Wetland Soils

Importance of wetland soils

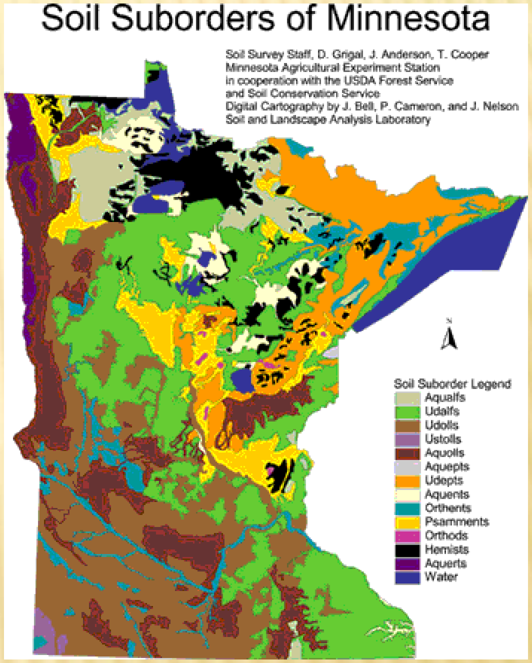
- Chemical transformations
- Chemical (nutrient) storage

These affect plant growth and peat formation

Lecture outline:

- What are soils?
- How does inundation change upland soils into hydric soils?
- What are the important distinguishing characteristics of hydric soils?
- What are the implications of the unique characteristics of hydric soils for plants and chemical transformations?

What are soils?



__________ = study of the components and formation of soils

Soil mapping is done by the Natural Resources Conservation Service (NRCS), a branch of the USDA.

Soil Definitions:

- Early definition of soil: the material capable of supporting the growth of **land** plants.

- A natural body comprised of solids (minerals and organic matter), liquid, and gases that occurs on the land surface, occupies space, and is characterized by one or more of the following: horizons, or layers, that are distinguishable from the initial material as a result of additions, losses, transfers, and transformations of energy or the ability to support rooted plants in a natural environment. (Soil Survey Staff 1998)

What are NOT soils?

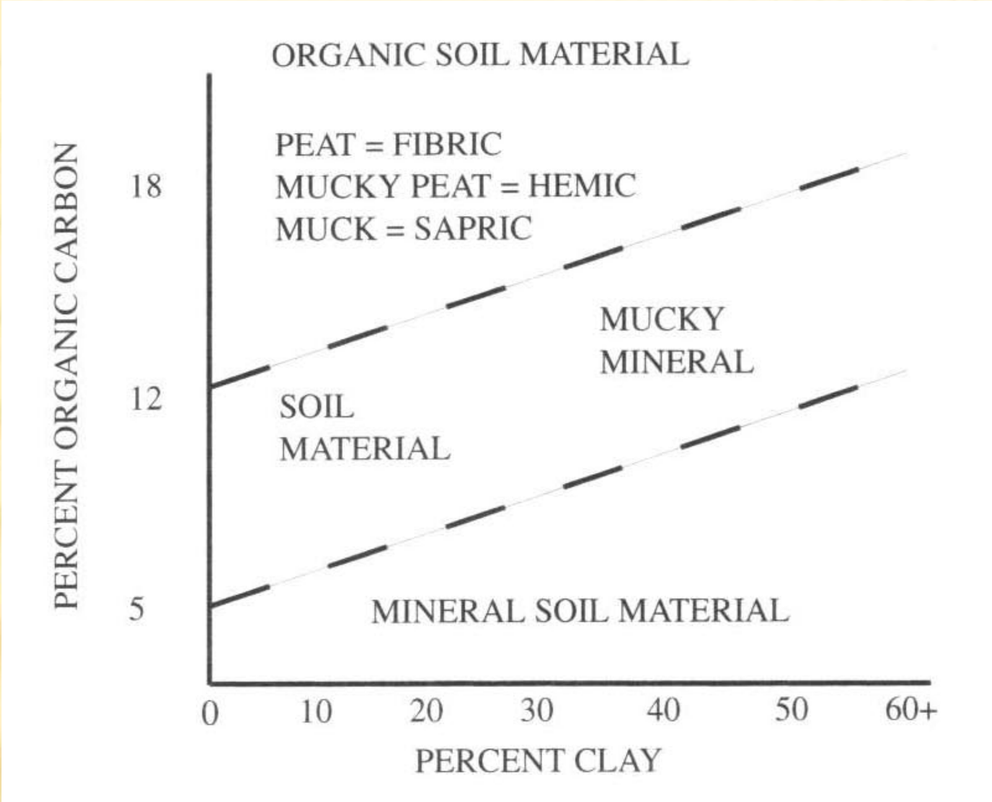
- Bedrock
- Rocky outcrops & plateaus
- Salt flats
- Sand beaches and sand bars
- Muddy shores
- Unconsolidated material lacking any vegetation cover
- Permanently flooded bottoms (this is SUBSTRATE)

Can you have a wetland if you don't have soil?

Tiner 1999: "Tidal mud flats, sandy intertidal beaches, and rocky shores are examples of nonvegetated wetlands occurring on nonsoils."

Soil Types

Two main types of soil: organic and mineral



% C = half the amount of % organic material, ~ > 40% organic material by weight

Organic matter must be ≥ 40 cm for a soil to be a histosol (organic soil); otherwise, it is a mineral soil with an organic layer (horizon) on the top.

Sprecher. 2001. In Richardson & Vepraskas, eds, Wetland Soils.

Organic Soils = Histosols

Formed when decomposition & mineralization of organic matter is greatly slowed due to either anaerobic conditions or cool-cold humid conditions.

3 of the 4 types of organic soils form due to hydric conditions:

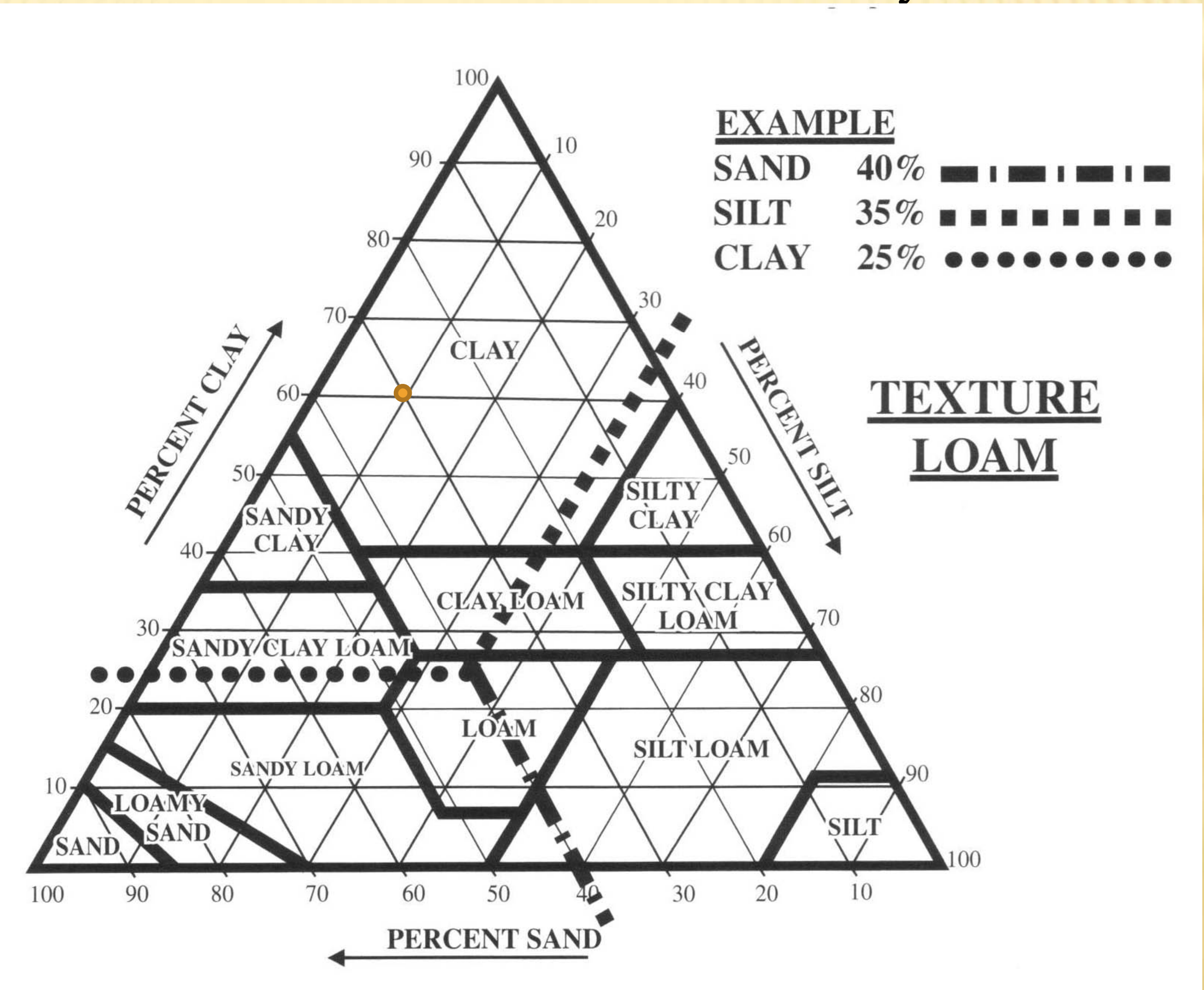
Decomposition

- Fibrists = peat less than ¼ decomposed, mostly identifiable plant fibers
- Hemists = mucky peat (peaty muck); intermediate decomposition and identifiability.
- Saprists = muck; mostly decomposed, mostly unidentifiable.

- Folists = non-hydric organic soils of boreal & tropical mountain areas

Mineral soil is comprised of particles < 2 mm in size

Sand Silt Clay



Sprecher. 2001. In Richardson & Vepraskas, eds, Wetland Soils.

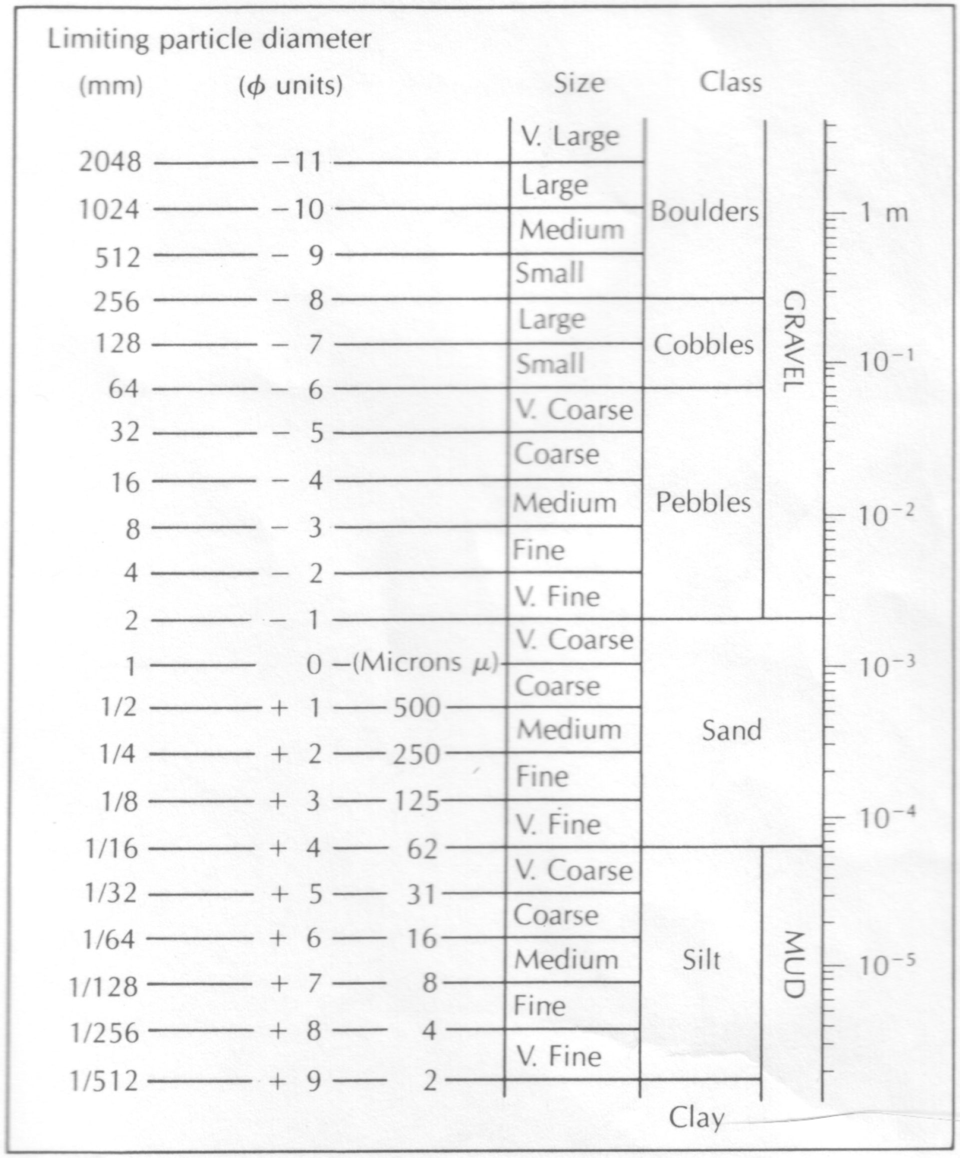
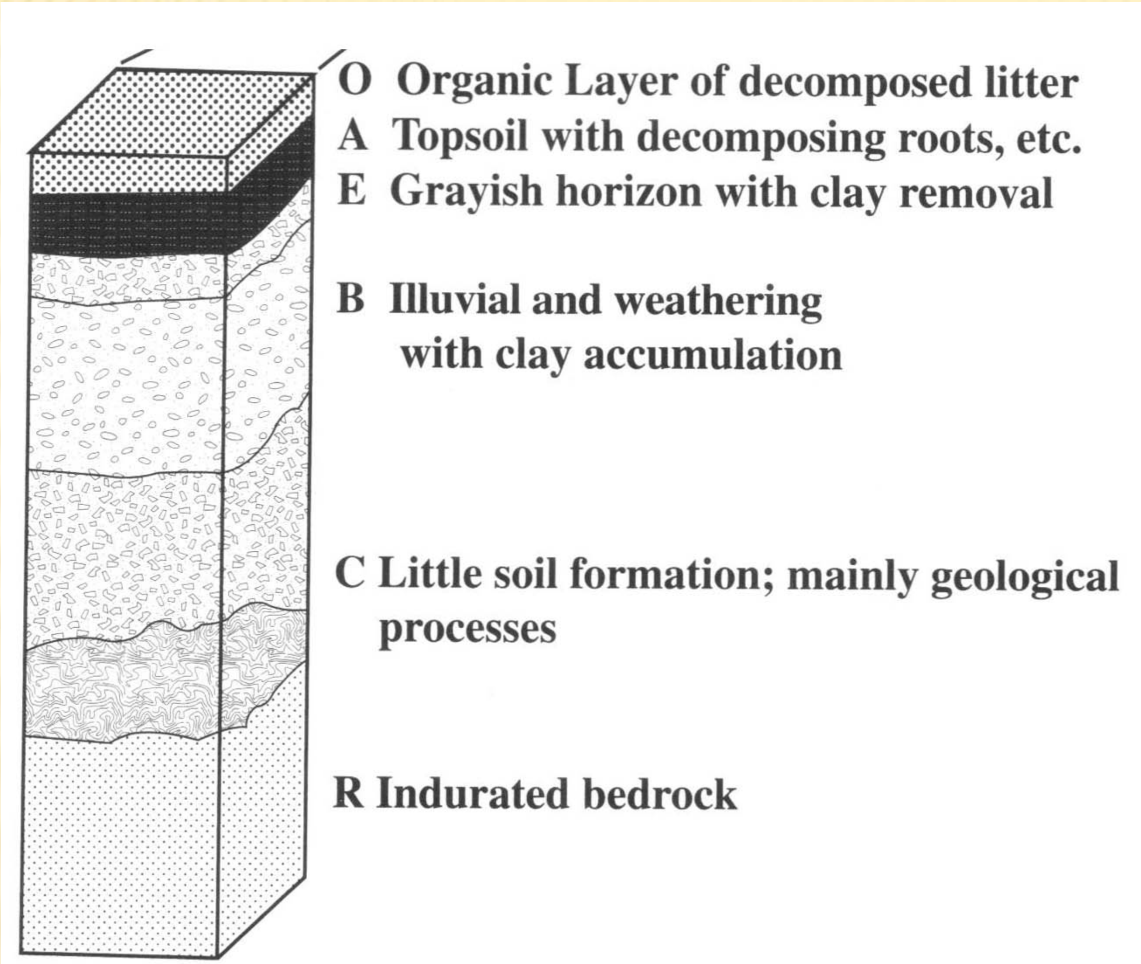


FIGURE 4.3 Standard sizes of sediments with limiting particle diameters and the ϕ scale of sediment size, in which ϕ is equal to $\log_2 s$ (the particle diameter). Source: G. M. Friedman and J. E. Sanders, *Principles of Sedimentology* (New York: John Wiley & Sons, 1978). Used with permission.

Soil Horizons



O = organic horizon:
- Oa = sapric
- Oe = hemic
- Oi = fibric

A = top mineral horizon
- E = light colored horizon depleted in clay, other minerals

B = mineral subsoil horizon

C = parent material

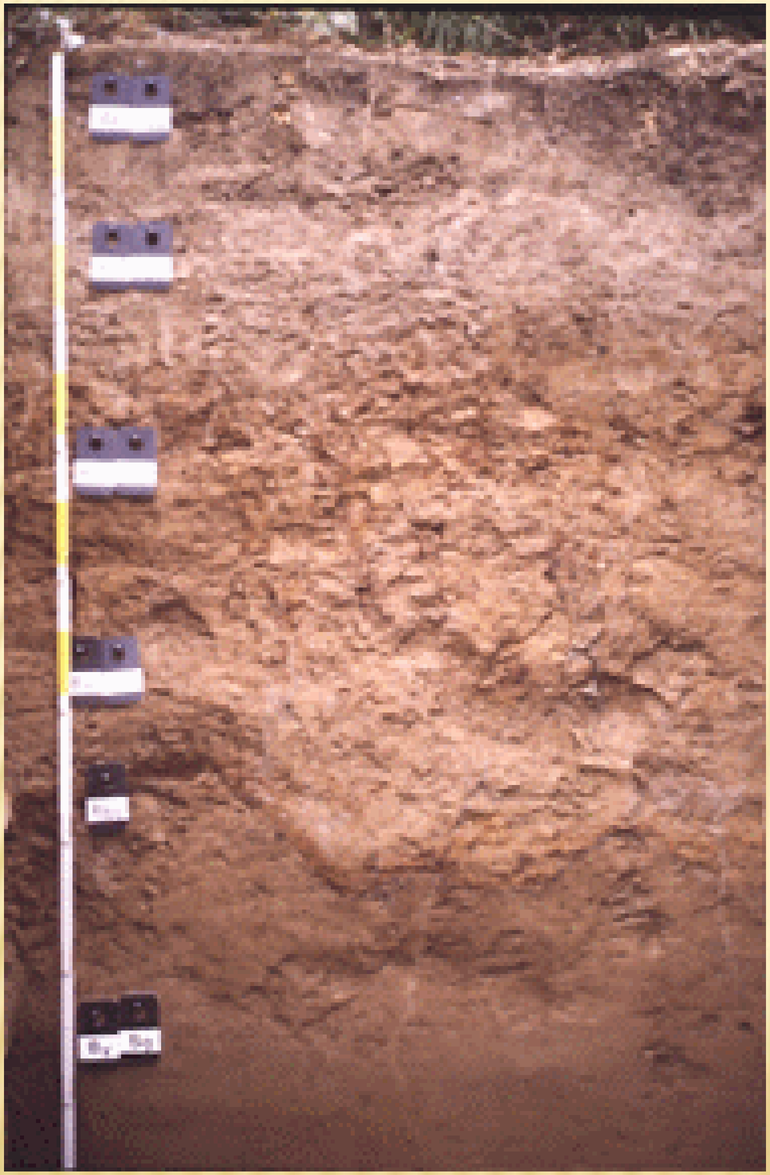
R = unweathered rock

Horizons are often missing in natural soil profiles

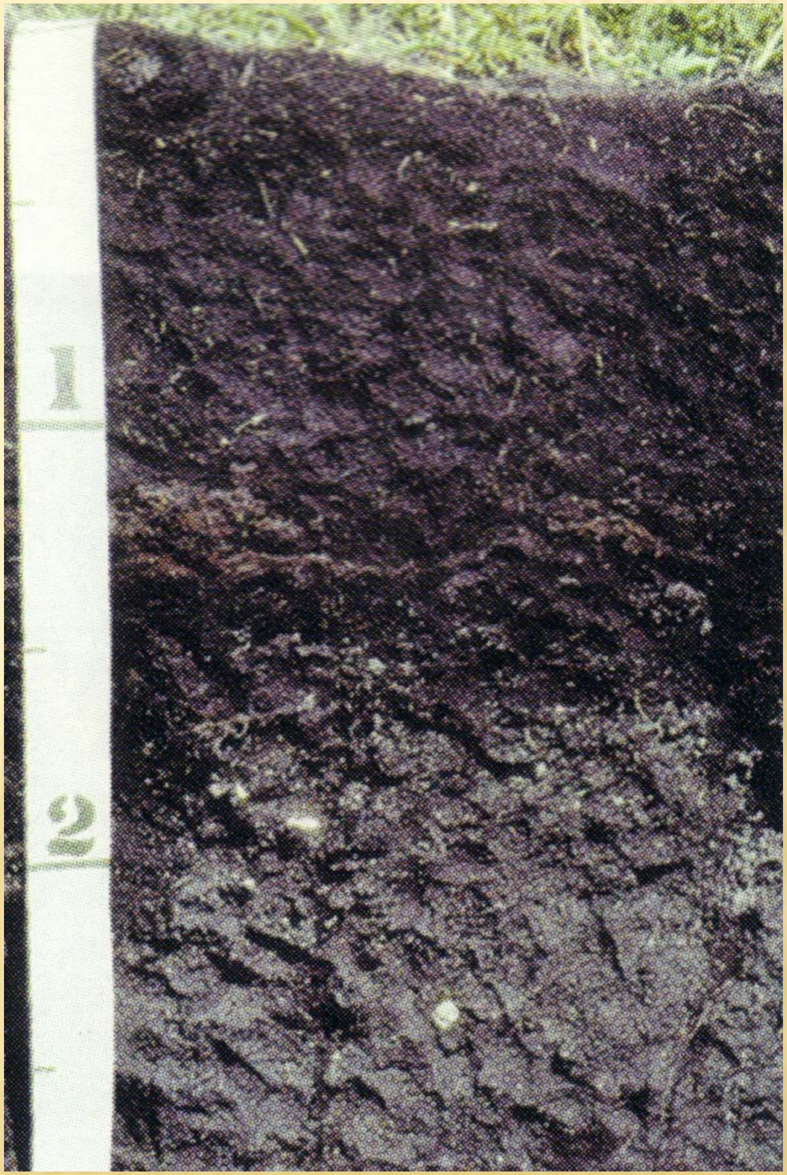
Soil is studied only to a depth of about 2 m

Sprecher. 2001. In Richardson & Vepraskas, eds, Wetland Soils.

Mineral soil, non-hydric



Histosol, hydric



Limnic Haplosaprist

E horizon

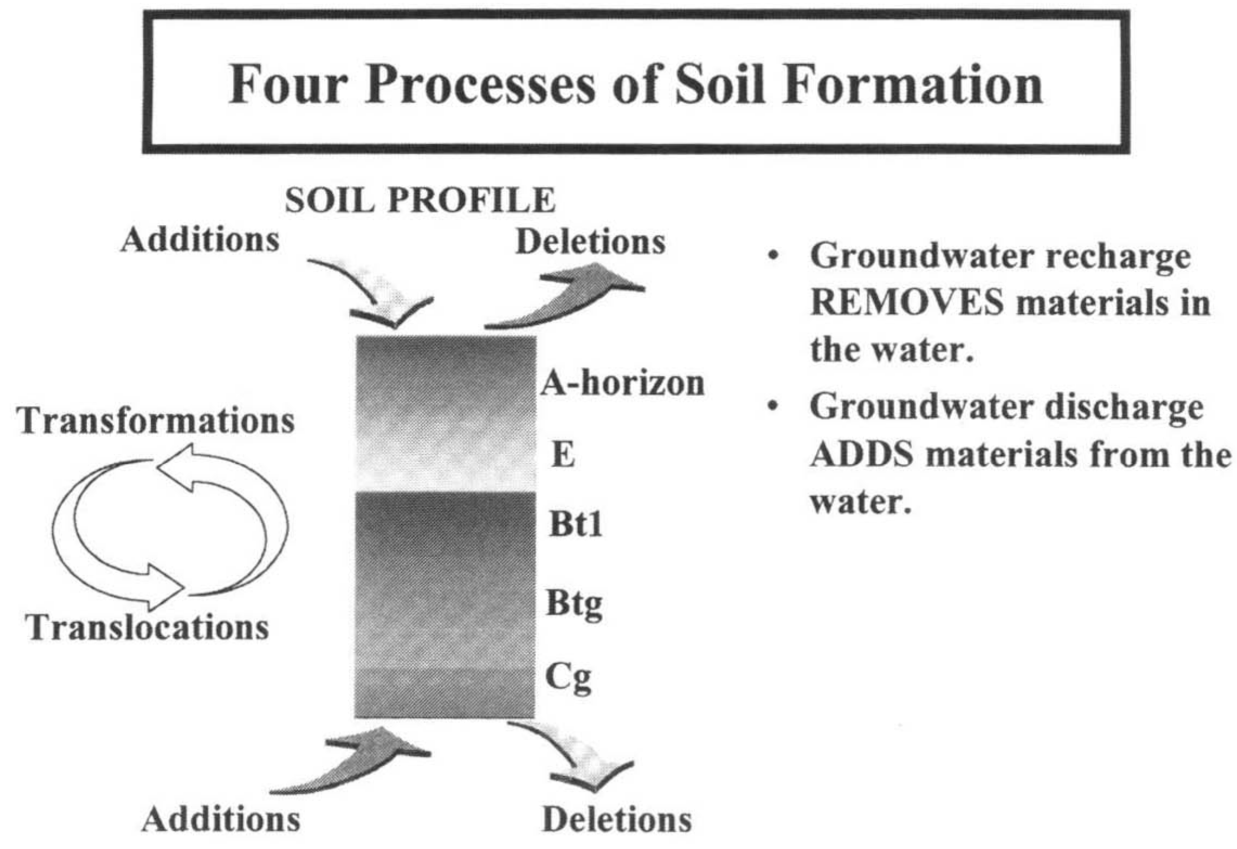
Comparison of organic & mineral soil properties

Soil Property	Organic soil	Mineral soil
Organic C content	> 12-18%	< 12-18%
Bulk density	< 0.6 g/cm^3	1-2 g/cm^3
Porosity	> 80%	45-55%
pH	< 4.5 Fens > 7.0	3.5 – 8.5
Nutrient availability	Low	Low – high
Cation exchange capacity	High	Low – high
Plant available water	High	Low – high
Hydraulic conductivity	Moderate – rapid	Very low – very rapid

Collins & Kuehl. 2001. In Richardson & Vepraskas, eds, Wetland Soils.

Soil Formation

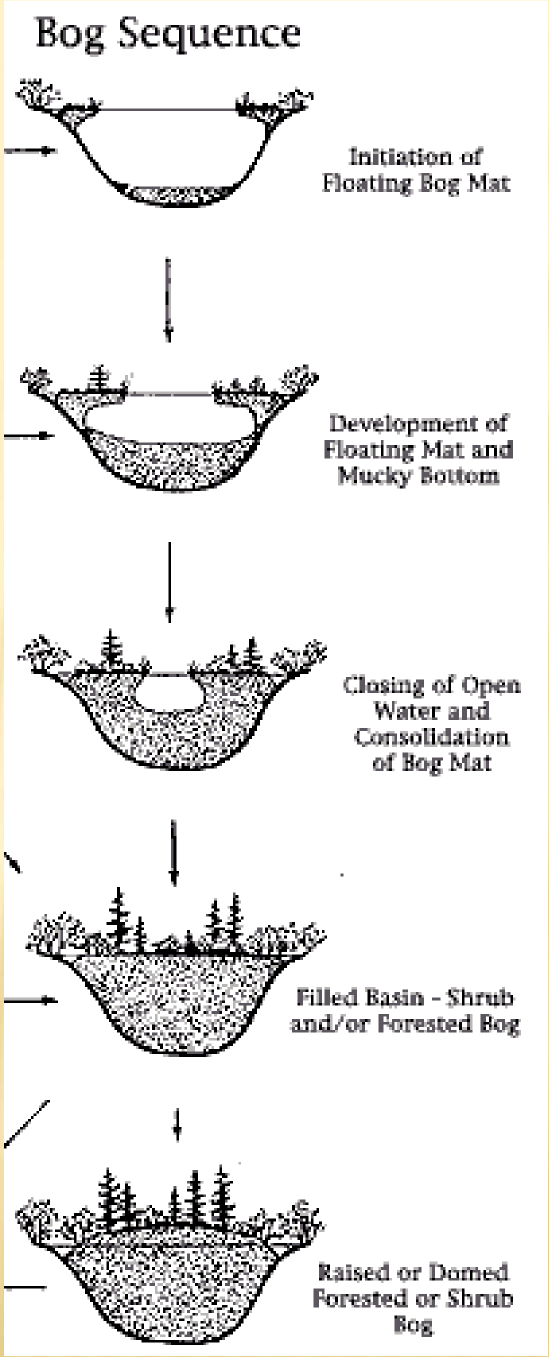
Factors: organisms, topography, climate, parent material, time.
Processes: additions, deletions, transformations, translocations



All four soil-forming processes involve water in some way.

Richardson, Arndt, & Montgomery. 2001. In Richardson & Vepraskas, eds, Wetland Soils.

Hydrarch Succession



Tiner 1998

Hydric soils

Definition: A hydric soil is a soil that is formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part. (Federal Register, Feb. 24, 1995, Vol 60, No. 37, p. 10349). (Upper part = rooting zone of non-tree vegetation; typically 2 ft).

Length of inundation:

Extended inundation → anaerobic conditions → slowed decomposition → organic matter buildup = organic soils

Wet-dry cycles → mineral soils with unique characteristics caused by aerobic/anaerobic cycles.

Anaerobic conditions develop due to (all are required for hydric soil):

- Slow diffusion of oxygen into water-filled soil pores (stagnant water)
- Microbial respiration
- Presence of organic material (microbe substrate)
- Sufficient temperature for biological activity in soil (0 – 2 C)

Oxidation-reduction process

Typical respiration (a redox reaction):

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

Half-reactions:

$C_6H_{12}O_6 + 6H_2O \rightarrow 6CO_2 + 24e^- + 24H^+$ (**Ox**idation = losing electrons, becoming more positive)

$6O_2 + 24e^- + 24H^+ \rightarrow 12H_2O$ (**Red**uction = gaining electrons, becoming more negative)

Alternate e^- acceptors:

NO_3^-

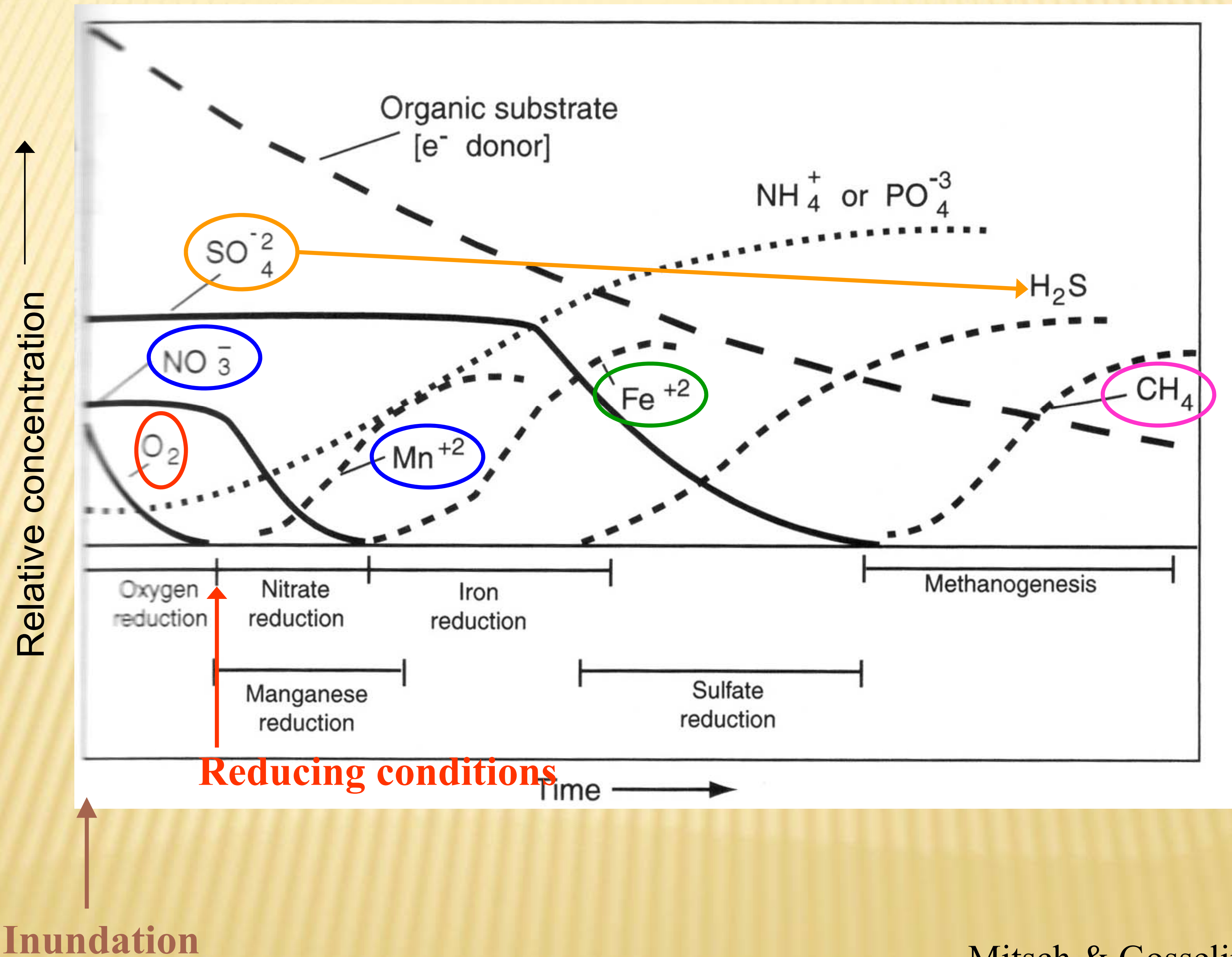
MnO_2

$Fe(OH)_3$

SO_4^{-2}

CO_2

Oxidation-reduction process



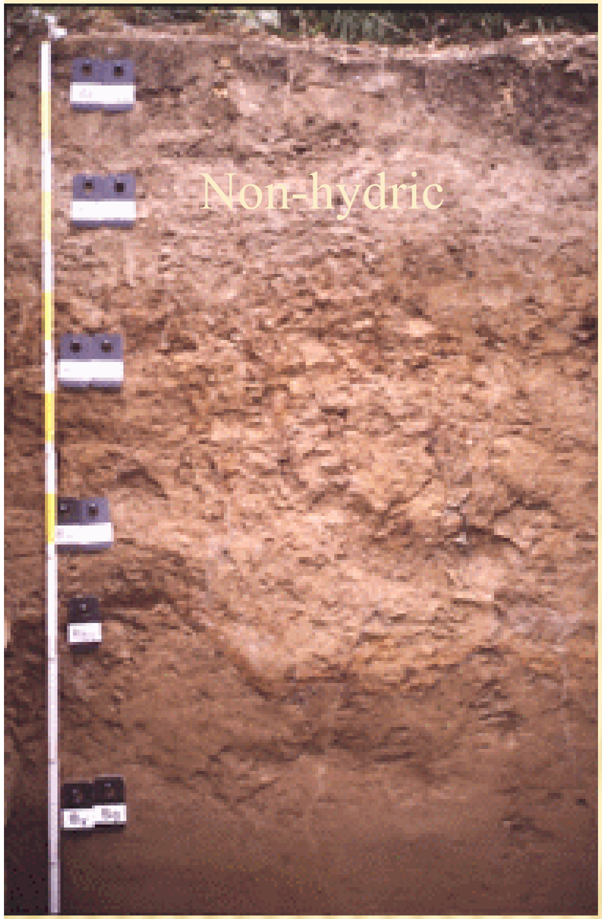
Mitsch & Gosselink 2000.

Oxidation-reduction process

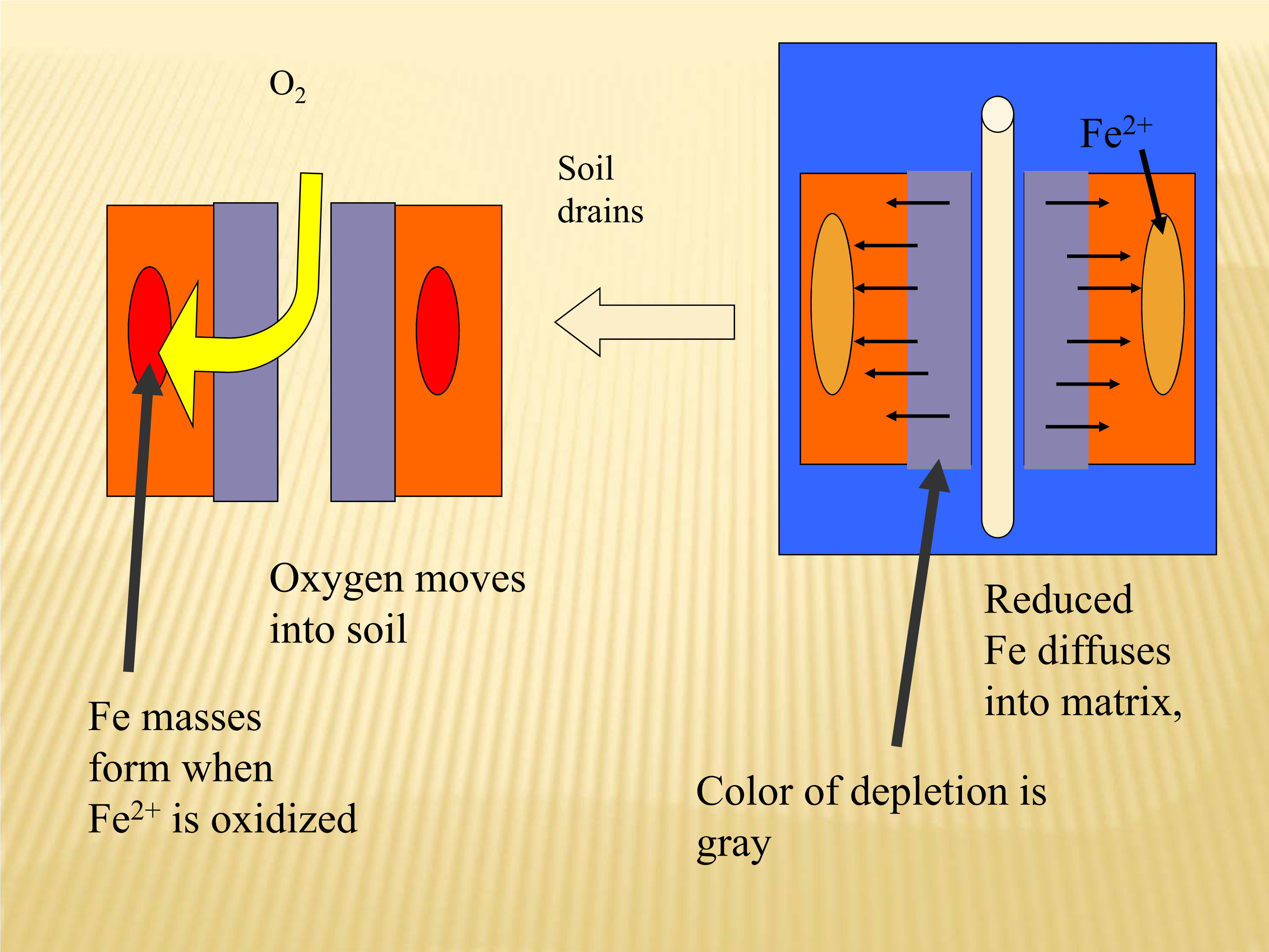
Terminal e- acceptor	Reduction Reaction	Soil colors
Oxygen	$O_2 + 4e^- + 4H^+ \rightarrow 2H_2O$	red, yellow, brown
Nitrate	$2NO_3^- + 10e^- + 12H^+ \rightarrow N_2 + 6H_2O$	no change
Manganese Oxides	$MnO_2 + 2e^- + 4H^+ \rightarrow Mn_2^+ + 2H_2O$	loss of mineral blacks
Iron Oxides	$Fe(OH)_3 + e^- + 3H^+ \rightarrow Fe_2^+ + 3H_2O$	gray, greenish, bluish
Sulfate	$SO_4^{2-} + 8e^- + 10H^+ \rightarrow H_2S + 4H_2O$	no change
Carbon Dioxide	$CO_2 + 8e^- + 8H^+ \rightarrow CH_4 + 2H_2O$	no change

Vepraskas & Faulkner. 2001. In Richardson & Vepraskas, eds. Wetland soils.

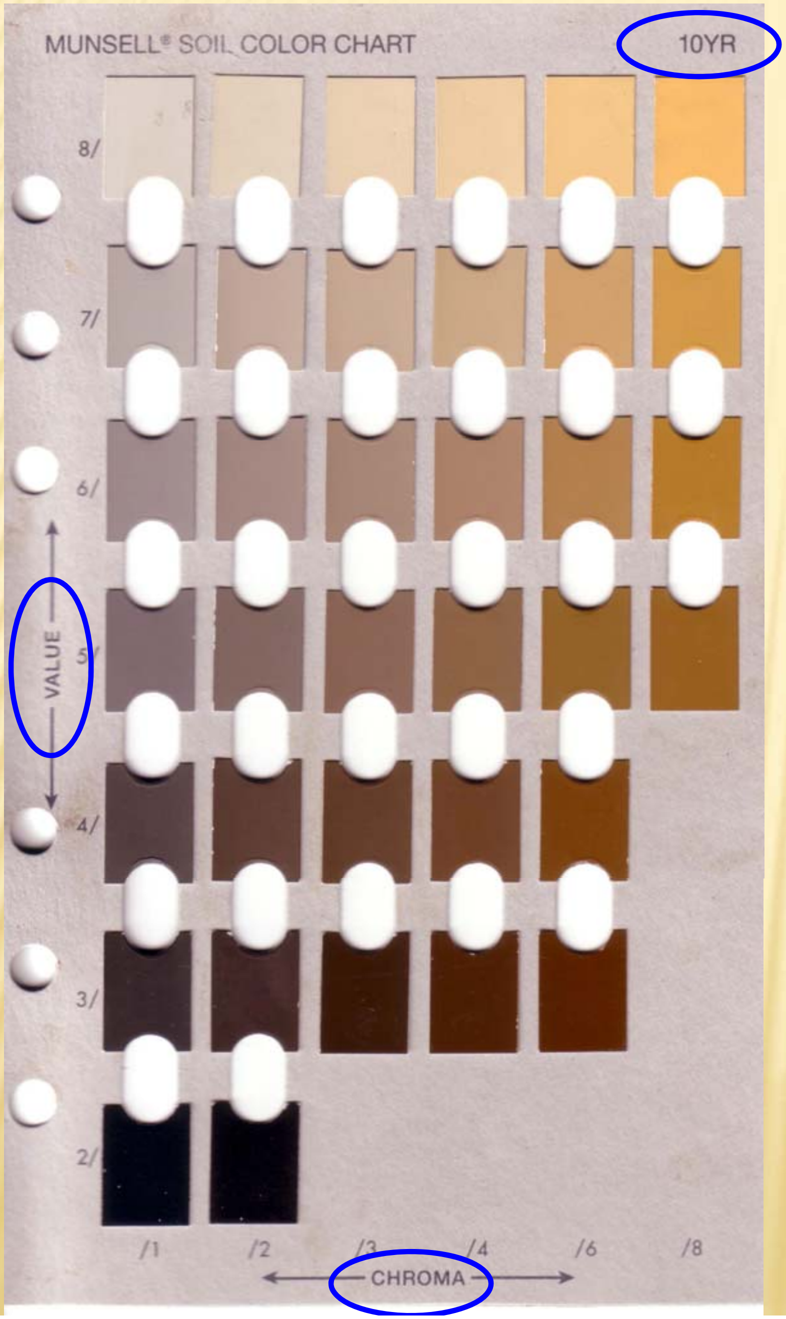
Hydric soil colors

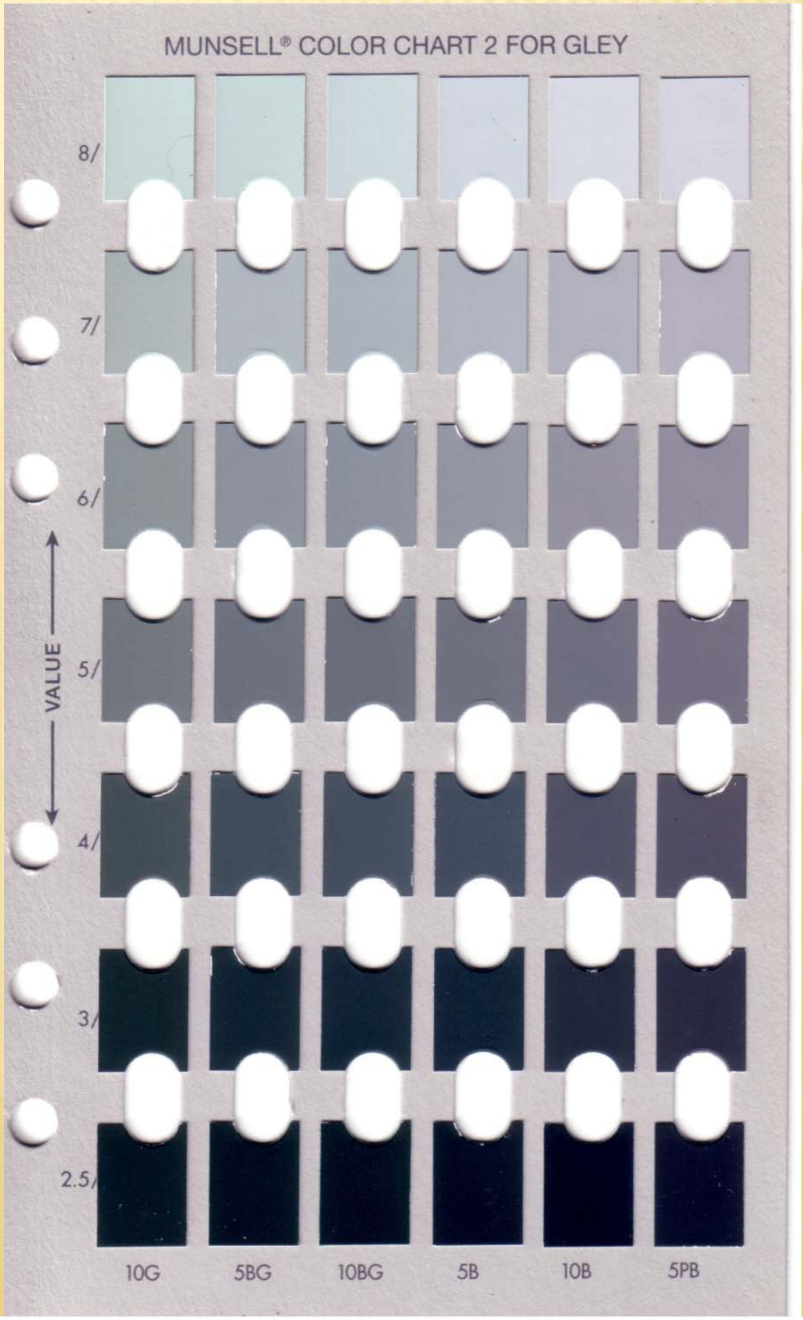


Gleization, Gleys
Pore linings
Oxidized rhizospheres
Redoxomorphic
Redox depletions

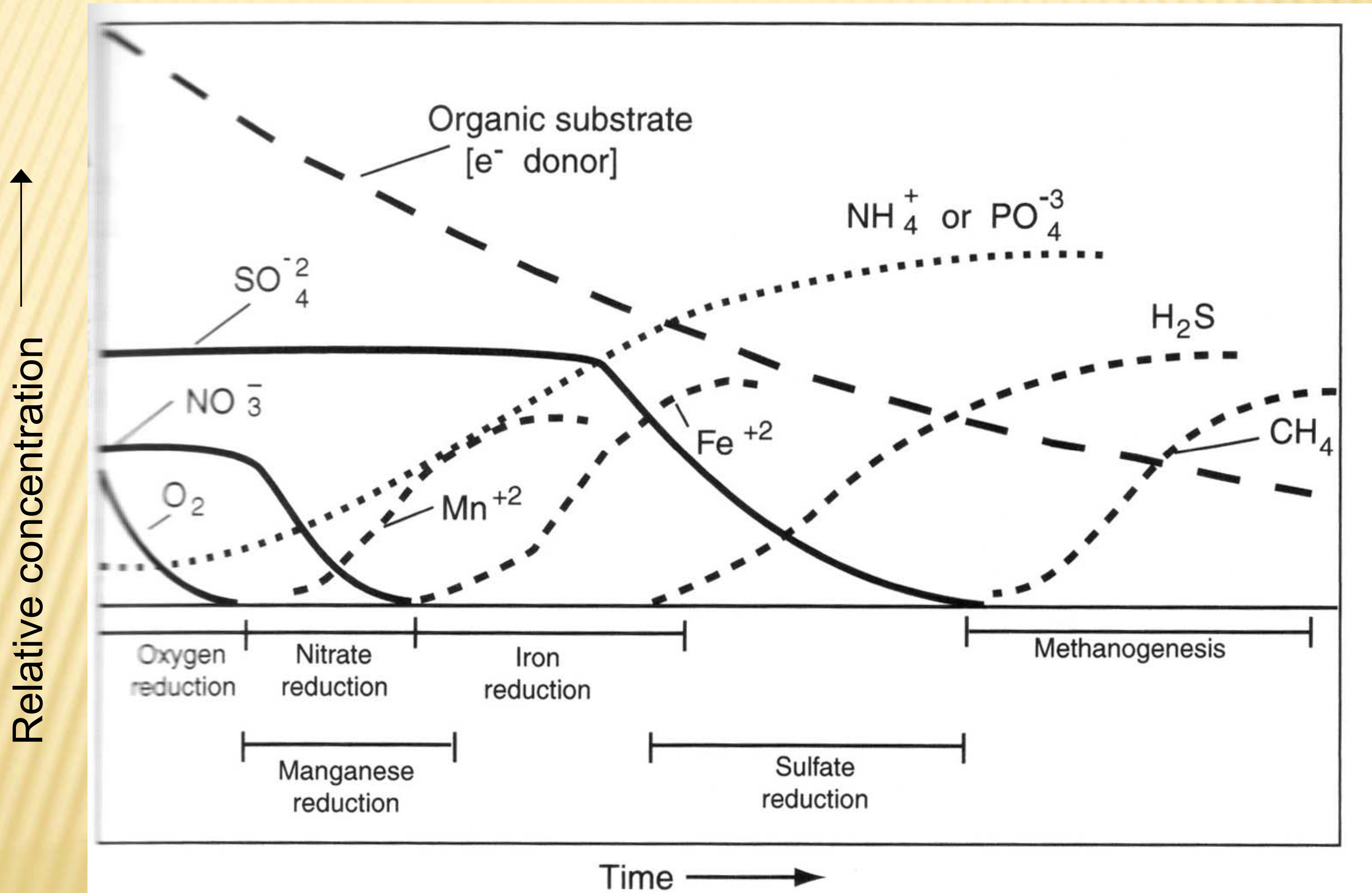

O_2
Soil drains
Fe^{2+}
Oxygen moves into soil
Reduced Fe diffuses into matrix,
Fe masses form when Fe^{2+} is oxidized
Color of depletion is gray

Munsell Color Charts



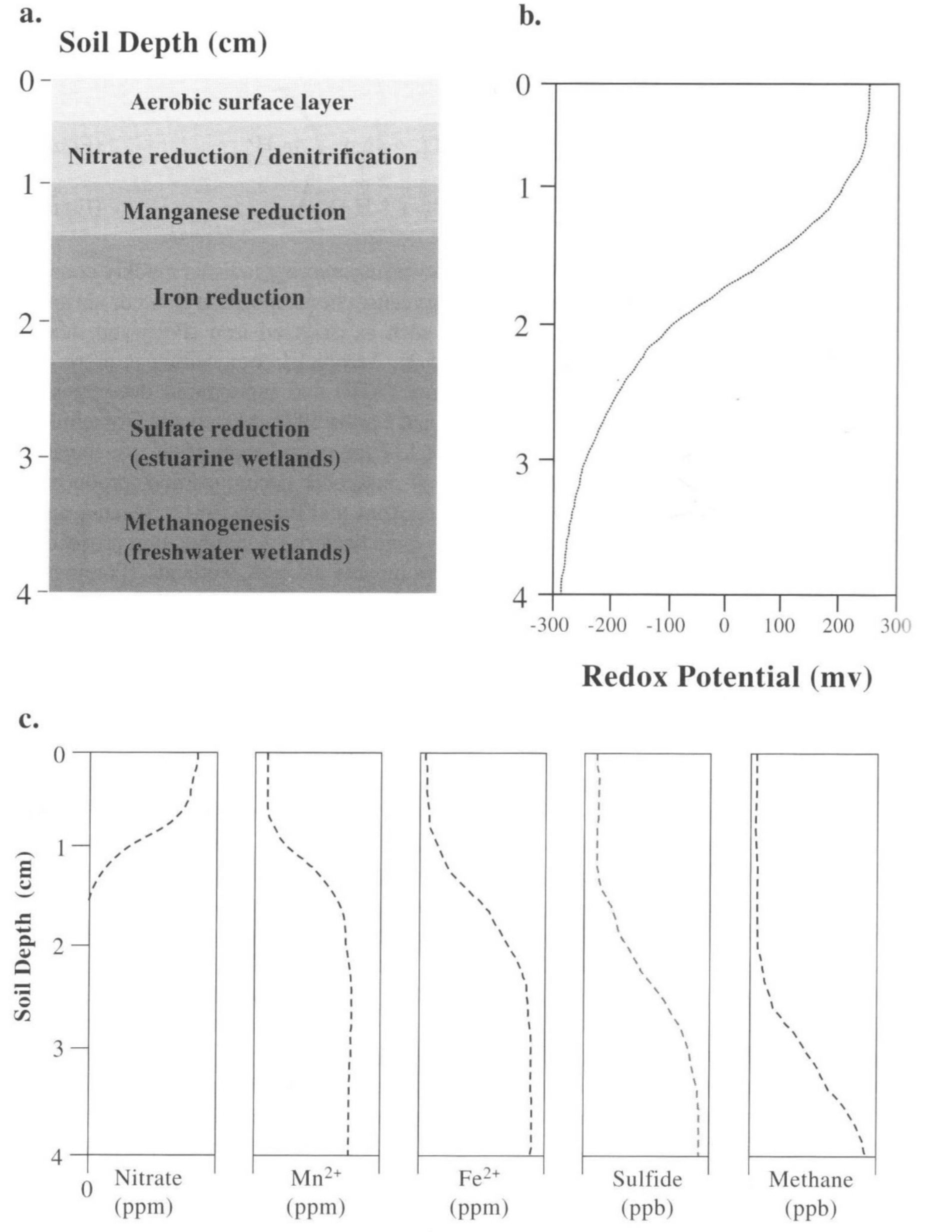


Oxidation-reduction cont.



Mitsch & Gosselink 2000.

Oxidation-reduction cont.



Craft. 2001. In Richardson & Vepraskas, eds. Wetland soils.

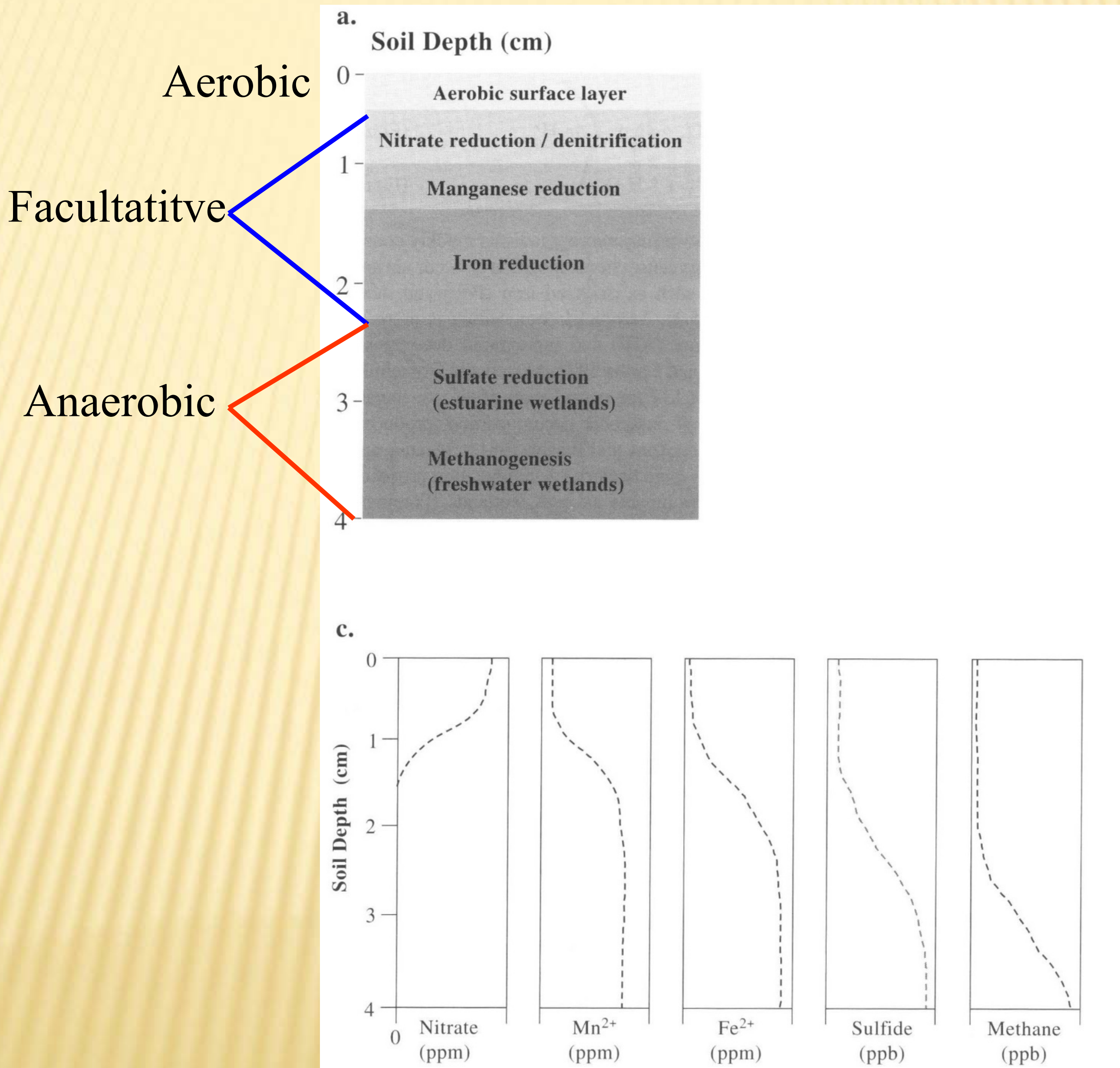
Oxidation-reduction cont.

Process	**Electron acceptor**	**Energy (-ΔG° kJ/mole e^-)***	**Redox potential (Eh) in (mV)****
Aerobic	O_2	125.1	> 300
Nitrate reduction	NO_3^-	118.8	250
Manganese reduction	MnO_2	94.5	225
Iron reduction	$Fe(OH)_3$	24.3	100 – (-100)
Sulfate reduction	SO_4^{-2}	25.4	-100 – (-200)
Methanogenesis	CO_2	23.2	< -200

* Reddy & D'Angelo 1994. In Mitsch, ed, Global wetlands.

** Redox potentials are rough estimates, they vary depending on pH and temperature. Mitsch & Gosselink 2000.

Oxidation-reduction cont.



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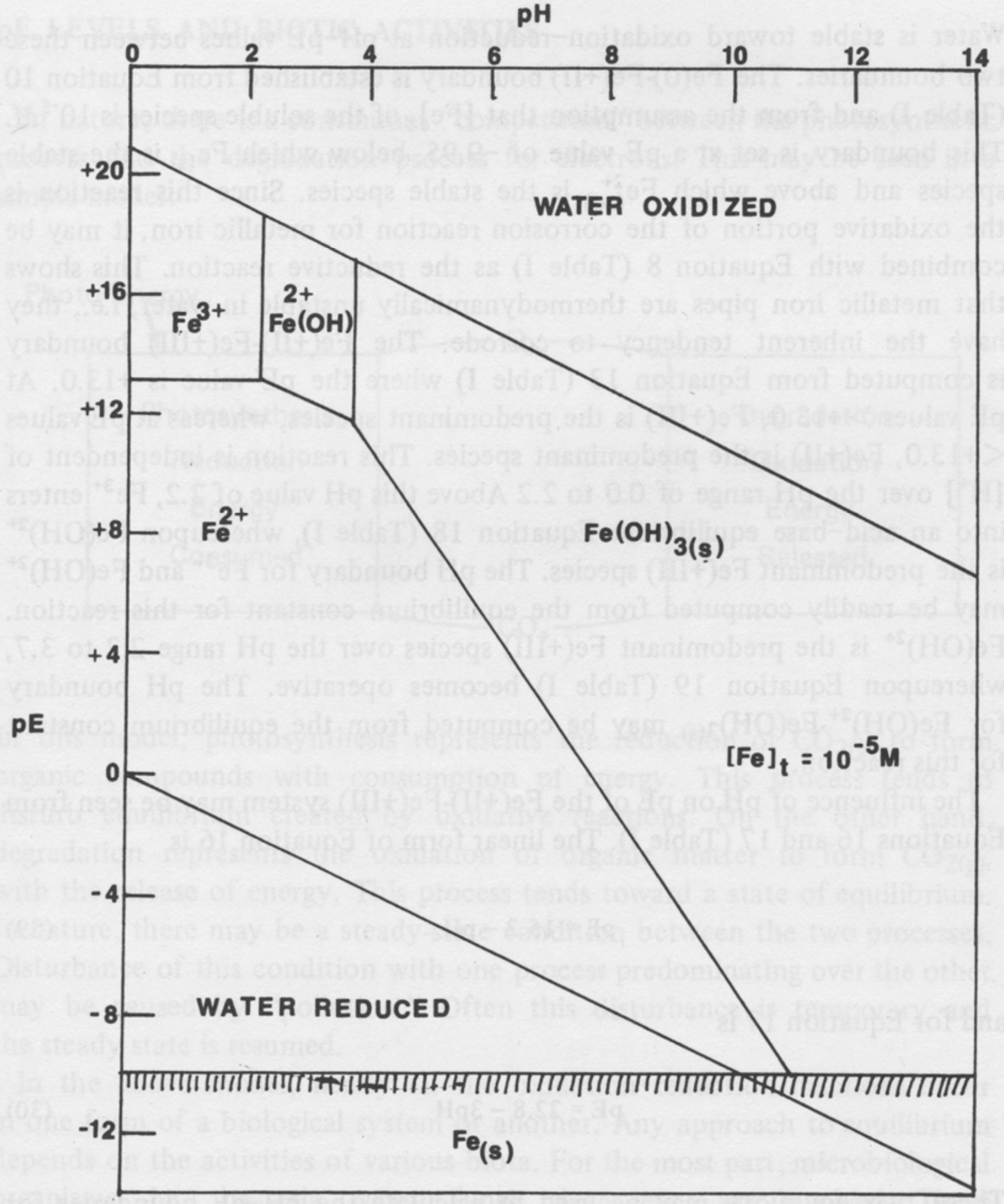
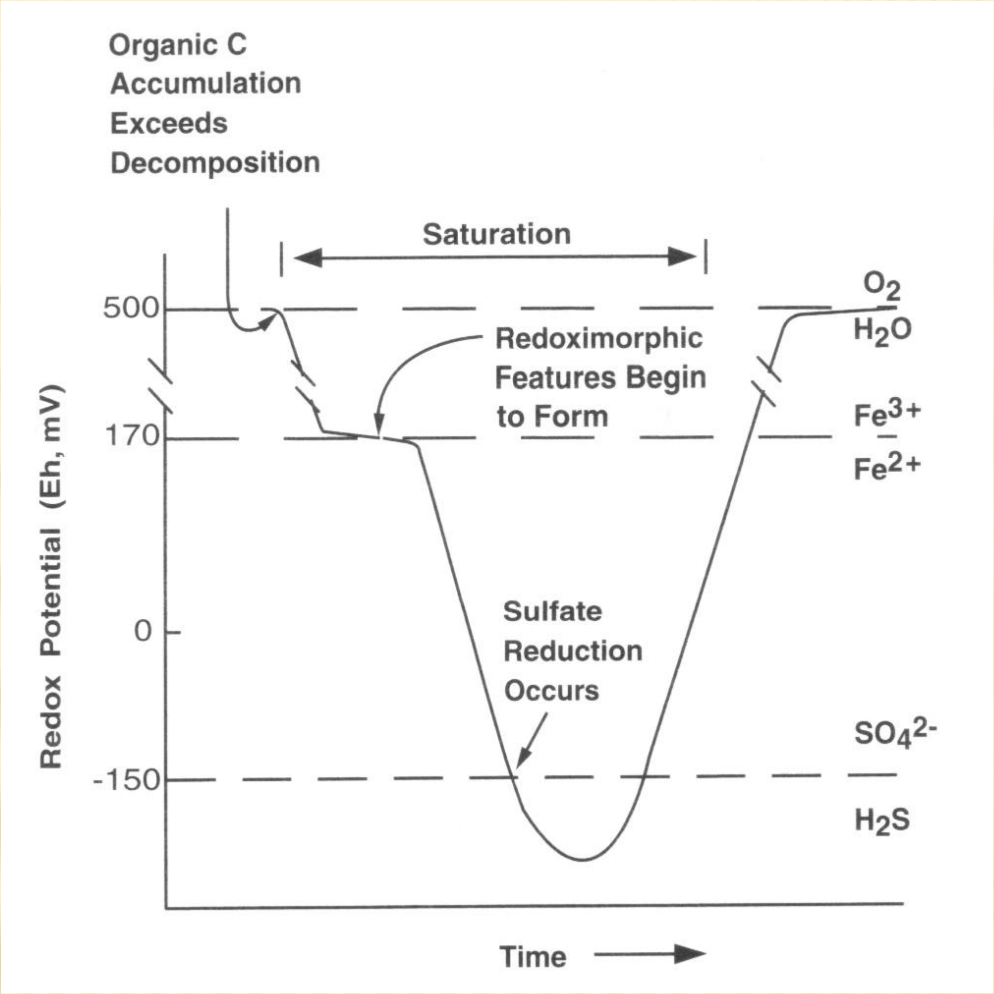


Figure 2. pE–pH diagram for the iron system.

Faust & Aly. 1981. Chemistry of Natural Waters. Ann Arbor Science Publishers, Stoneham MA

Hypothetical changes in redox potential over a wet-dry cycle



Vepraskas. 2001. In Richardson & Vepraskas, eds. Wetland soils.