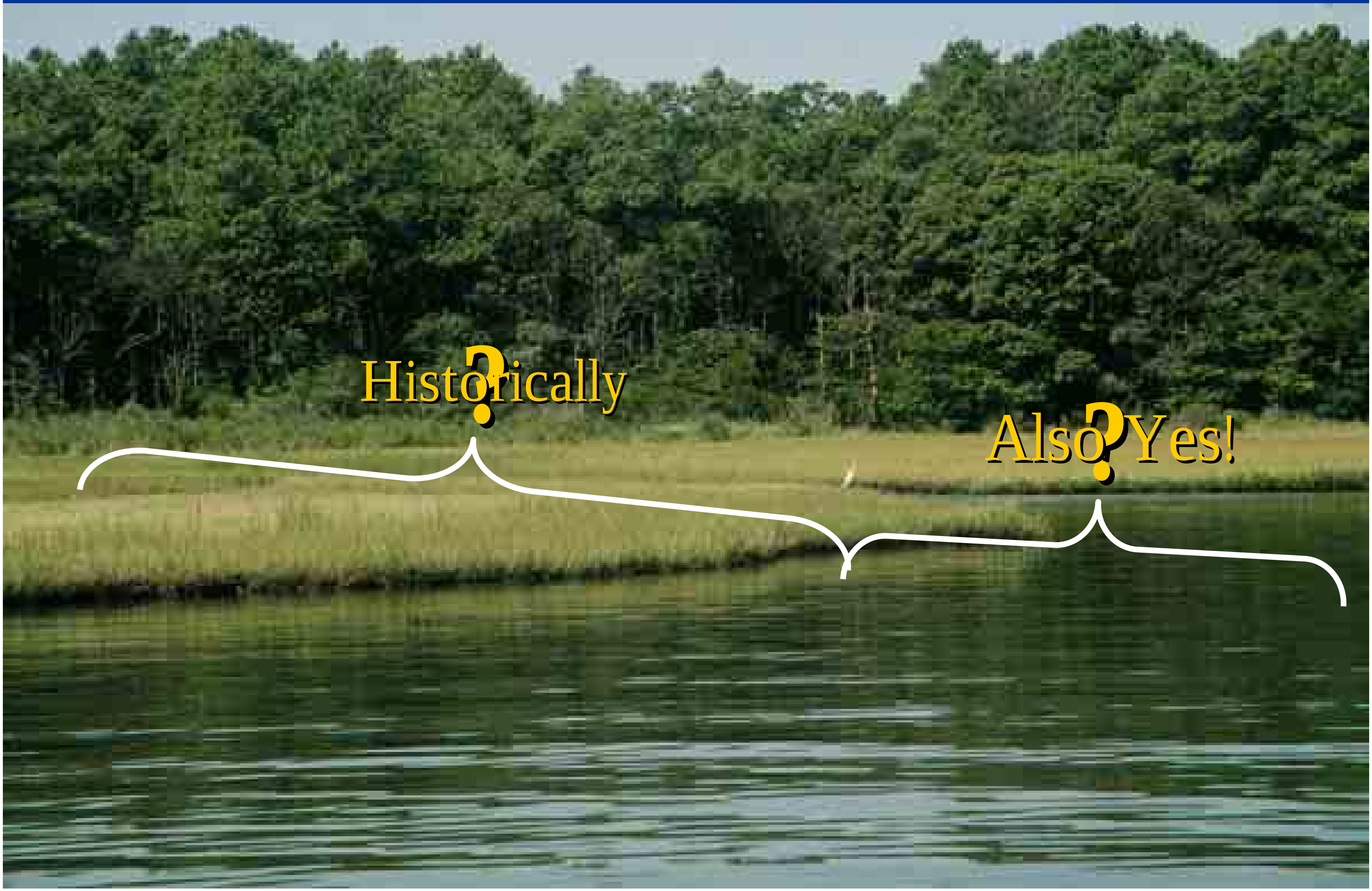
# An Introduction to Subaqueous Soils

# Where do we work?



# Early Concept Papers

- Demas, G. P. 1993. Submerged Soils. Soil Survey Horizons.
- Demas, G. P., M. C. Rabenhorst, and J. C. Stevenson. 1996. Subaqueous Soils: A pedological approach to the study of shallow water habitats. Estuaries 19: 229-237.

# Awards given to George Demas for pioneering work in Subaqueous Soils

- USDA - Secretary’s Honor Award for Scientific Research

- Soil Sci. Soc. of America - Emil Truog Award for outstanding contribution to Soil Science through the Ph.D. thesis

# Definition of Soil

- *Soil* .... is a natural body .... that occurs on the land surface, ... and is characterized by [either]
  - 1. ..... horizons, or layers, that are distinguishable from the initial material as a result of additions, losses, transfers, and transformations of energy and matter *or*
  - 2. the ability to support rooted plants in a natural environment.....

from *Soil Taxonomy 1999*

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  - 2. the ability to support rooted plants in a natural environment.....
- The upper limit of soil is the boundary between soil and air [or] shallow water, ...... [not]… too deep (typically more than 2.5 m) for the growth of rooted plants.

from *Soil Taxonomy 1999*

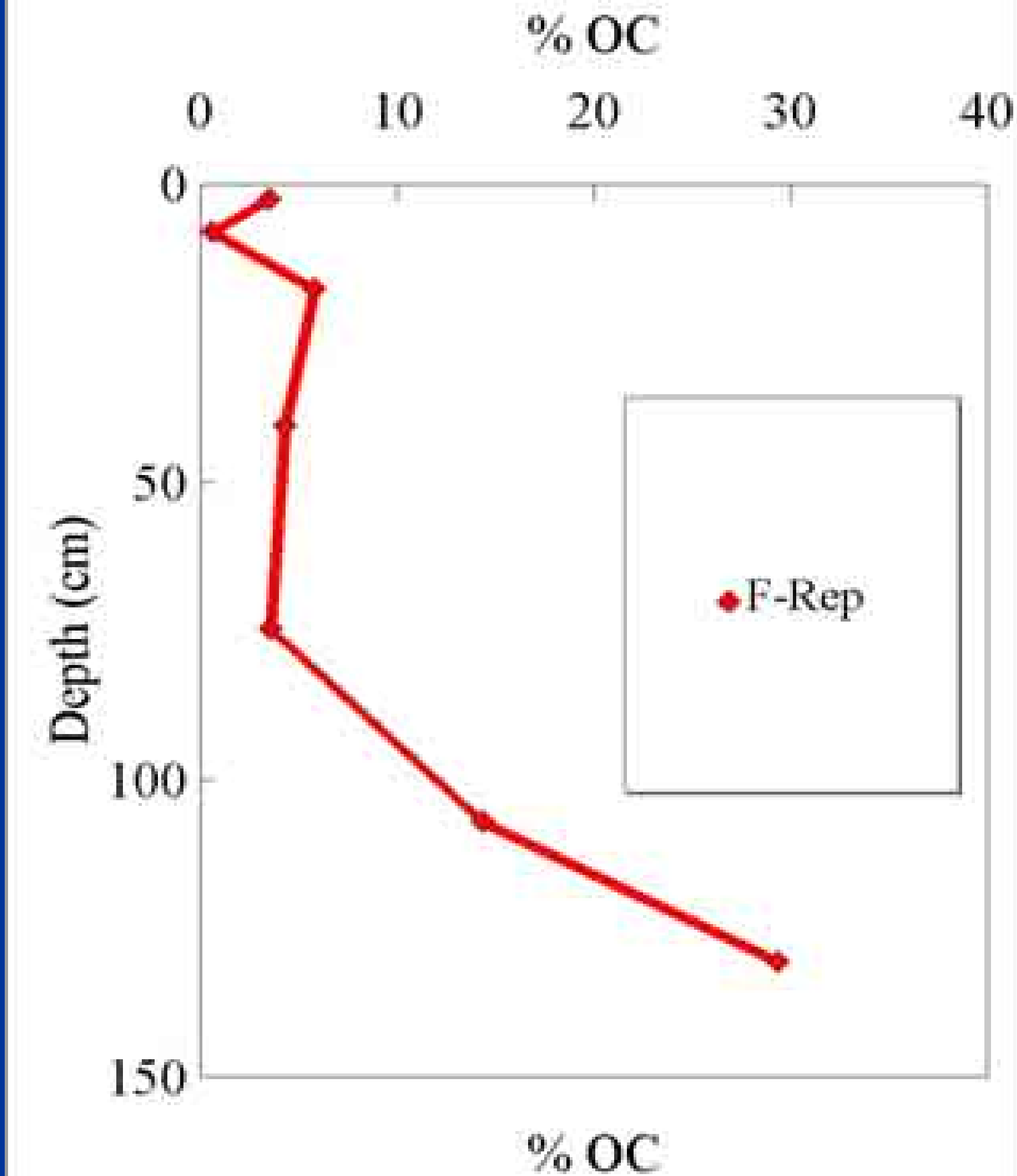
# Soil Horizons

# Simonson's Generalized Theory of Soil Genesis

- Soil horizons form as a result of:
  - Additions
  - Losses
  - Transfers
  - Transformations
- How are these processes at work in subaqueous environments?

# Additions

- Additions of mineral sediments
  - Evidenced by buried soils
  - Perhaps more like a geological than pedologial process
  - Exhibit discontinuities and buried surfaces similar to terrestrial alluvial soils like Fluvents and Fluvaquents
  - Equally important in both in both environments


% OC
0
10
20
30
40
0
50
100
150
Depth (cm)
F-Rep
% OC

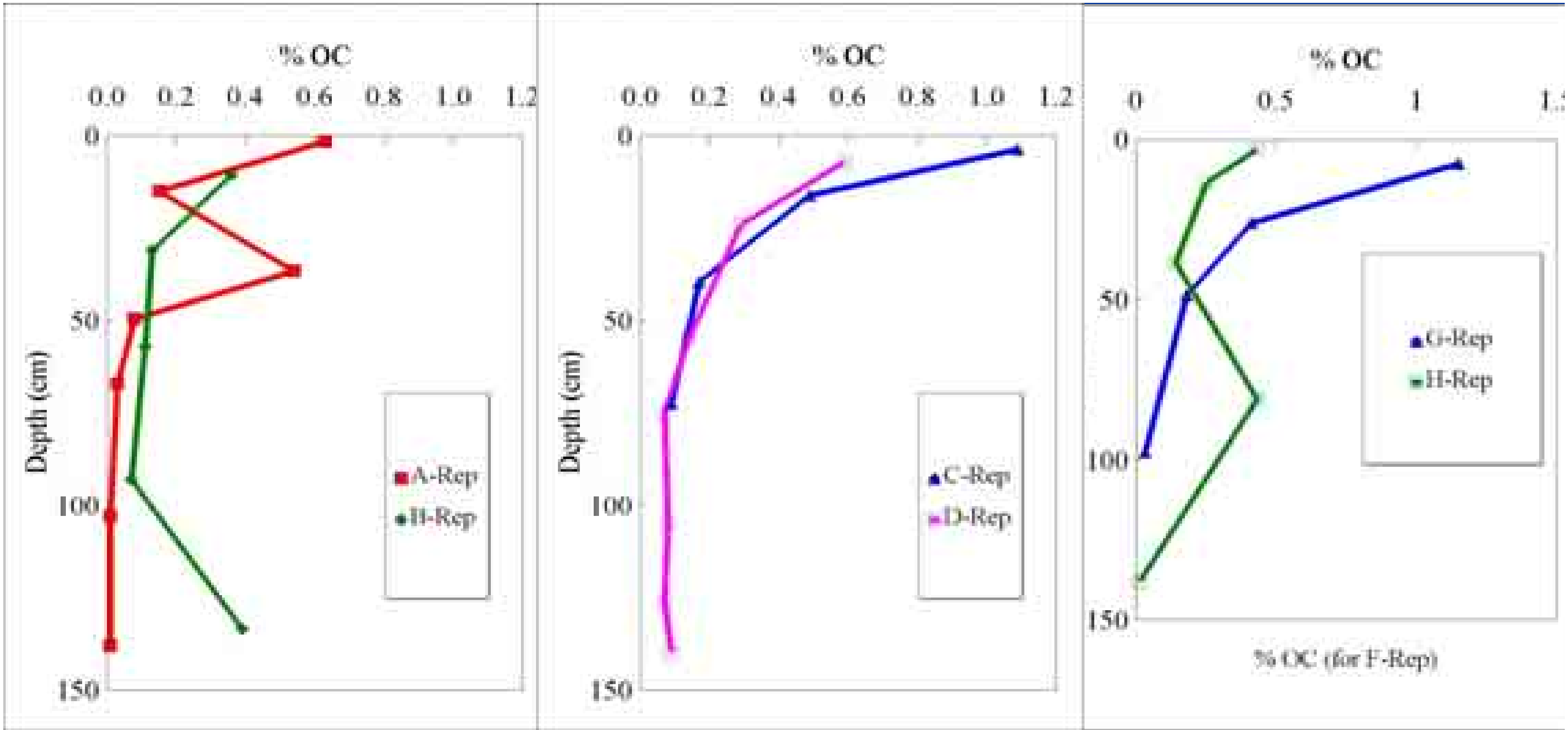
# Additions

- Additions of sediments of biological origin
  - Shell fragments
    - Oysters (Crassostrea virginica)
    - Hard clams (Mercenaria mercenaria)
    - Jacknife clams (Ensis directus)
    - Razor clams (Tagelus sp.)
    - Marsh periwinkle snail (Littorina irrorata)
  - Where observed, 1% to 40%
  - Added *in situ* by benthic organisms
  - May later be moved and redeposited


Clam
Snails

# Additions

- Additions of organic carbon
  - Stems and leaves as vegetative debris
  - Partially decomposed soil organic matter
  - Depth functions similar to terrestrial alluvial soils




- Elevated levels at the surface
- Generally, OC decreases with depth, but
- There are commonly, irregularities

# Losses

- In terrestrial systems, mostly through erosion and leaching
- In subaqueous systems, leaching and seepage not important
  - Low hydraulic gradients
  - Permanently submersed
- Erosion is important
  - Wave agitation
    - Wind
    - Storms
    - boating
  - Tidal currents
- Like terrestrial systems, vegetation helps protect against erosion

# Losses

- Decomposition of organic matter
- Example: In a NC estuary
  - Primary production in an eelgrass meadow 350g/$m^2$/yr
    - 20-50% below ground
  - Up to 275g/$m^2$/yr added from external sources (detritus)
  - This is the equivalent of approximately 0.5%/yr (in the upper 10 cm)
- Quantities of OC in surface horizons are approximately 0.5 – 2.0%
- This demonstrates the significant magnitude of losses of OC

# Transfers

- Diffusion
  - Soluble components move from zones of higher concentration to zones of lower concentration
    - Diffusion of oxygen across the water-sediment interface into the upper layer of the soil
    - Balanced by consumption by heterotrophic microbes
- Enhanced by bioturbation

# Transfers

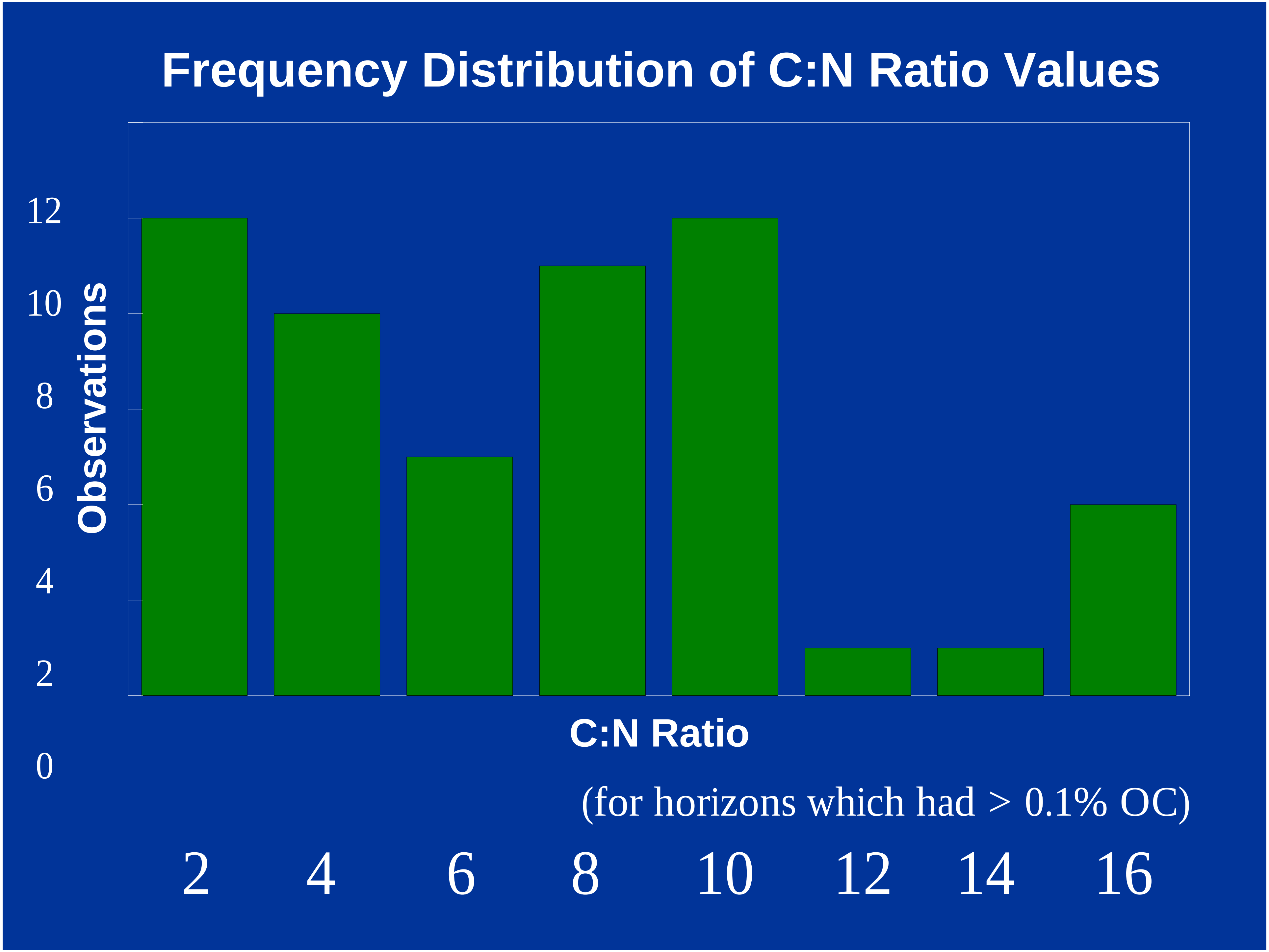
- Bioturbation
  - Often thought to counter horizon differentiation
  - In these systems, enhances formation of oxidized surface layer
- Accomplished by burrowing benthic organisms
  - Tubeworms
  - Clams
  - Scallops
- May increase thickness of oxidized zone from mm to cm

# Bioturbation

# Oxidized Soil Surface

# Transformations

- Chemical transformations of organic matter
  - C:N ratios in SAV 20:1 to 30:1
  - C:N ratios in subaqueous soils 8:1 to 15:1


Frequency Distribution of C:N Ratio Values
Observations
12
10
8
6
4
2
0
C:N Ratio
(for horizons which had > 0.1% OC)
2
4
6
8
10
12
14
16

# Formation of Sulfide Minerals

$SO_4^{2-} + 10H^+ + 8e^- \text{--->} H_2S + 4H_2O$

If reactive Fe is present

$H_2S + Fe^{2+}$ ---> FeS (black) - - -> $FeS_2$

(sulfidization)

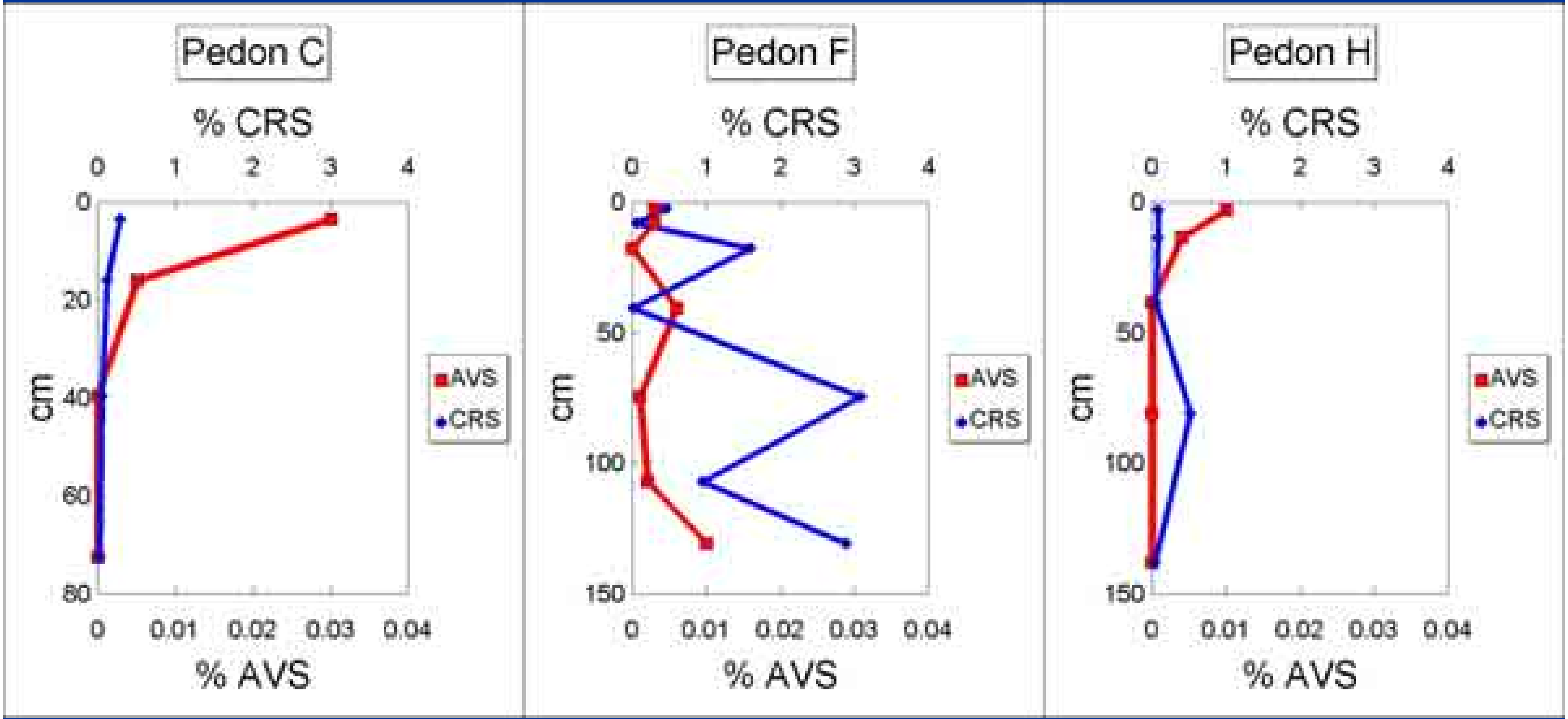
# Formation of Sulfide Minerals (Sulfidization)

$SO_4^{2-}$ + $2CH_2O$ ----------> $H_2S$ + $2HCO_3^-$

If reactive Fe is present

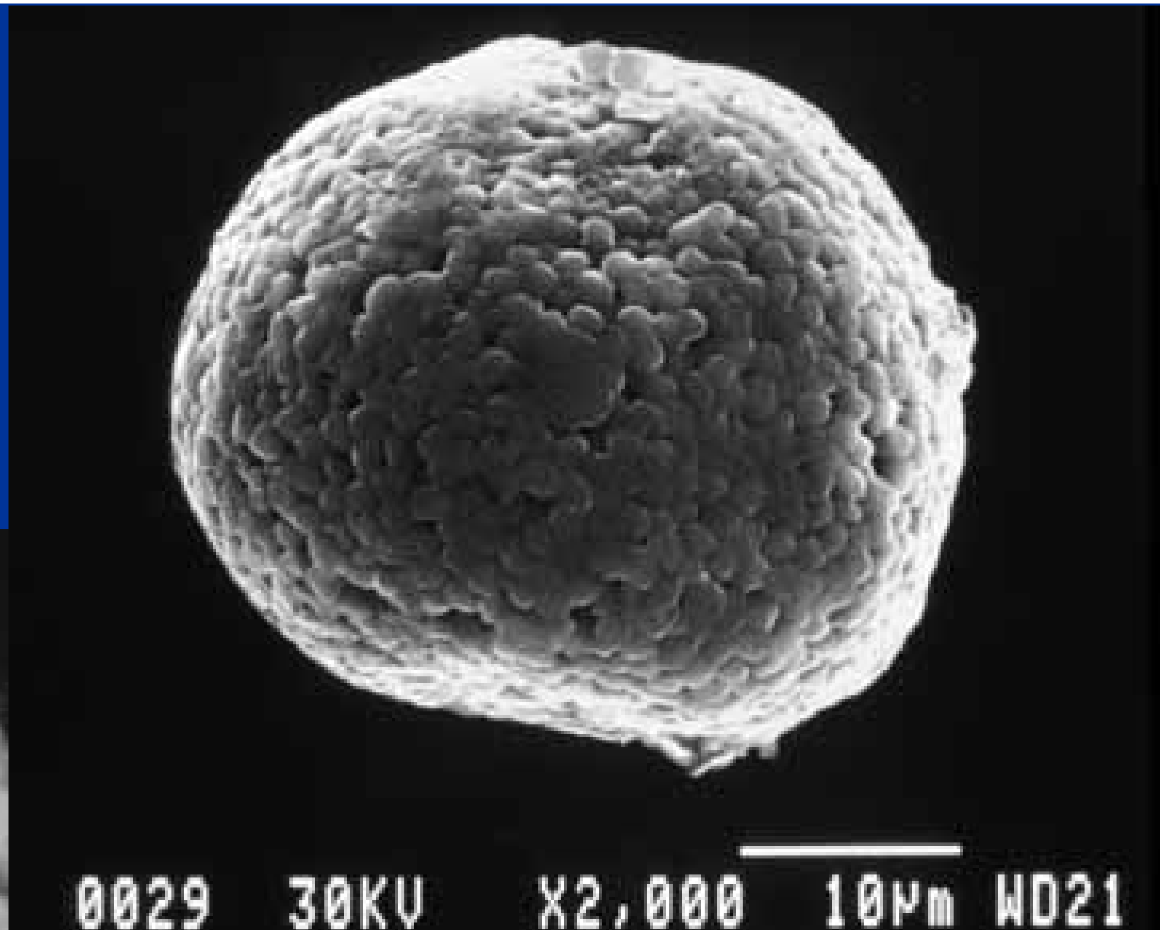
$H_2S$ + $Fe^{2+}$ ---> FeS (black) - - -> $FeS_2$

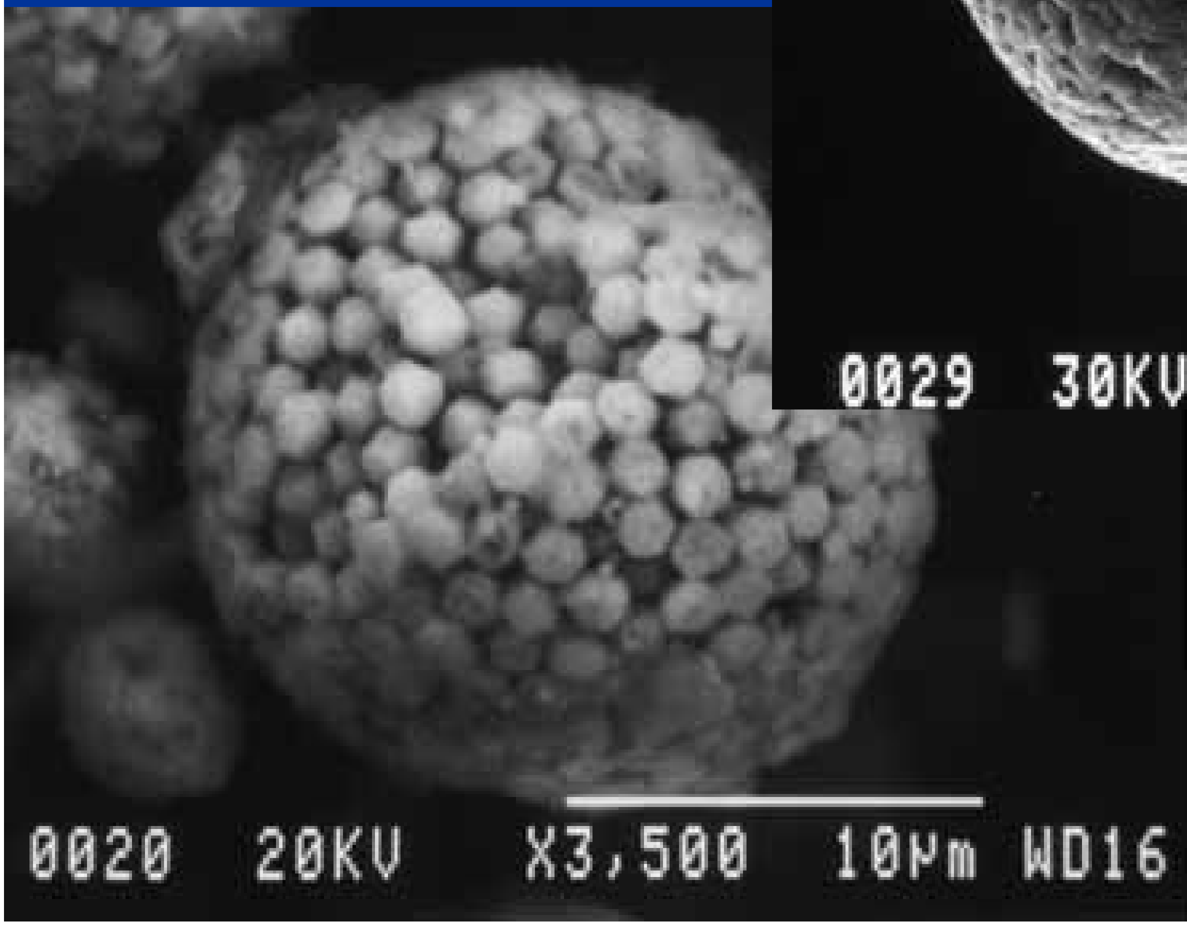
(simplified)



Pedon C
% CRS
0 1 2 3 4
0 20 40 60 80
cm
0 0.01 0.02 0.03 0.04
% AVS
AVS
CRS
Pedon F
% CRS
0 1 2 3 4
0 50 100 150
cm
0 0.01 0.02 0.03 0.04
% AVS
AVS
CRS
Pedon H
% CRS
0 1 2 3 4
0 50 100 150
cm
0 0.01 0.02 0.03 0.04
% AVS
AVS
CRS


# Black Monosulfides


0029 30KV X2,000 10μm WD21


0020 20KV X3,500 10μm WD16

# Significance and Value of Subaqueous Soil Inventory

- Sediment characteristics presented to a greater depth (2 m), rather than a "surficial" approach
- Provides a comprehensive classification scheme for shallow water sediments
- Could provide a major leap forward in the utility of maps for SAV restocking and other estuarine protection, restoration and management efforts

# The Present Paradigm for Dry Terrestrial Systems
# The Soil - Landscape Model

- Within the soil-landscape unit:
  - the five soil forming factors interact in a distinctive manner
  - areas of the same soil-landscape unit develop the same kind of soil
- Once the relationship among soils and landscape units have been determined for an area, the soil type can be inferred by identifying the soil-landscape unit.

From Hudson 1992 (SSSAJ 56:836-841)

# Typical Block Diagram Showing Soil-Landscape Relations

Can this be applied to subaqueous settings?