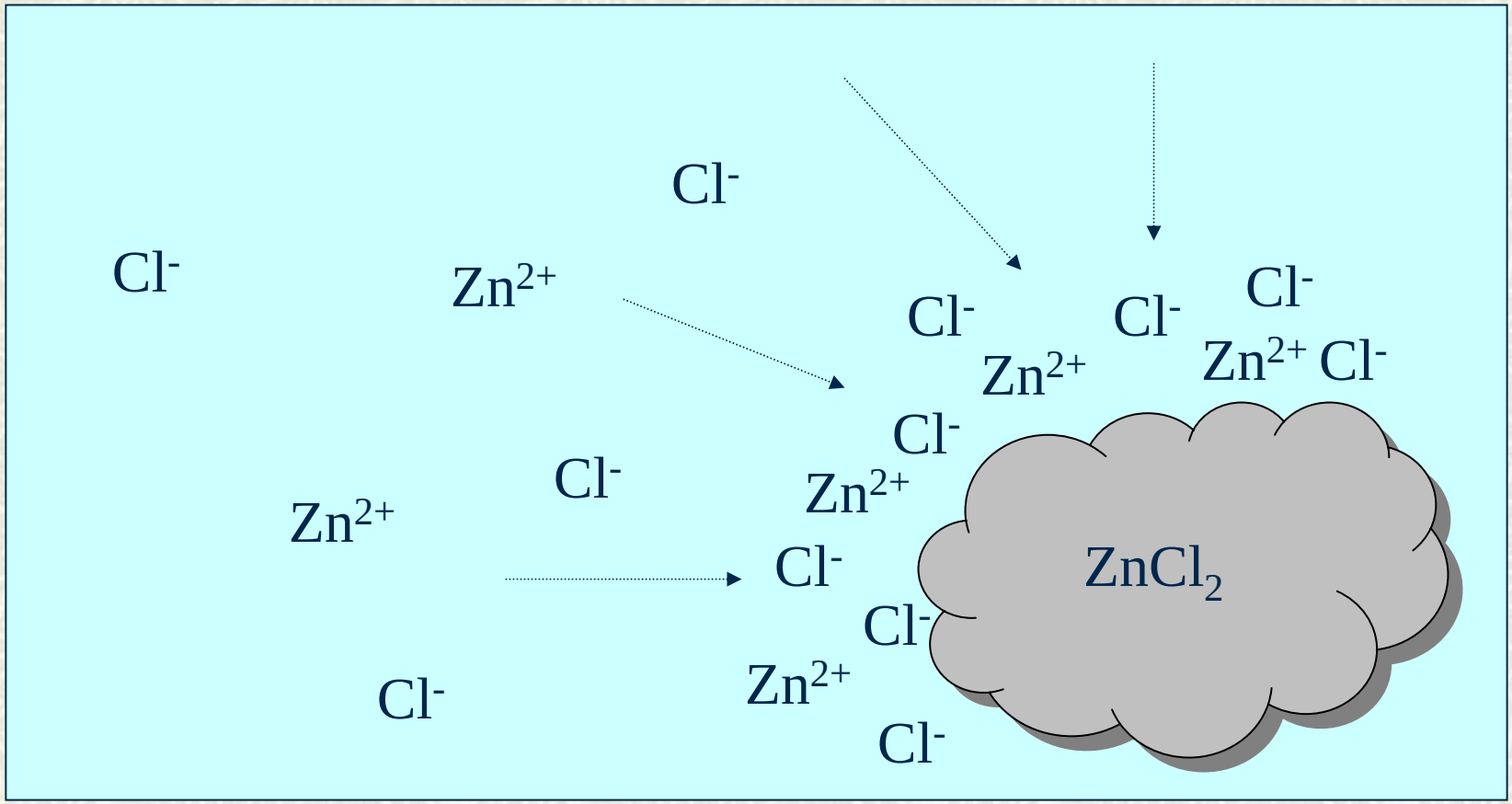
Solubility Reactions



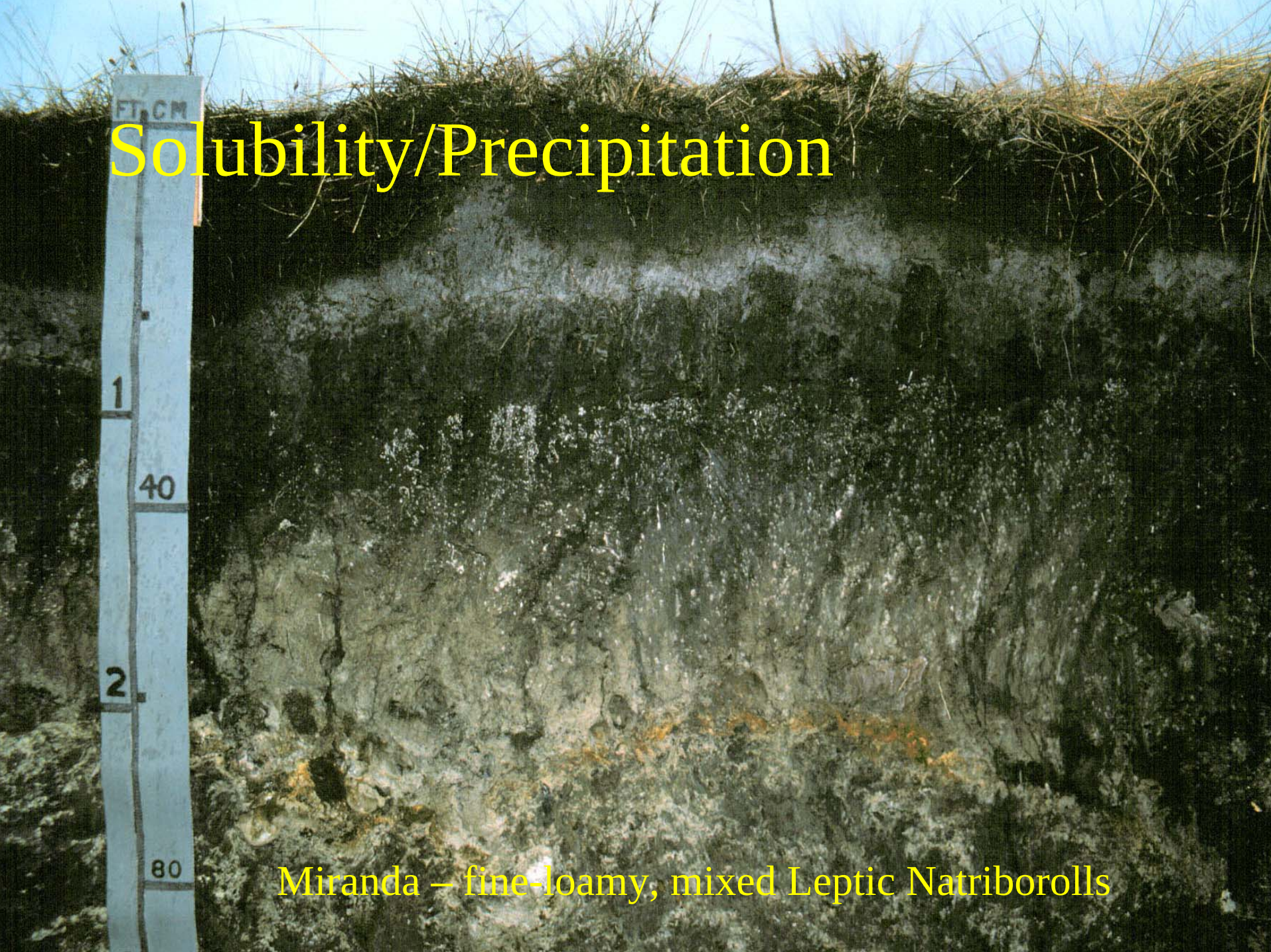
Precipitation Reactions

- Occurs when solubility exceeded.
- Drying and concentrating solutes.

Precipitation Reactions



Solubility/Precipitation



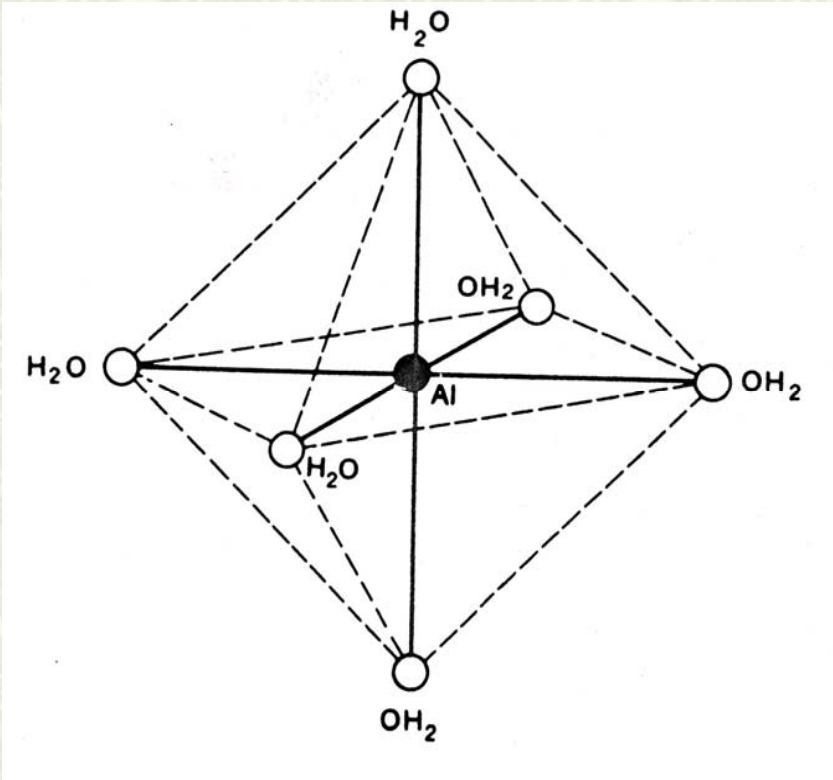
Miranda – fine-loamy, mixed Leptic Natriborolls

Hydrolysis/pH Reactions

- Ionic reaction/interaction with H_2O molecules in soil solution.
- May influence soil/solution pH.
- May be influenced by soil/solution pH.
- Classic examples - Al, Fe

Hydrolysis/pH Reactions

- Example: Al^{3+}



Hydrolysis/pH Reactions

- Reactions:

$$Al(H_2O)_6^{3+} \longleftrightarrow Al(H_2O)_5(OH)^{2+} + H^+$$

$$\longleftrightarrow Al(H_2O)_4(OH)_2^{+} + H^+$$

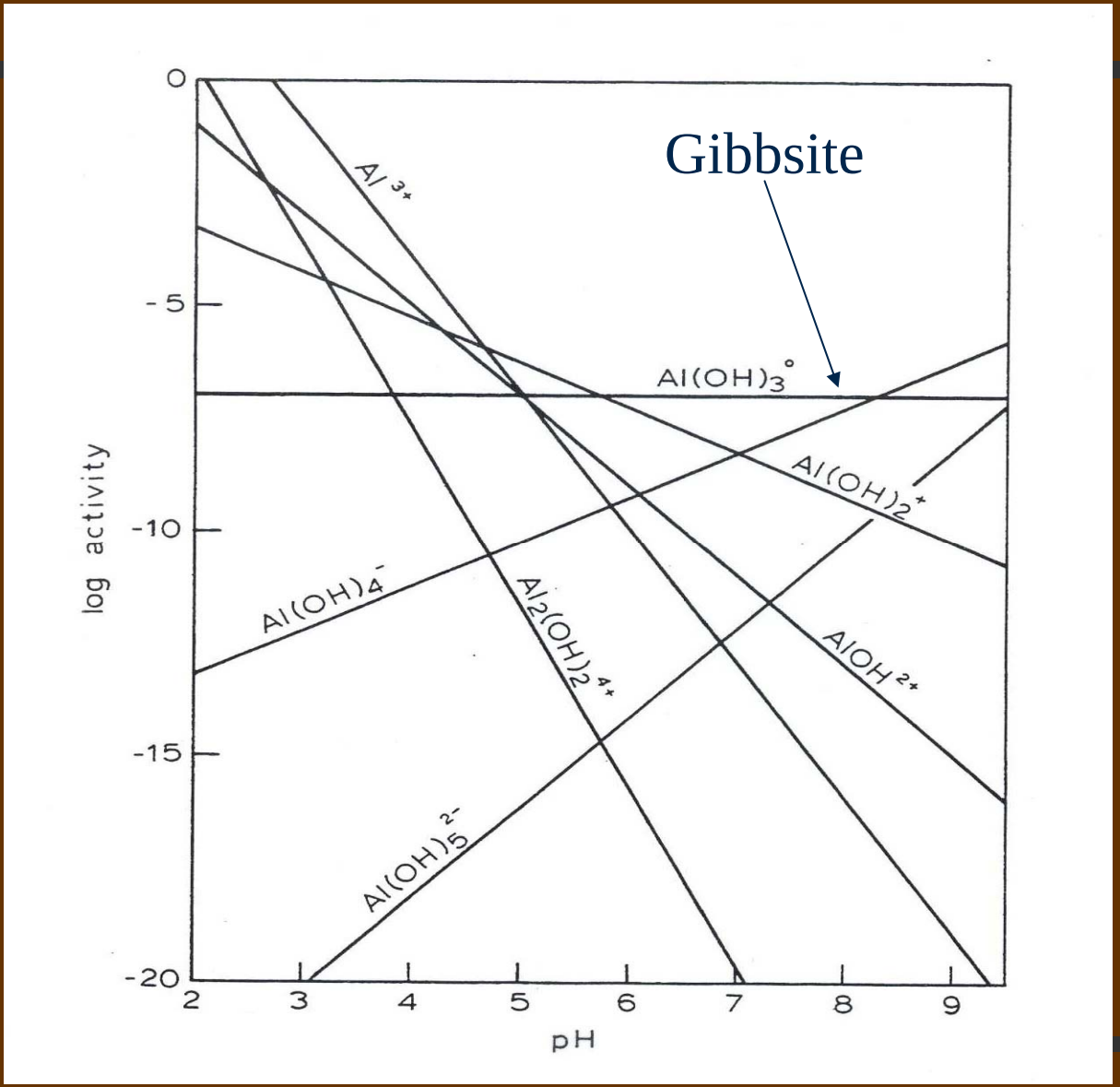
$$\longleftrightarrow Al(H_2O)_3(OH)_3° + H^+$$

$$\longleftrightarrow Al(H_2O)_2(OH)_4^{-} + H^+$$

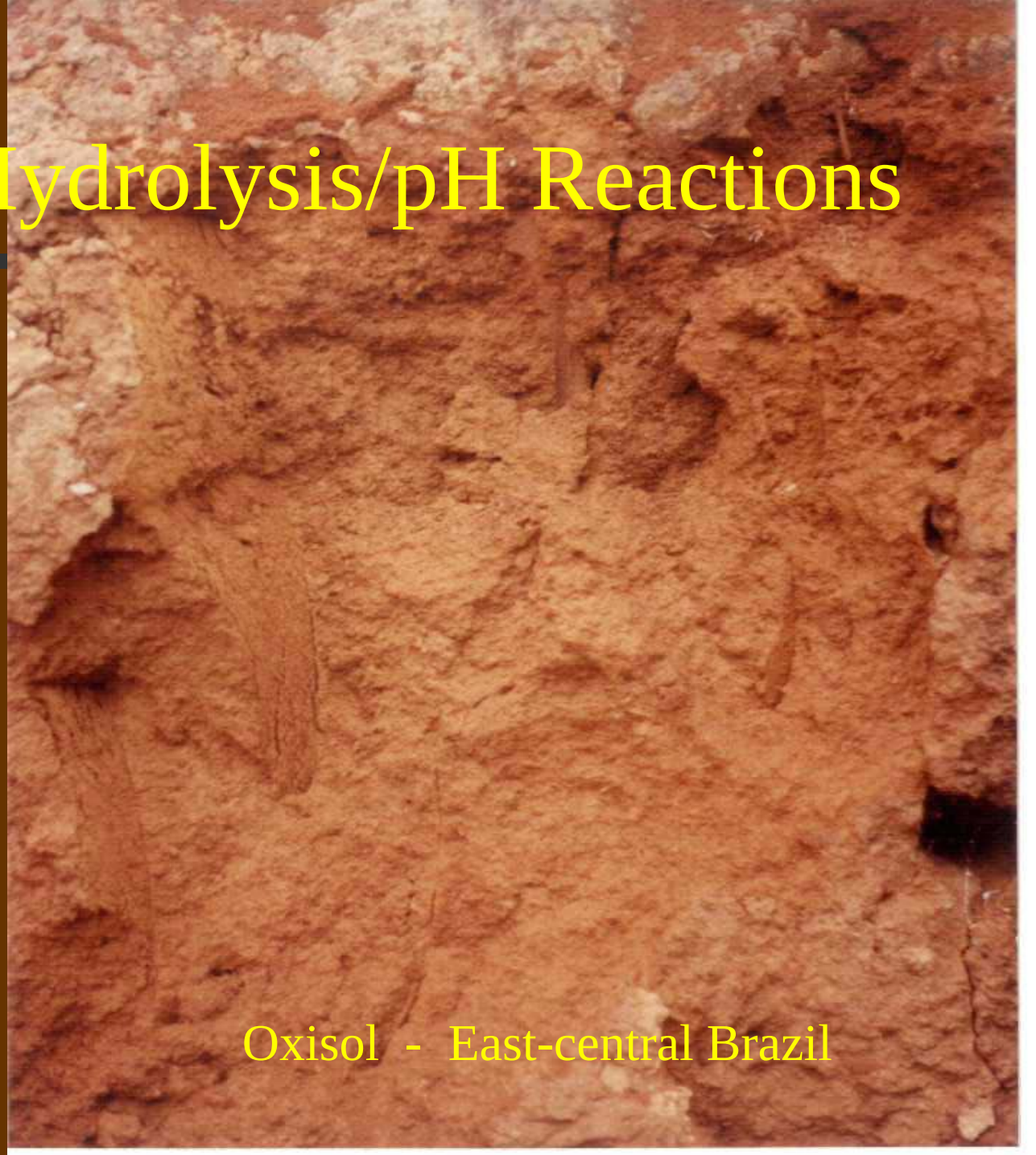
$$\longleftrightarrow Al(H_2O)(OH)_5^{2-} + H^+$$

Note: $Al(H_2O)_3(OH)_3°$ = Gibbsite ($Al(OH)_3$

Hydrolysis/pH Reactions



Hydrolysis/pH Reactions

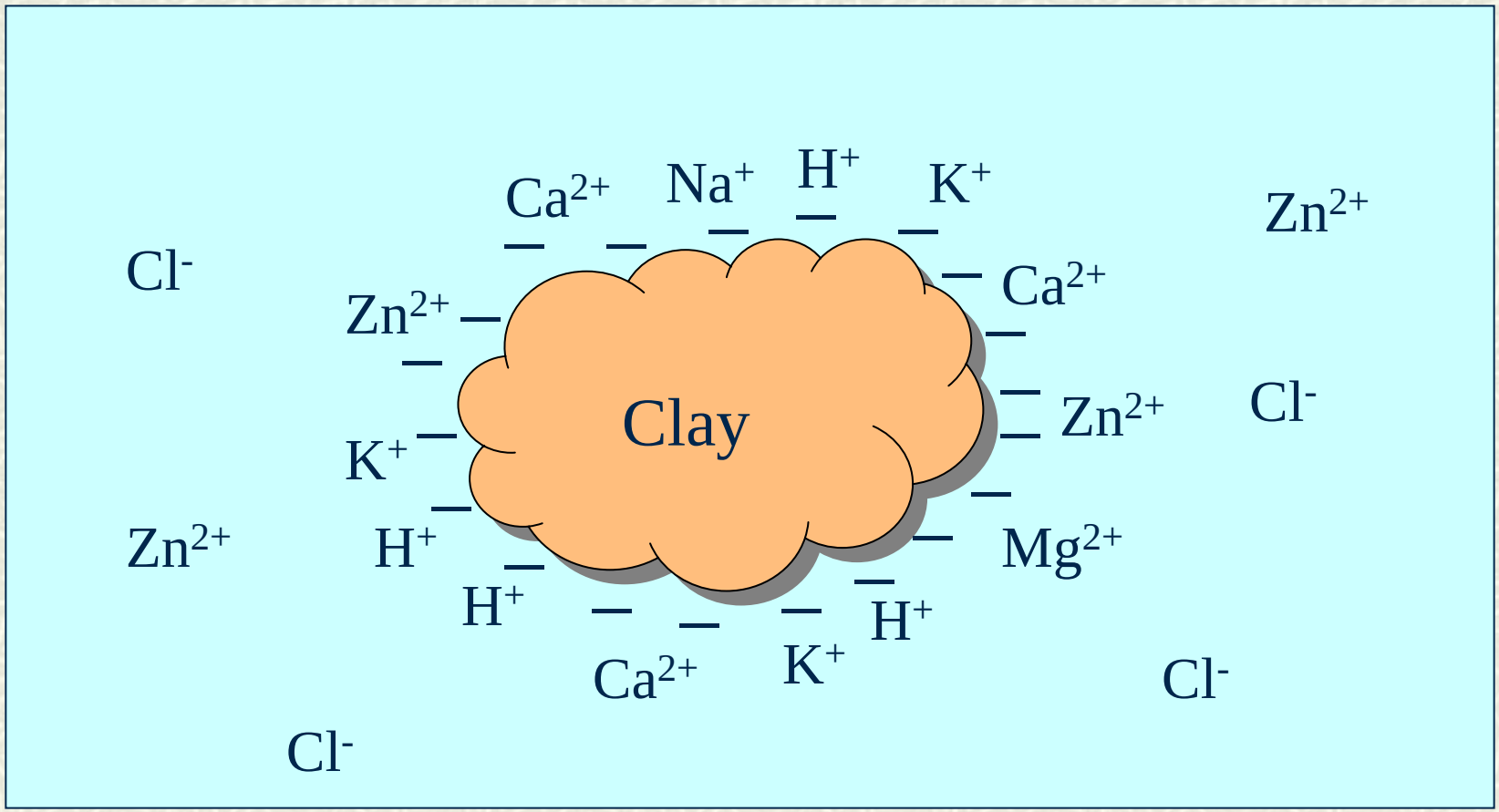


Oxisol - East-central Brazil

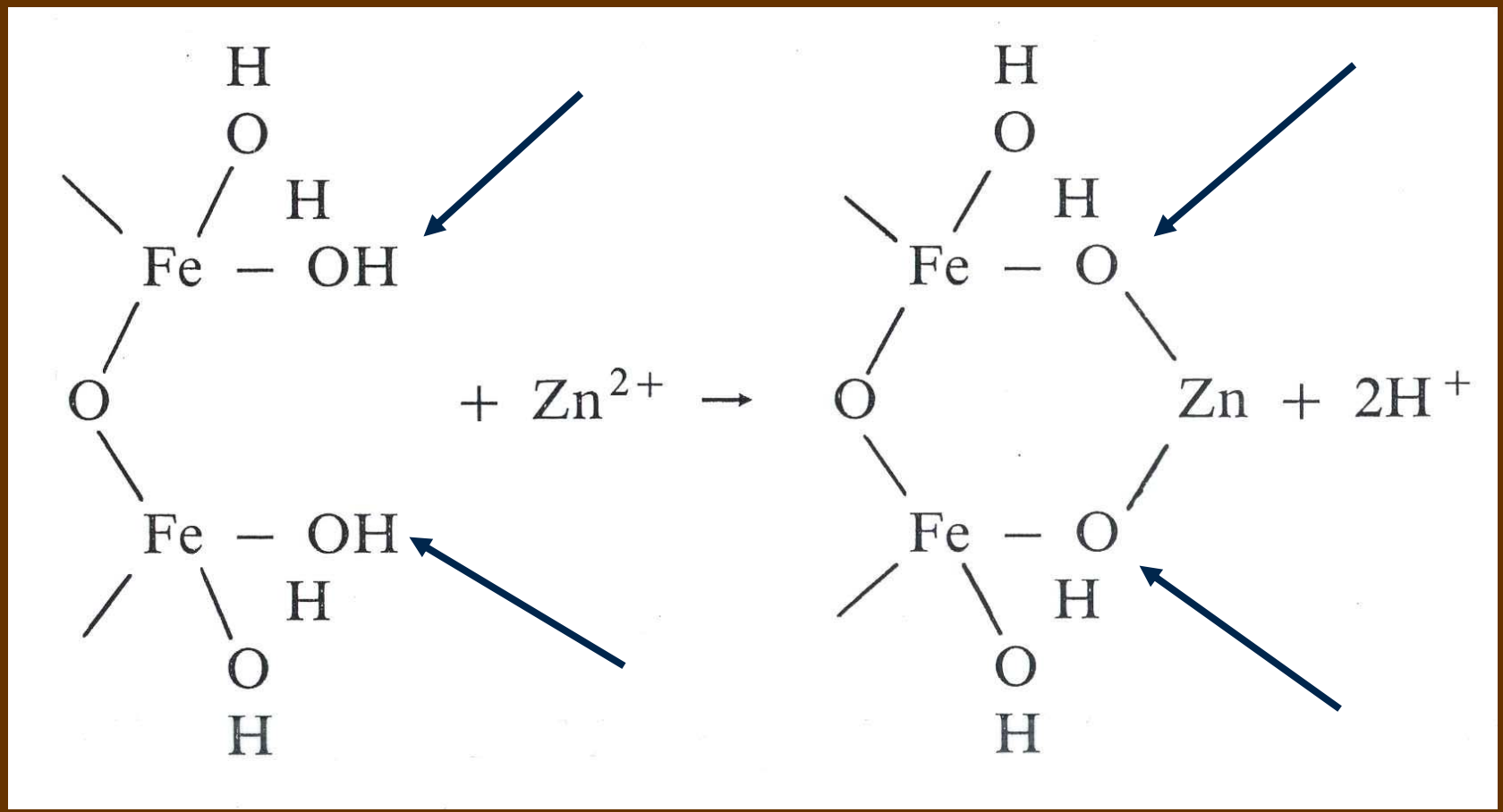
Exchange/Adsorption Reactions

- Soil minerals tend to be negatively charged.
- Trace metals and positively charged.
- “Magnet effect”.
- Polarity.

Exchange/Adsorption Reactions



Exchange/Adsorption Reactions

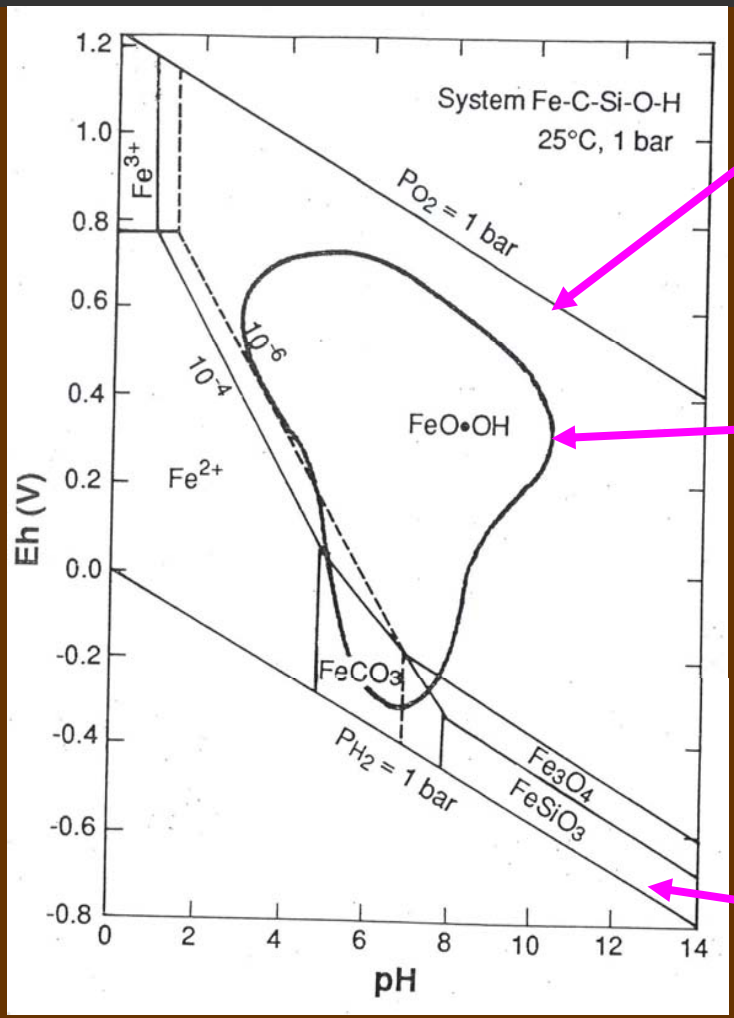


Oxidation-Reduction(Redox) Reactions

- Involves exchange of electrons by a metal.
- Oxidation – loss of electron(s).
- Reduction – gain of electron(s)
- Related to presence/availability of oxygen (O_2).
- Usually expressed as half-cell reaction.

$$Fe^{3+} + e^{-} \rightleftharpoons Fe^{2+}$$

Redox Reactions



Completely Oxidized

Normal range of soils

Completely reduced

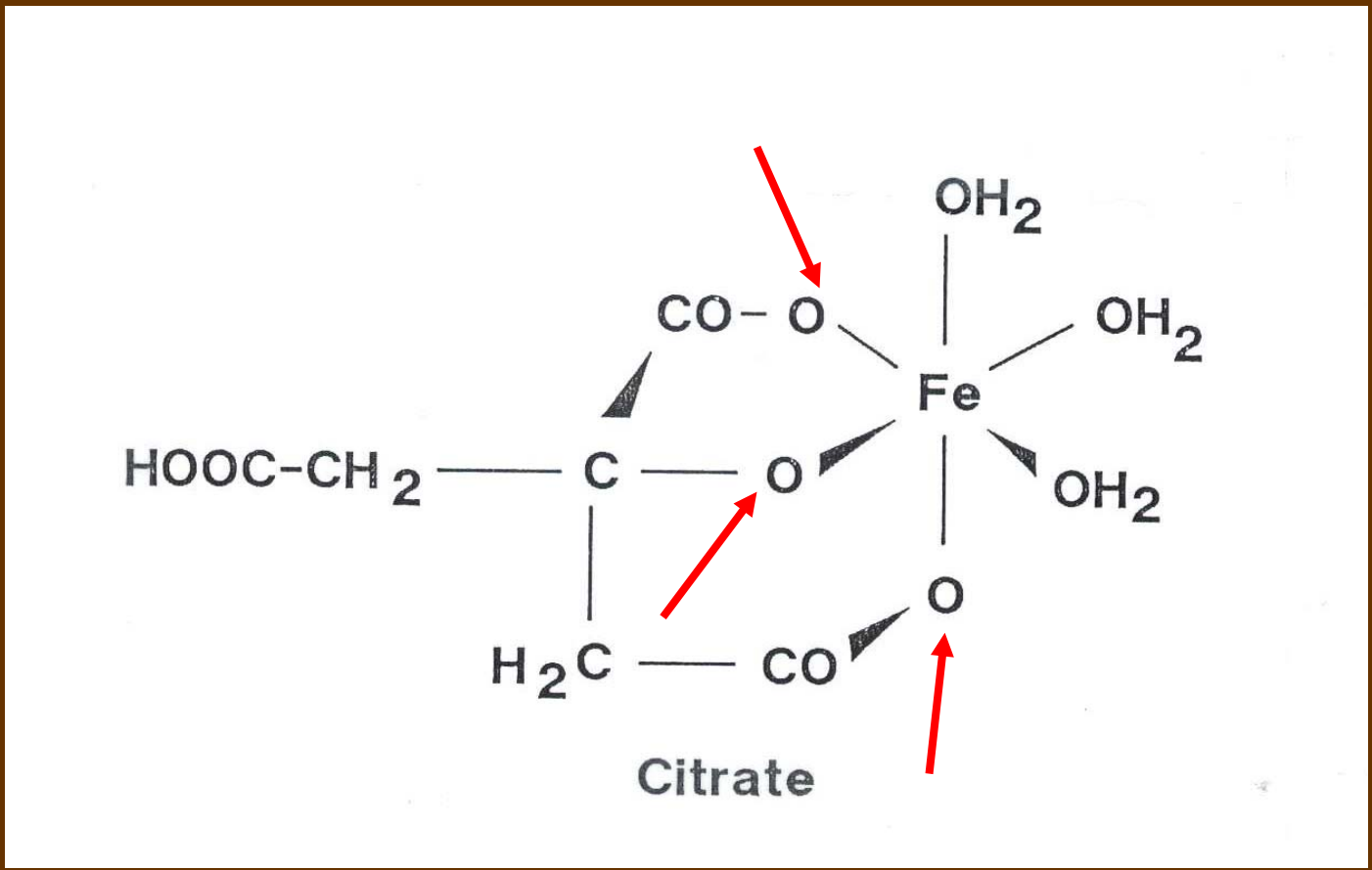
Redox Reactions

Mottling

Chelation

- Chele - Greek word for “claw”
- Reaction with organic compounds in the soil.
- Organic compounds hold the metal and protect it from other reactions.

Chelation

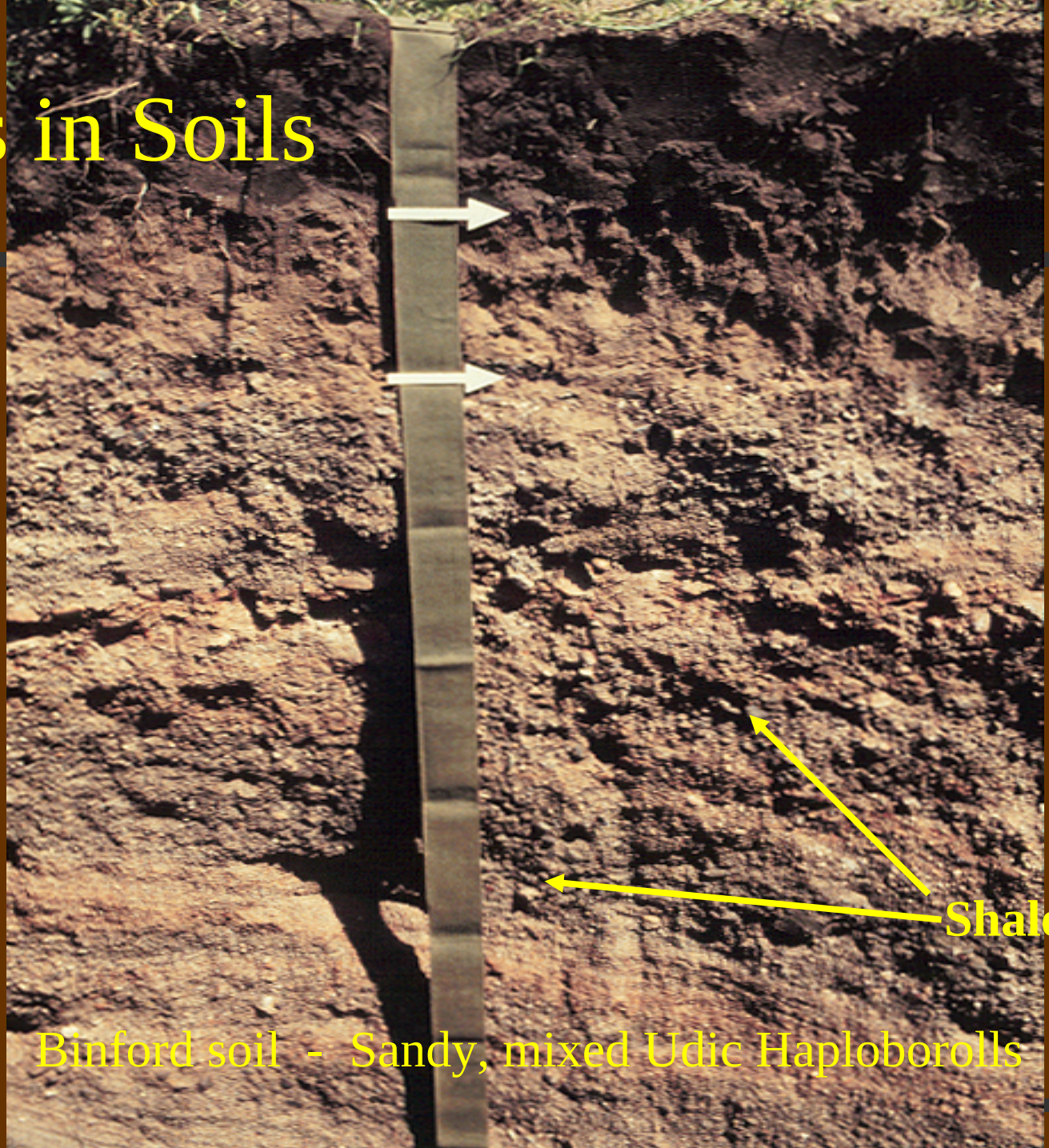


Chelation

Organic Matter – Fe Complex

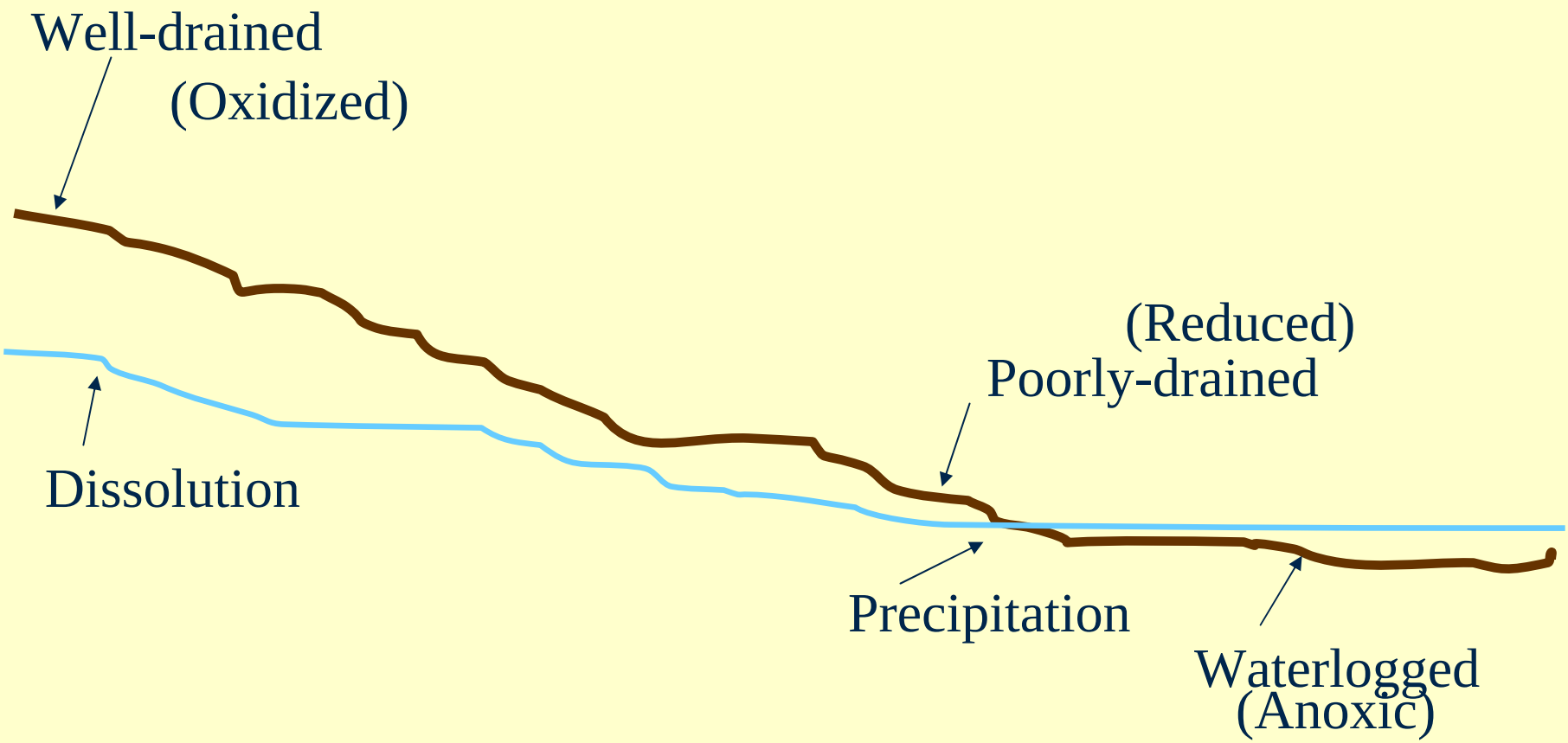
Spodosol

Metals in Soils

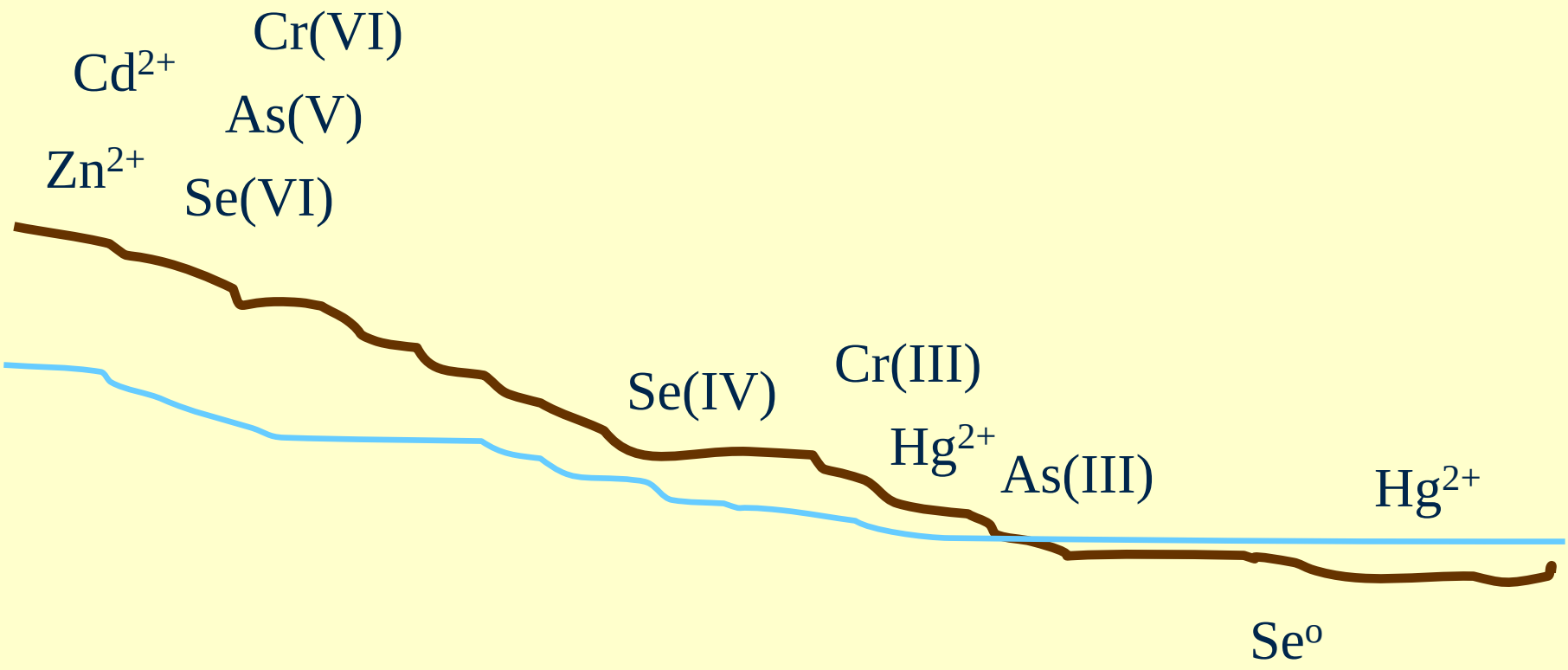


Binford soil - Sandy, mixed Udic Haploborolls

Trace Metals in Landscapes



Trace Metals in Landscapes



Summary

- Trace metals in soils are affected by many factors:
  - Soil mineralogy
  - Mineral solubility
  - Other cations/anions
  - pH
  - Redox
  - Organic matter

Summary

- Other Factors:
  - Drainage
  - Aeration
  - Local hydrology
  - Local biota

Summary

- Soil characteristics and formation factors that influence soil classification also may influence status of trace metals.
- Knowledge of soil mineralogy and chemistry aids soil survey.

References

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