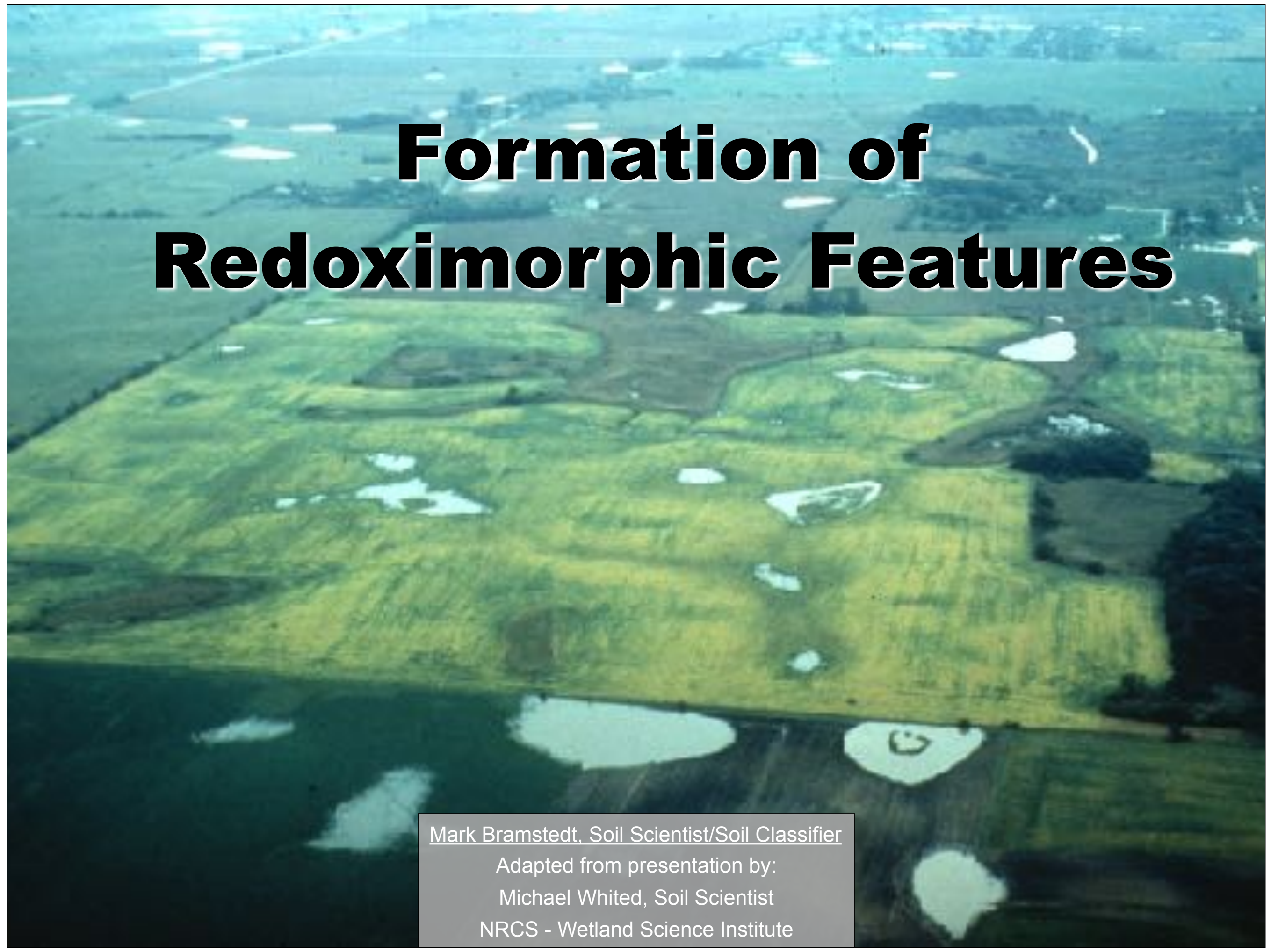


Presentation developed by: Michael Whited, Soil Scientist, NRCS - Wetland Science Inst., August, 2000
It was modified by Mark Bramstedt, Soil Scientist, NRCS Illinois 2017
This is a complete presentation on redox features.

Objectives

- Learn terminology used to describe redoximorphic features
- Explain how redoximorphic features form in wet soils
- Identify and describe redoximorphic features for identifying hydric soils

Self-explanatory

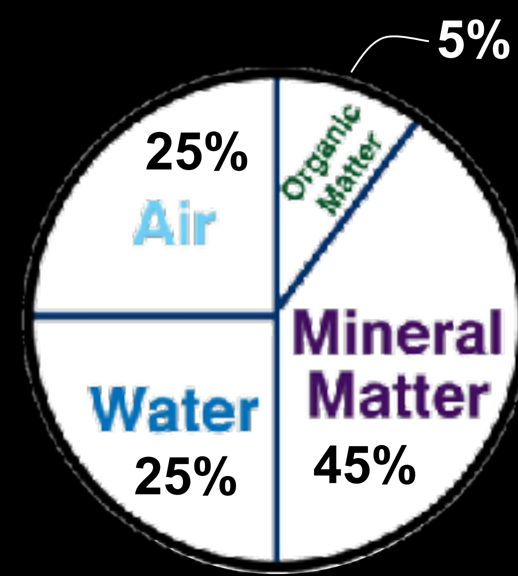
Definition of Hydric Soil

A hydric soil is a soil that is saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions in the upper part.

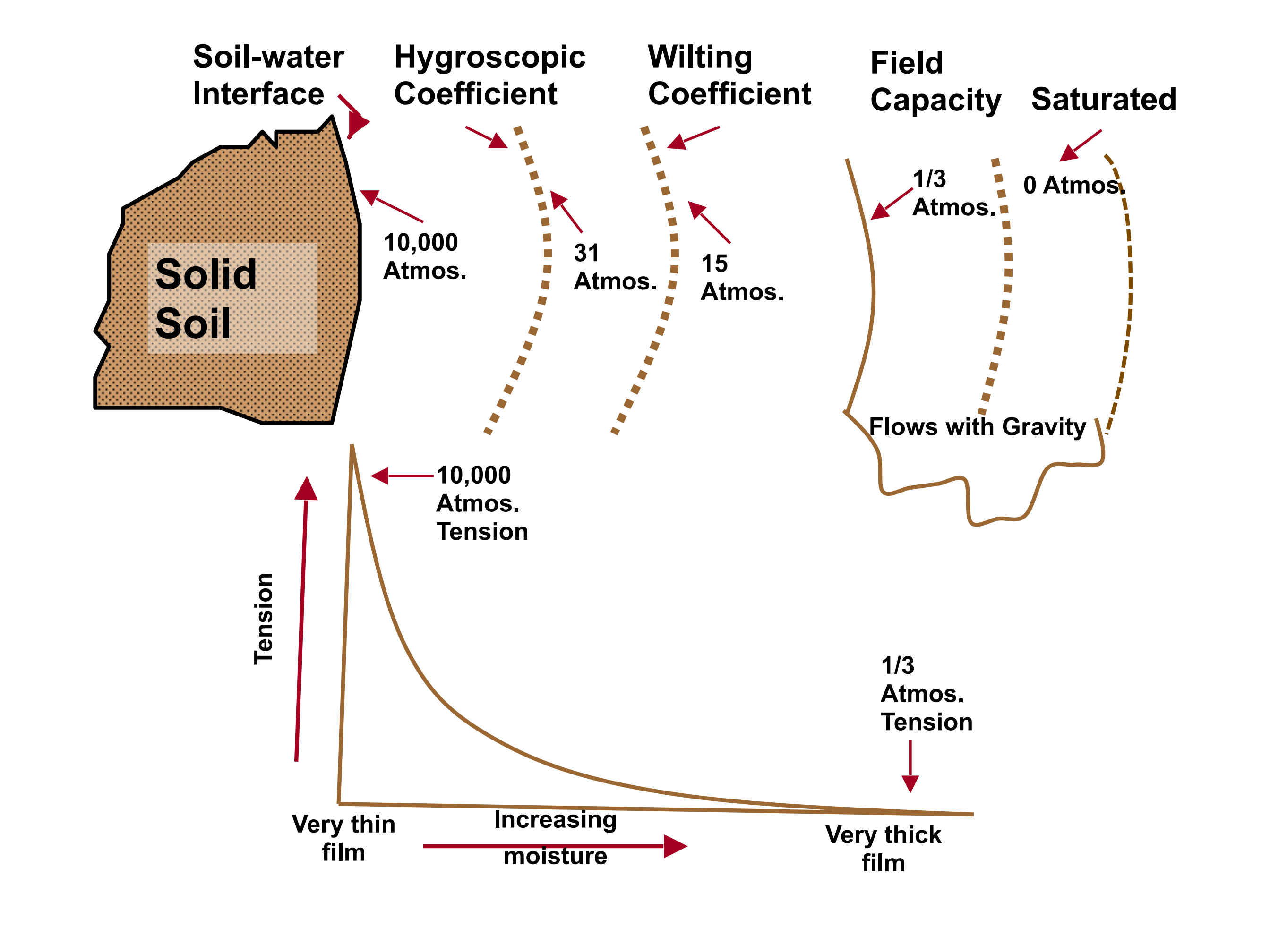
Self-explanatory.
Growing season – portion of year at a depth of 50 cm below surface temperature > 5^{0}C.
Upper part – 30 cm for loamy soils and 15 cm for sandy soils
Concept -

1. Supports growth and regeneration of hydrophytic vegetation
2. Artificially wet (anthric) soils are considered hydric
3. Artificially drained soils are considered hydric

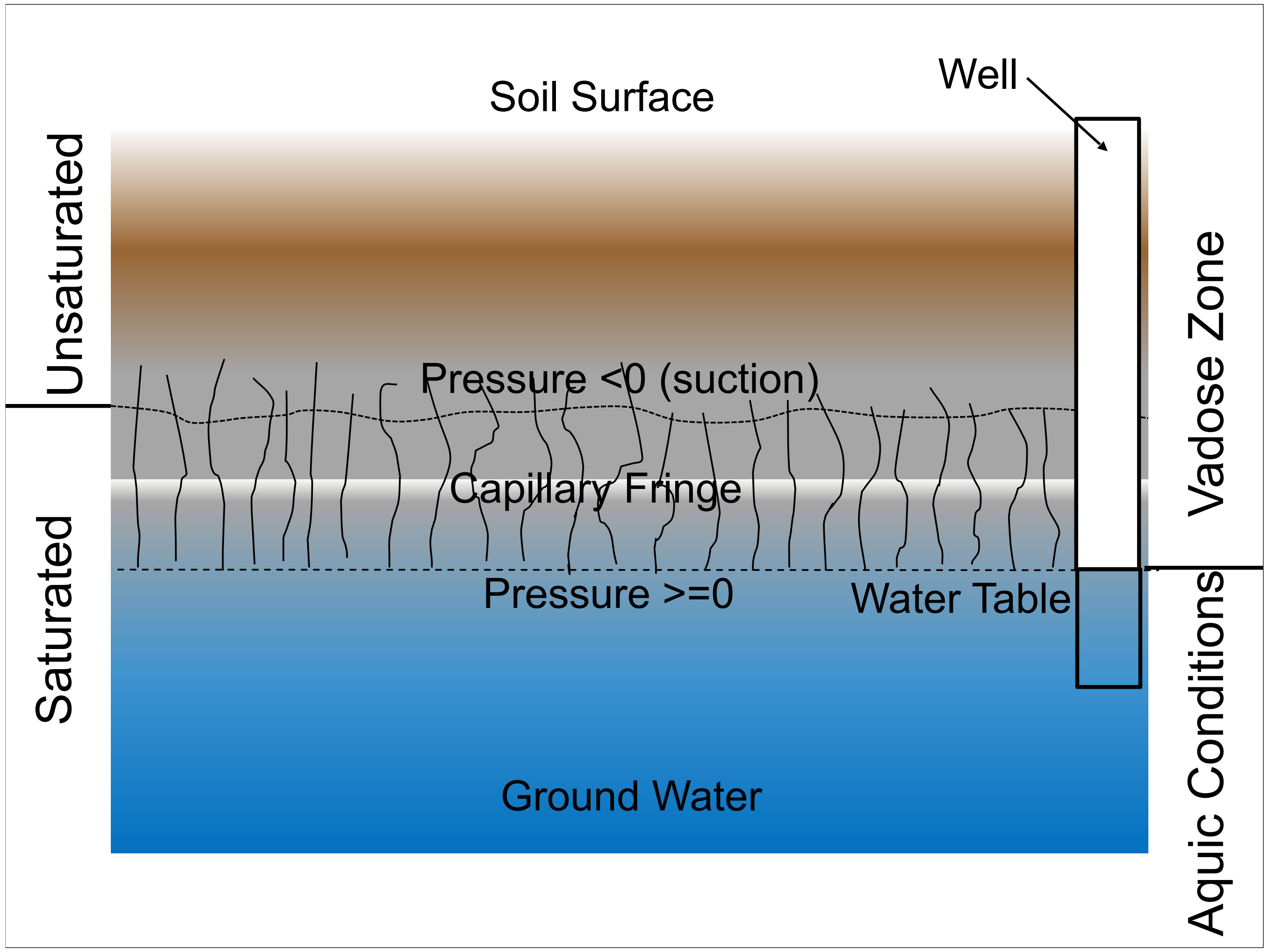
Composition of Average Soil



Self-explanatory
When talk about saturation you are dealing with pore space specifically that which is normally occupied by air (macropores).



Drop dry sponge which represents soil into a water container.
-Let it hydrate to represent field capacity (micro and macropores are all filled).
-Squeeze sponge to represent gravitational water.
-What remains in the sponge is far greater than gravitational water.



Water Table is not the same as Saturation and difficult to define precisely. Above the water table is a tension-saturated zone (*capillary fringe*) where the soil is effectively saturated due to capillary rise. Capillary Fringe is not part of Aquic Conditions UNLESS Iron Reduction occurs. Vadose Zone is the unsaturated zone above the water table, and it includes the capillary fringe. Aquic Conditions are where the soil is Saturated AND Reduced.

Redoximorphic Features

"Redoximorphic Features for Identifying Aquic Conditions"

Technical Bulletin 301
M. Vepraskas
North Carolina State Univ.
Aug 2000/2015 reprint

It would be beneficial to the viewer to have a copy. Good educational source.
This bulletin needs to be read and subsequently re-read to reach a good understanding of oxidation and reduction processes and how they relate to the formation of observable redoximorphic features. These features are then in turn used as field indicators for identifying and delineating hydric soils.

Aquic Soil Conditions

"Soils with aquic conditions are those which currently experience continuous or periodic <u>saturation</u> and <u>reduction</u>. The presence of these conditions is indicated by <u>redoximorphic</u> features and can be verified (except in artificially drained soils) by measuring saturation and reduction." (***Keys to Soil Taxonomy***)

Emphasize that measurements are required to know if you have aquic conditions that reduction is present. You need a meter to measure redox potentials (estimate of electron activity) or a, a`-dipryidyl. For saturation piezometers or tensiometers. So hydric soil indicators were developed to indicate that soils which meet the indicator currently experience continuous or periodic saturation.

Redoximorphic features do not apply to organic soils.

Aquic soil conditions was introduced to cover the requirements of saturation, reduction, and morphological indicators used to define the modified aquic moisture regime. Thus soils with aquic moisture regimes have aquic conditions.

Aquic Soil Conditions

- Artificially drained soils are included with soils that have aquic conditions.
- Artificial drainage = the removal of free water to the extent that water table levels are changed significantly.

Self-explanatory.
Saturated conditions are not required in this case. In general this is because the soil will once again become saturated should the drainage system cease to function.

Aquic Soil Conditions

Requires 3 Conditions:

- **Depth of saturation: a horizon is considered saturated when the soil water pressure is zero or positive**
- **Occurrence of reduction: requires reduction of Fe as well as the depletion of oxygen**
- **Presence of redoximorphic features (mottles)**

Saturation – from the surface to two meters.
Water content definition - Air in all pore space replaced by water.
Water pressure definition - Characterized by zero or positive pressure in the soil water and can generally be determined by observing free water in unlined auger or bore holes.
Types – endosaturation (all layers between surface and two meters, episaturation (saturated layer overlies unsaturated layer within a depth of two meters, and anthric saturation (similar to episaturation by with controlled flooding)

Reduction is a chemical process – Fe must be present in a reduced form at some time.
No minimum time period required for reduction
Any method showing Fe reduction can be used – platinum electrodes to measure redox potential or use of a-a' dipryidyl.

Redox features are observable – visual evidence. Form in soil by reduction, translocation, and oxidation. Will discuss specifics later.

Anaerobic Conditions

Require:

- **Saturation - most all pores filled with water**
- **Oxygen removed from soil by microbes**

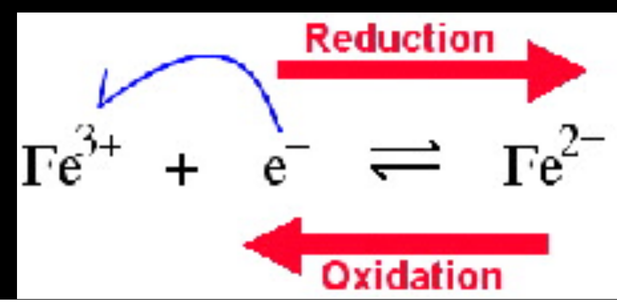
Self-explanatory – If talk about saturation and reduction in aquic soil conditions than you will have anaerobic conditions.
O_2 virtually absent.
OM accumulates whereas it is rapidly oxidized in aerobic environments

Reduction & Oxidation

(redox)

- **Reduction – gain an electron**
  (reduces cation valence – Fe^{+3} to Fe^{+2})
- **Oxidation – lose an electron**
  (increases cation valence – Fe^{+2} to Fe^{+3})

- **Simple Terms – the breakdown of organic material by micro-organisms with oxygen (or other elements) being consumed. Reduction & oxidation occur together.**



Factors Affecting Reduction

- Organic Matter
- Amount of oxygen
- Presence of microorganisms
- pH
- Temperature

Formation of Redoximorphic Features

- **Anaerobic conditions**
  - soil is saturated, pores filled with water, absence of oxygen
- **Prolonged anaerobiosis**
  - changes the chemical processes in the soil
- **Reduction of Fe and Mn oxides**
  - results in distinct soil morphological characteristics
    - most are readily observable changes in soil color

In order for a soil to develop anaerobic conditions it must be saturated so that (most) all pores are filled with water (this water easily drained). When this occurs, any dissolved O_2 that may be present in the soil water is rapidly removed (couple of days, or so) by respiration of micro-organisms, roots, and soil fauna. An anaerobic condition is a condition in which oxygen is virtually lacking from the soil.
Prolonged anaerobic conditions changes biogeochemical processes in the soil. This change in chemical processes results in distinctive soil morphological characteristics being present in most hydric soils. The most important of these are the results of:
reduction, movement (translocation) and subsequent oxidation of iron and manganese, and accumulation of organic matter under anaerobic conditions. In most aerobic environments OM is rapidly oxidized and does not accumulate as readily as in wet soils.
The first process results in the formation of redoximorphic features. Large enough to be seen with naked eye.

Formation of Redoximorphic Features

Organic matter is oxidized and oxygen is reduced.

$$CH_2O + O_2 \xrightarrow{\text{Obligate Aerobes}} CO_2 + H_2O$$

The microbes that facilitate this reaction are known as "obligate aerobes" because they can only exist in the presence of oxygen.

Time: 0 days

Temperature: 15 C

O_2 Content: High

Water Content: Moist

Process occurs when only micropores are filled with water, macropores carry air.
CH_2O represents organic matter. Microbes digest/breakdown OM – oxidized. H^+ ions and electrons released and oxygen takes up electrons – reduced. If OM is not available reduction does not occur.

Formation of Redoximorphic Features

When a soil becomes saturated, aerobic organisms consume oxygen, decreasing the oxygen content in the soil water.

$$CH_2O + O_2 \xrightarrow{\text{Obligate Aerobes}} CO_2 + H_2O$$

$$\xrightarrow{\text{Facultative Anaerobes}}$$

This will create partial anaerobic conditions causing populations of facultative anaerobes to flourish.

Time: 1 day

Temperature: 15 C

O_2 Content: Low

Water Content: Saturated

Macropores filling with water, less air (O_2) entering soil. Microbes which can respire with or without O_2 begin to thrive.

Formation of Redoximorphic Features

These microbes can use an alternative electron acceptor besides oxygen -- in this case nitrate.

Nitrate is usually converted to nitrogen gas through denitrification.

$$CH_2O + O_2 \xrightarrow{\text{Obligate Aerobes}} CO_2 + H_2O$$

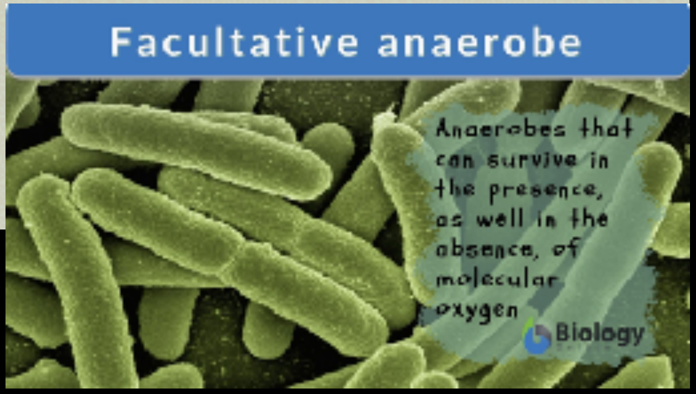
$$CH_2O + NO_3^- \xrightarrow{\text{Facultative Anaerobes}} NO_2^- + H_2O$$

Time: 1 day

Temperature: 15 C

O_2 Content: Low

Water Content: Saturated



While O_2 is being used up, nitrate begins to be reduced by microbes to nitrite or N_2. This particular process is an important function of wetlands. The reduction of nitrate to N_2 gas or denitrification removes the nitrate from agricultural run-off and reduces nutrient loading of streams,

Formation of Redoximorphic Features

Anaerobic Conditions

Usually, 1 to 2 days following saturation, all of the oxygen is depleted from the soil.

Organisms that exist under these conditions are know as "Obligate Anaerobes."

Time: 2 days

Temperature: 15 C

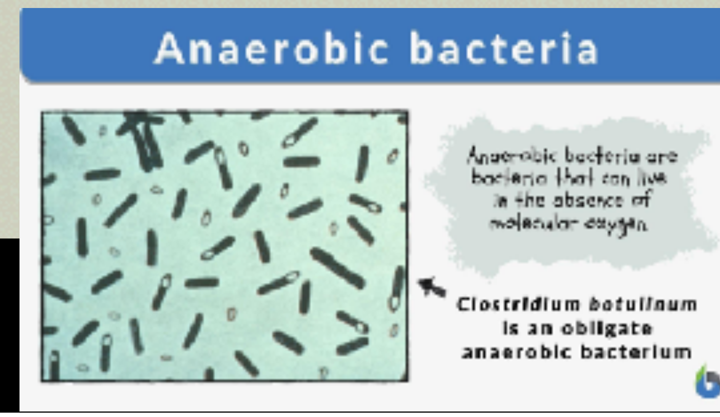
O_2 Content: None

Water Content: Saturated

$$CH_2O + O_2 \xrightarrow{\text{Obligate Aerobes}} CO_2 + H_2O$$

$$CH_2O + NO_3^- \xrightarrow{\text{Facultative Anaerobes}} NO_2^- + H_2O$$

$$\xrightarrow{\text{Obligate Anaerobes}}$$



The rate of diffusion of O_2 through water is much slower than that through air. As a result micro-organisms quickly use up the remaining O_2 in a given area. After about two days oxygen is depleted and anaerobic conditions exist.

Formation of Redoximorphic Features

Anaerobic Conditions

The strongest acceptor of this series is manganese, which occurs in the soil in a manganic form ($Mn^{+3, +4}$)

As these microbes "oxidize" organic matter, manganese is "reduced" to a manganeous (Mn^{+2}) form.

$$CH_2O + O_2 \xrightarrow{\text{Obligate Aerobes}} CO_2 + H_2O$$

$$CH_2O + NO_3^- \xrightarrow{\text{Facultative Anaerobes}} NO_2^- + H_2O$$

$$CH_2O + MnO_2 \xrightarrow{\text{Obligate Anaerobes}} Mn^{2+} + H_2O$$

Time: 5 days

Temperature: 15 C

O_2 Content: None

Water Content: Saturated

Once anaerobic conditions exist manganese is the first substance to be reduced. Reduction of manganic to manganous ion.

Formation of Redoximorphic Features

Anaerobic Conditions

Manganic manganese is insoluble.

Whereas, manganeous is soluble.

This is important because manganese is mobile when reduced and will precipitate upon reoxidation.

This often creates concentrated zones of manganese in the soil profile.

Time: 5 days

Temperature: 15 C

O_2 Content: None

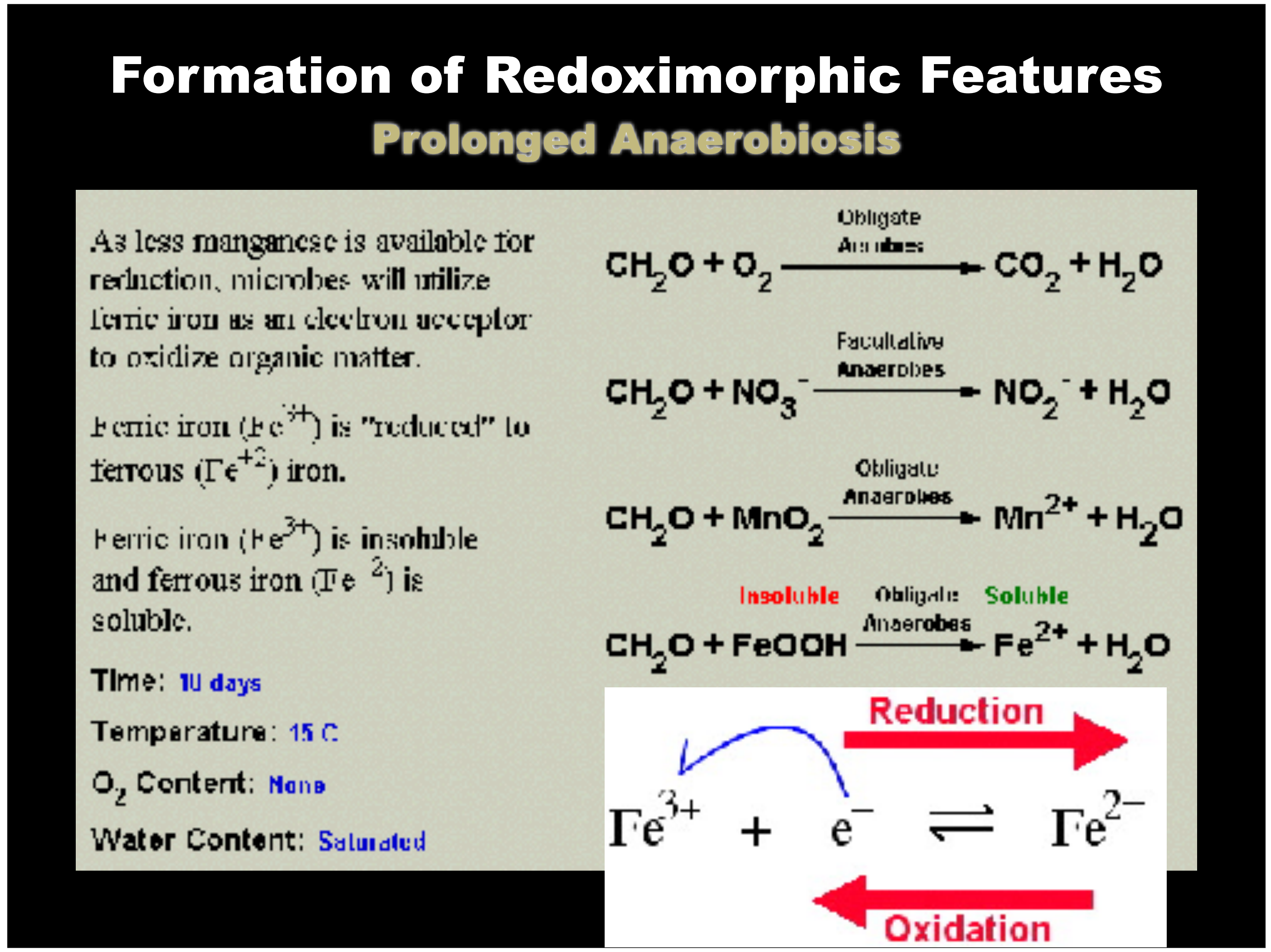
Water Content: Saturated

$$CH_2O + O_2 \xrightarrow{\text{Obligate Aerobes}} CO_2 + H_2O$$

$$CH_2O + NO_3^- \xrightarrow{\text{Facultative Anaerobes}} NO_2^- + H_2O$$

$$CH_2O + \underset{\text{Insoluble}}{MnO_2} \xrightarrow{\text{Obligate Anaerobes}} \underset{\text{Soluble}}{Mn^{2+}} + H_2O$$

Manganic ions will stay in place. Manganous ions will flow with the water. If encounter O_2 will precipitate out.



Once prolonged anaerobiosis take place (about 10 days) Fe is next substance for microbes to act on once Mn has been reduced. Note that the reduction of Mn and then Fe does not occur simultaneously throughout the whole soil profile but within localized areas. Ferric ions stay in place while ferrous ions move with the water.

Formation of Redoximorphic Features

Prolonged Anaerobiosis

Iron is one of the primary soil components that determines soil color.

When iron is in the ferrous form it is soluble and can be concentrated in some areas and depleted in others.

Therefore, this reaction will result in changes in soil color that can be used to indicate hydric soil conditions.

$$CH_2O + O_2 \xrightarrow[\text{Aerobes}]{\text{Obligate}} CO_2 + H_2O$$

$$CH_2O + NO_3^- \xrightarrow[\text{Anaerobes}]{\text{Facultative}} NO_2^- + H_2O$$

$$CH_2O + MnO_2 \xrightarrow[\text{Anaerobes}]{\text{Obligate}} Mn^{2+} + H_2O$$

Insoluble | Soluble

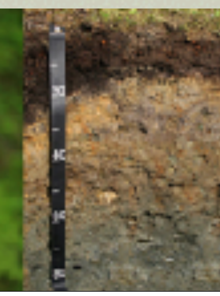
$$CH_2O + FeOOH \xrightarrow[\text{Anaerobes}]{\text{Obligate}} Fe^{2+} + H_2O$$

Time: 10 days

Temperature: 15 C

O_2 Content: None

Water Content: Saturated



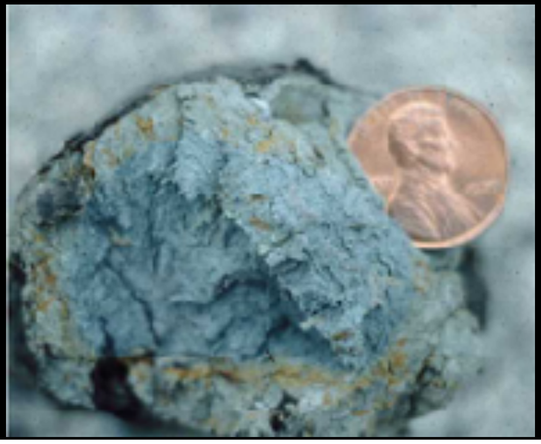
Fe is main component of soil color. Iron oxide coats soil particles giving soil its color. Ferric and ferrous iron key in determining hydric soil conditions.

How Do Redoximorphic Features Form?

Fe^{+3} and Mn^{+3} & Mn^{+4} are reduced by bacteria decomposing organic matter under anaerobic conditions.

If organic matter is dead root tissue, reduction will occur in the soil near the root.

If organic compounds are dissolved in the water, then reduction occurs wherever pores are filled with water.



Since Fe and Mn are keys in determining field indicators need to re-emphasize these points. Oxidized states changed to reduced states by microbial action.

How Do Redoximorphic Features Form?
(continued)

Once reduced:

- Fe and Mn begin to dissolve in water
- Soil color changes to gray
- Reduced Fe+2 and Mn+2 ions diffuse, or move with the soil water to other parts of the soil, or are leached from the soil
- Fe+2 & Mn+2 can be oxidized and form features as Fe+3 & Mn+3 oxides in the presence of O2

Reduced states are soluble. Moves with water. Accumulate in some areas or could exit entire soil profile.
Once Fe and Mn coatings dissolve the natural color of the uncoated soil grains becomes evident which is gray.

Formation of Redoximorphic Features

Prolonged Anaerobiosis

As iron become less available, microbes will use sulfate (SO_4^-) as an electron acceptor.

Sulfate is reduced to hydrogen sulfide (H_2S).

Hydrogen sulfide has a "rotten egg" odor and is often associated with permanently saturated portions of wetlands.

Time: 1 month

Temperature: 15 C

O_2 Content: None

Water Content: Saturated

$$CH_2O + O_2 \xrightarrow{\text{Obligate Aerobes}} CO_2 + H_2O$$

$$CH_2O + NO_3^- \xrightarrow{\text{Facultative Anaerobes}} NO_2^- + H_2O$$

$$CH_2O + MnO_2 \xrightarrow{\text{Obligate Anaerobes}} Mn^{2+} + H_2O$$

$$CH_2O + FeOOH \xrightarrow{\text{Obligate Anaerobes}} Fe^{2+} + H_2O$$

$$CH_2O + SO_4^- \xrightarrow{\text{Obligate Anaerobes}} H_2S + H_2O$$

Common with organic soils. Is indicator.
CO_2 is next to be reduced after sulfate. Produces methane or natural gas (swamp gas).

Reduction Sequence In Soils

+350 mV	Oxygen	O_2	→	H_2O
+220 mV	Nitrogen	NO_3^-	→	N_2; NH_4^+
+200 mV	Manganese	Mn^{+4}	→	Mn^{+2}
+120 mV	Iron	Fe^{+3}	→	Fe^{+2}
-150 mV	Sulfur	SO_4^{-2}	→	H_2S
-250 mV	Carbon	CO_2	→	CH_4

Summary of sequence of reactions.
Reduction-oxidation potentials identified.
Obligate aerobes, facultative anaerobes, and obligate anaerobes.
Anaerobic conditions begin with Mn reduction.
+400 to +700 mV for oxidized soils, +100 to +400 mV for moderately reduced soils, -100 to +100 mV for reduced soils, and <-100 mV for highly reduced soils.
Oxidation sequence goes in reverse order. So if soil begins to drain and becomes oxygenated and Fe is present, Fe will oxidize before Mn.
Well we can not easily measure denitrification in a normal field evaluation of a site, the reactions with manganese are a little complex. If we smell sulfur we are probably in a hydric soil – The answer – we can see the result of the change in the amount and distribution of iron in the soil.

Formation of Redox Features

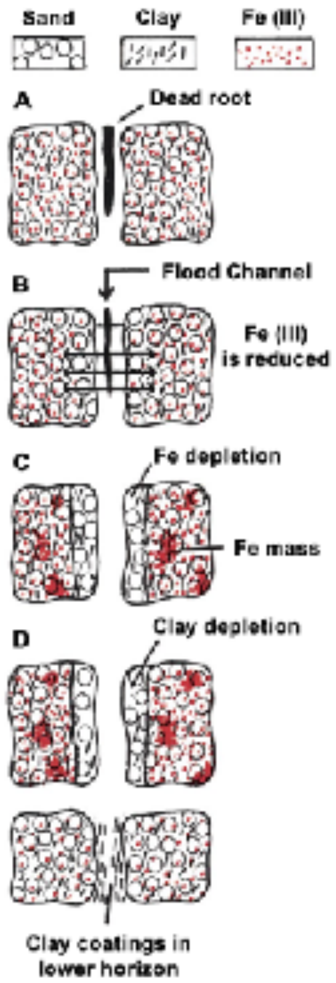
The process begins with…

A. A decomposing root lying in a channel

B. Fe in soil along Channel is reduced when the root's decomposition occurs anaerobically. The reduced Fe (II) may diffuse into the soil matrix. An Fe depletion occurs along the channel when enough Fe has been lost to produce a color chroma of 2 or less.

C. Iron masses form when the Fe (II) in the matrix oxidizes to Fe (III). The loss of Fe makes clay along the channel dispersible, and water moving along the channel may illuviate this clay to a lower horizon.

D. Clay depletions form where the clay has been removed.



Where all the microbe and chemical reactions are taking place within the soil.

Reduction and oxidation can take place at the same time within a soil profile. Depending upon where there is O_2 or a lack of it which is dependent on the wetting and drying of a soil.

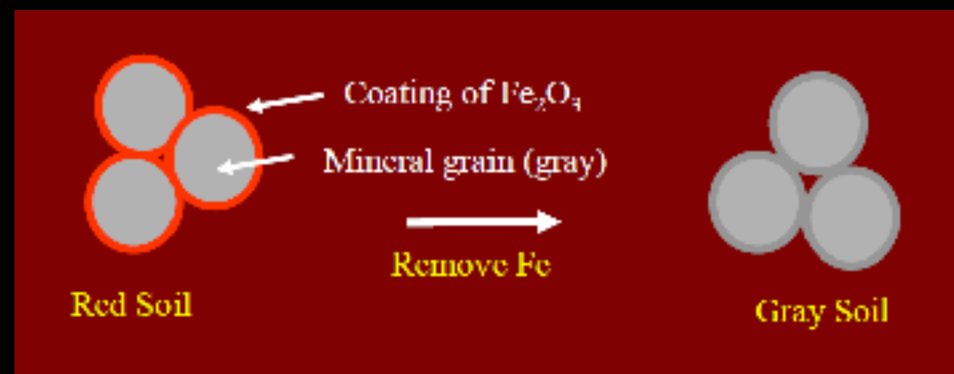
We will talk specifically about types of redoximorphic features in a bit.

Soil Color & Oxidation/Reduction

Natural color of uncoated mineral soil grains is typically gray.
The more OM the darker the color.
Iron oxide coatings on particles gives them yellow, brown, or red colors depending on which mineral form the iron is in.

Soil Color & Oxidation/Reduction

- Fe^{3} and $Mn^{3\&4}$ oxides “paint” soil particles brown, red, yellow.
- When reduced, Fe^{2} and Mn^{2} are mobile, stripped from the soil, leaving grayish mineral grains .



NOTE: gray does not mean reduced Fe is present but that oxidized Fe is absent.

Most mineral soil grains are dominantly silica, so they are generally “colorless”, i.e. gray or whitish, unless they are coated by OM or Fe.
Oxidized state of Fe on the left and reduced state of iron on the right.

Types of Redoximorphic Features

Redox Concentrations
- Masses
- Pore Linings
- Nodules and Concretions

Redox Depletions
- Depleted Matrix

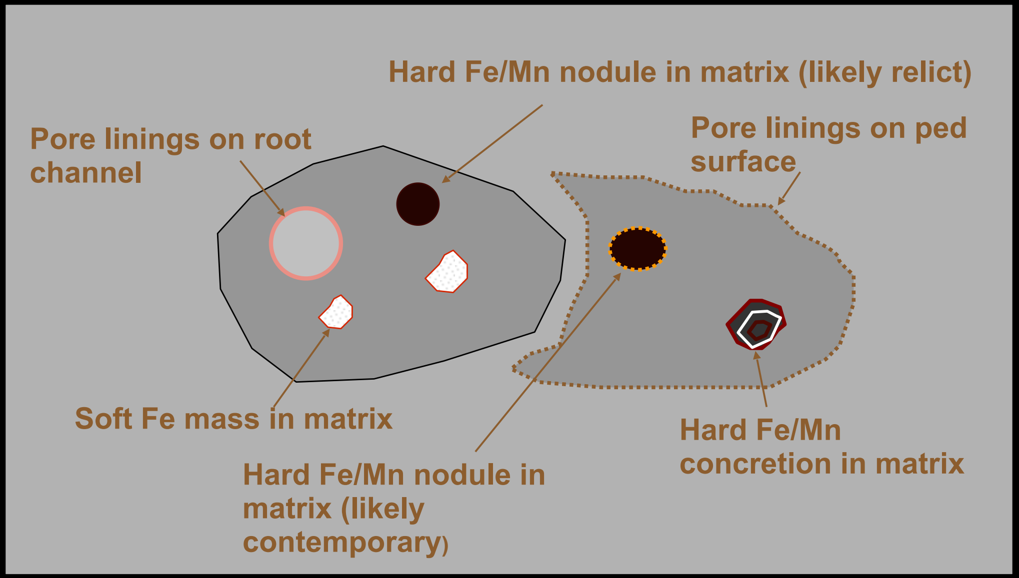
Reduced Matrix

Formerly identified as mottles and low chroma colors.
Types of redox features listed. These features formed by the reduction, translocation, and oxidation of iron and manganese oxides.

Redox concentrations are oxidized state.
Redox depletions are reduced state.
I have added Depleted Matrix as a “subset” of redox depletions, after all it is a big depletion.

1) These features are easily identified and described by soil mappers in the field.
2) They are a telltale sign of the soil hydrology and persist for a very long time.
3) Because they are formed as a result of the soil hydrological condition they are good indicators of the drainage characteristics of the soil.

Redox Concentrations



Schematic illustration showing different kinds of redox concentrations and their relationship to soil macropores and matrices

Review this adaptation of Fig. 1, pg. 7 in Vepraskas (1995)

Redox Concentrations

Accumulation of Fe-Mn oxides

- Masses
- Pore Linings
  - ped faces
  - root channels
- Nodules & Concretions

Redox concentrations, most often (in upper horizons) they occur as pore linings in root channels and pore linings on ped faces.

Note the difference in soil terminology vs. hydrology indicators. Soil scientists say redox concentrations as pore linings in root channels, NOT the same as oxidized rhizospheres which require living roots. In fact, the rhizosphere is on / immediately adjacent to root and the roots should have an iron "plaque" on them in order to be used as a hydrology indicator.

Picture is redox concentrations occurring as pore linings on ped faces and in root channels.

Soft Masses

- Soft bodies
  - frequently in the soil matrix
  - variable shape
  - may be removed from the soil “intact”
  - diffuse boundaries

Formerly called reddish mottles
With reduced iron and manganese soil grains have gray colors. Iron and manganese will be oxidized (red, yellow, and brown colors coat soil particles) where air slowly penetrates into a horizon.
Darker colored masses are dominated by Mn.

Coatings in pores

Zones of accumulation

- coatings on a pore surface
- Impregnation of coatings in matrix next to pores

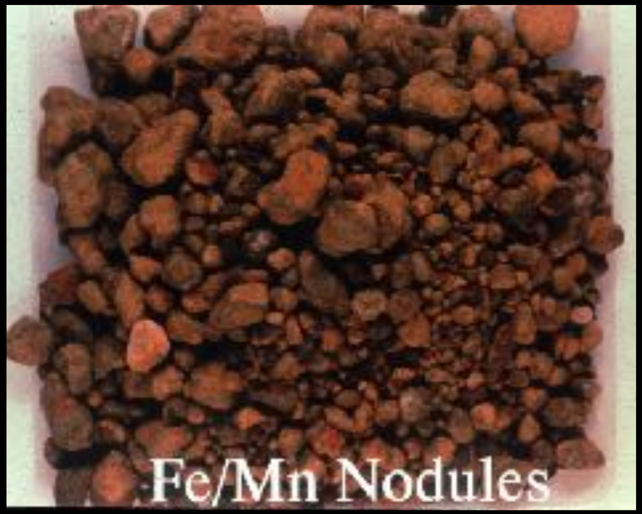
Picture is of pore linings along root channels.
Pore linings also occur along ped surfaces
Pores become aerated. Reduced Fe migrates towards pores and oxidizes adjacent to pores.
This is an obvious case of “oxidized rhizospheres.”

Nodules and Concretions

Firm to extremely firm bodies

- **often relict**
- **should be irregular shape***
- **diffuse boundary***
  - **“halo” or “corona”**

*** Contemporary**



Many sizes
Screened Fe nodules from a soil in Texas. In Texas these features are sometimes used on “gravel” roads. These are most likely relict.
Contemporary concretions / nodules should have “halos”, diffuse boundaries, or be irregular in shape. Diffuse = currently forming. Relict concretions have sharp boundaries. Also possibly redder hues 10R, 5R, 2.5YR vs. 5YR, 7.5YR, 10YR, 2.5Y.
Concretions have concentric rings, nodules do not. Nodules have uniform internal fabric
The material making up concretions is believed to come from the surrounding sediment, being redeposited/precipitatied around a nucleus. They are similar in composition to the sediments that surround them.
Nodules are hard bodies which differ in composition than the sediments that contain them. Nodules may also form by the selective precipitation of dissolved minerals that completely replace the original sediment.
Generally if concretions and nodules are the only redoximorphic feature present they should be considered relict features.

Photo from M. Vepraskas.

Redox Depletions

Bodies of low chroma; Fe-Mn oxides have been stripped

- **value ≥ 4 & chroma ≤ 2**
- **formerly called “gray mottles”**

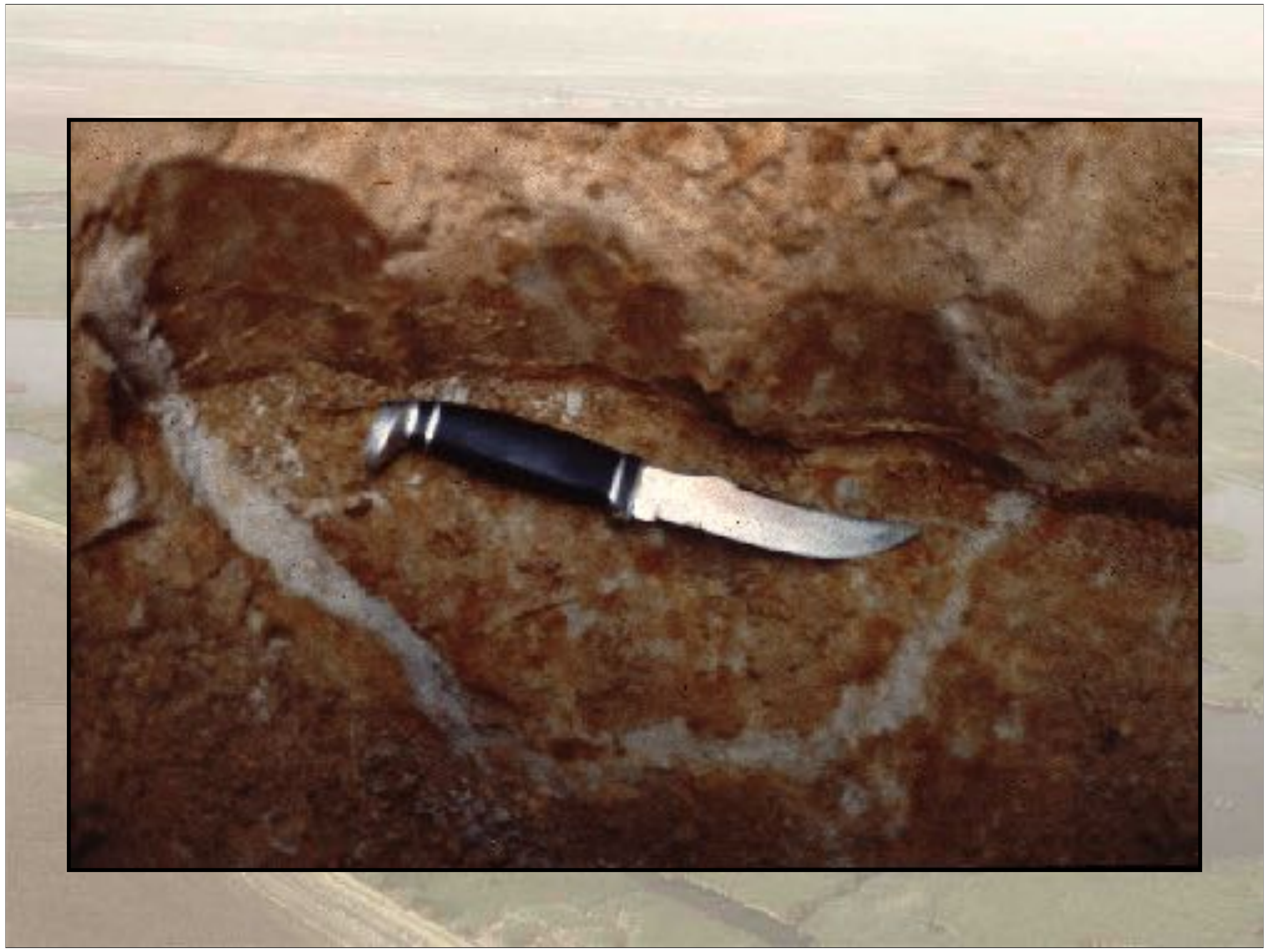
Picture shows redox depletions along root channels. Redox depletions are most common along root channels because this is where the OM is available to energize the microbial reduction process.

Redox depletions are generally not used to identify hydric soils unless the depletions dominate and therefore become the matrix color which is defined by the term “depleted matrix.”

Note: Although not defined in any of the present soil survey guidance it is possible to have redox depletions that are not so gray. For example a 4 chroma (possibly red parent material) soil with 3 chroma “mottles.” If one was sure these features formed as a result of saturation and reduction they should be considered redox depletions. (Mike Vepraskas, pers. commun.).

Redox depletions along root channels in an episaturated (perched water table) soil. The upper part of the profile is depleted. Water perches on the clay layer and as it trickles down through root channels into subsoil reduction occurs along root channels.

Photo by Warren Lynn - NRCS.



Redox depletion along ped face in subsoil. This is common morphology in subsoils with fragipans.
Picture is looking down at a horizontal cross-section.

Depleted Matrix

- Dominant color of the soil is "gray"
- Commonly used to identify hydric soils
  - Discussed more in hydric indicators section

Depleted matrix with iron masses. Essentially a depleted matrix is a fairly continuous iron depletion. Organic carbon has to be in solution for depleted matrix.

Reduced Matrix

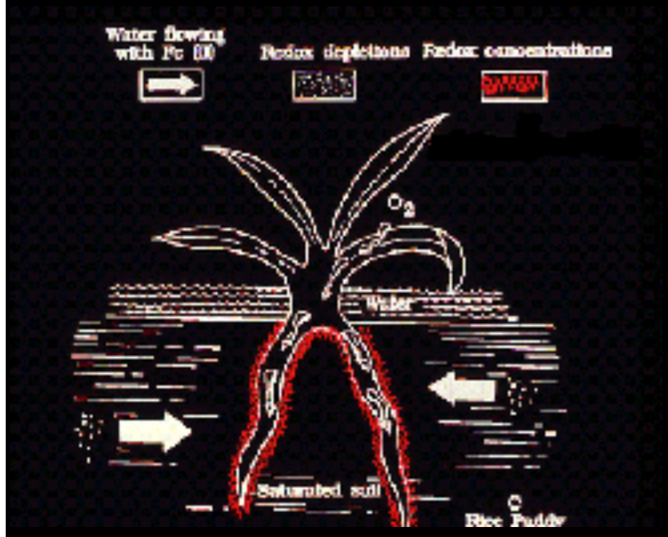
Soils have high value, low chroma in situ
Color changes when exposed to air

- **Reduced Fe is present**
- **Fe^{2} is oxidized to Fe^{3} upon exposure turning yellowish after 30 minutes**

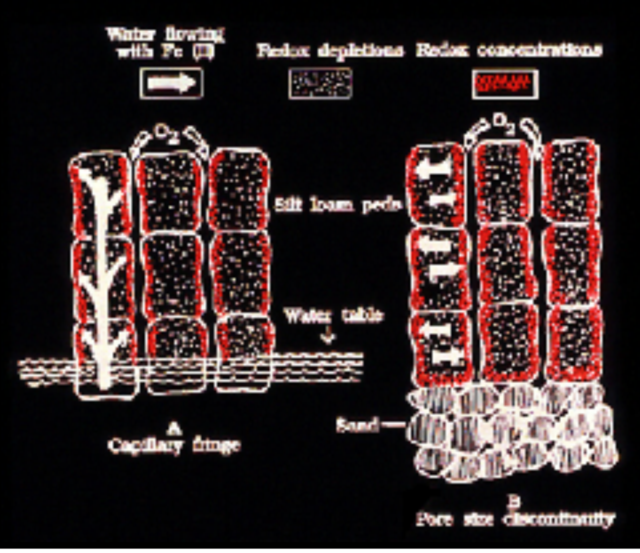
Reduced matrix in Missouri River flood sediments. Large polygons were cracked so that outside surface had been exposed to air (brown color), when broken open the interior color was gleyed.

Redox Concentrations
Processes of Formation

- **Oxidized Rhizosphere: Oxygen pumped from leaves to roots**



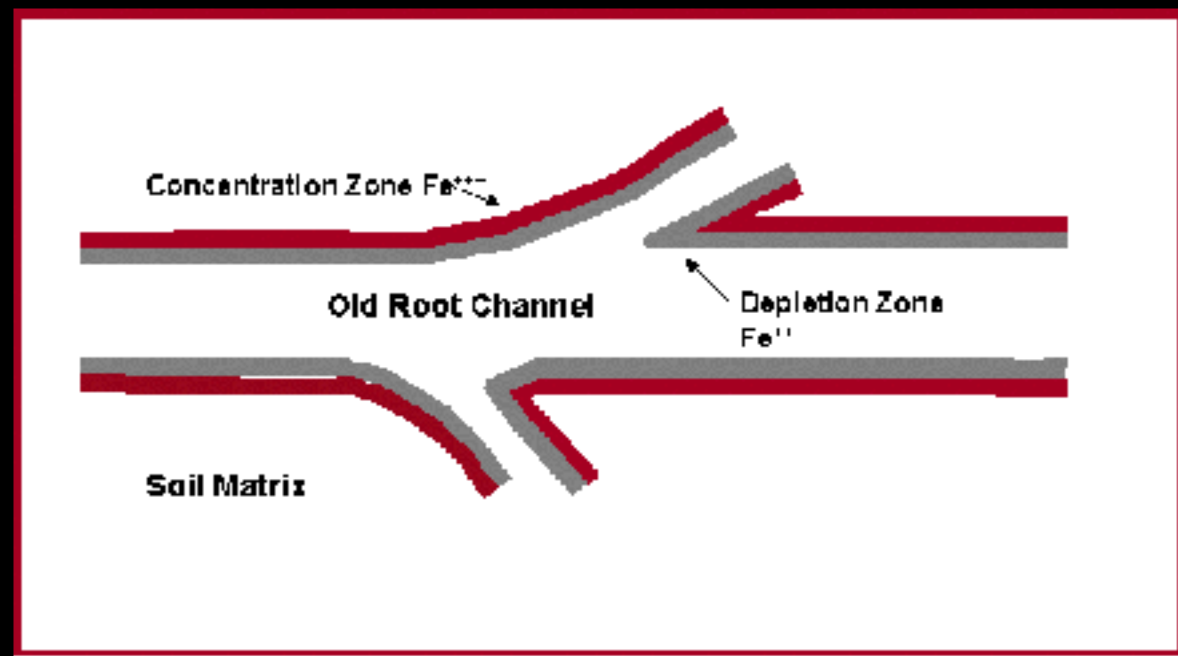
Unsaturated Flow: diffusion of Fe & Mn ions to aerated macropores



See page 5.7 in student book for this sequence of slides
Methods of transport.

Redox Depletions

Process of formation



Formation of redox depletions and concentrations along root channels

Explain based on "Redoximorphic Features..." booklet.

See pages 13 - 14 in Vepraskas (1995).

Need stable macropores so features can enlarge. Decaying root provides energy source. Macropore is filled with water and is devoid of O_2. Fe is reduced and forms depletion along the channels. Ferrous iron diffuses across root channel boundary to matrix where O_2 is present and oxidizes forming iron concentrations.

Arrangement of redox depletions and redox concentrations in a horizon might be used to interpret how water and air move through a soil. To do this effectively you must specify which features lie along macropores and which lie in the matrix. If horizon has both depletions and concentrations, the water moved from the depletions to the concentration.

Rate of Feature Formation

Variable - 2 mm thick Fe depletion around a root channel <1yr - >100 years

Recently constructed wetlands should have redox depletions evident within a couple of years if wetland hydrology is present during the “growing season”

Everyone asks this question, the basic answer is “it depends”.
A soil can become anaerobic under the right conditions in as little as 1 day (warm temperatures, stagnant water, fresh OM, etc.) and reduced in less than a week.
Note: The amount of iron depletions is dependent upon how long the soil has been reduced not how long it has been saturated.
Note: When soil scientists say “reduced”, they are talking about the level of reduction necessary to change ferric Fe to ferrous Fe.
In flooded rice paddies, pore linings can form within seven days around aerated roots once the iron in the matrix has been reduced.

Age of Features

Redox features do not always indicate current hydrologic condition

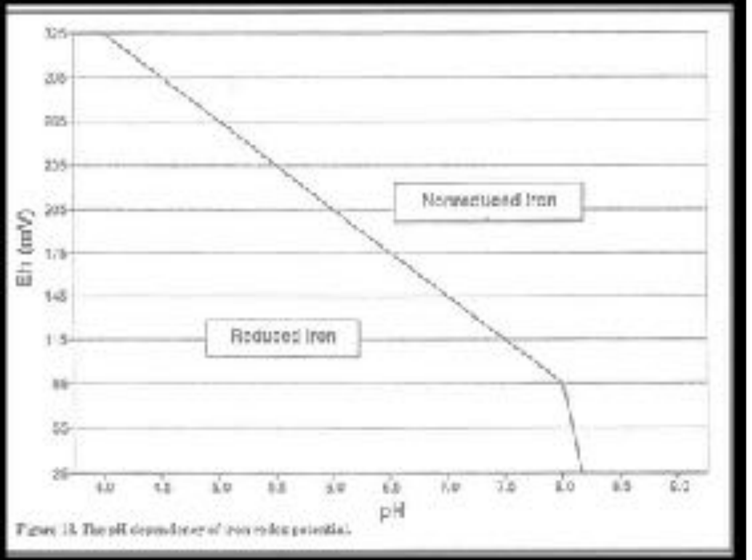
- commonly found in drained (historic) wetlands
- can be relict of past climates
- relict features - sharp edges & abrupt boundaries with soil
- contemporary features -e diffuse boundaries associated with ped faces or root channels

Redox features can persist for 1000's of years.

Interpretation Problems

Redoximorphic features do not occur in all soils

- Low amounts of carbon
- High pH >8.2
- Cold temperatures
- Low amounts of Fe
- Aerated groundwater



Low amounts of OM, generally , < 2% OM (e.g. sandy soils) – low energy source
High pH, iron will not become soluble at pH> 8.2, redox status is pH dependent, explain chart.
Cold temperatures, below “biological 0” (<5^{0}C or 41^{0}F). Research has shown that the concept of biological zero may not be valid as reduction occurs in “frozen” soils in Alaska; however, the rate of reduction is very slow.
If no Fe in the soil system can’t form redox features (e.g E horizons of Spodosols, some parent materials such as sand).
Aerated groundwater - Water must move slowly or stagnant for reduction to occur. Soil may be wet (even saturated) but O_2 in water prevents reduction (fast moving water in floodwaters, sloping wetlands, sandy soils with rapid permeability). When water table rises due to rainfall alone.
(more of this in “Problem Soils” module).

a, a' - Dipyridyl

A dye used to test for the presence of reduced Fe

- pink reaction to Fe^{+2}
- dye sensitive to light and heat
- apply to freshly broken open soil ped

a, a' - Dipyridyl applied to a fresh slice of soil from top to bottom

Summary
Development of Hydric Soils

Inundation or soil saturation

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Anaerobic conditions

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Chemical reduction (O, N, Mn, Fe, S, C)
by microbial action

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Removal or re-oxidation
(Fe & Mn)

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Redoximorphic Features

↓ ↓

Concentrations (oxidized) **Depletions (reduced)**

Flooding, ponded, or saturated (soil water pressure is zero or positive relative to atmoshpheric pressure)
Pores saturated. Microbes consumed all the oxygen.
Fe and Mn have most effect on color for redoximorphic features .
Redoximorphic features are produced which are key in field indicators for hydric soils.

Gotta love those redoximorphic features!