Properties and Characterization of Subaqueous Soils

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What is unique to this system?

- Assumption: You are familiar with properties and characterization of soils in general.
- So what makes subaqueous systems different?

What is unique to this system?

- They are permanently submerged
  - Impacts sampling – big time!
  - Affects the properties of the soils themselves
  - Air excluded, except from the uppermost zone (mm to cm); strongly anaerobic
- They are young (at least in the upper part)
  - Mostly late Holocene in age
  - Generally weakly developed profiles
- Many have formed in brackish or saline environments
  - Sulfate a dominant anion that affects products of reduction

Sampling

- Bucket Auger
  - Limited to shallow water – must sample ***in*** water
  - Fast and inexpensive
  - Poor horizon resolution
  - May have difficulties with high n-value material
  - No volume controls (for Bulk Density)
  - During warm season or dry suits needed

Sampling

- MacCauley Sampler
  - Relatively fast
  - Can be done from a boat
  - Samples collected in 50 cm sections as “undisturbed half cores”
  - Good horizon resolution and good for bulk density
  - Limited to soft materials
  - Small sample size
  - Moderate cost – ($1000)


Sampling

- Vibracoring
  - Excellent undisturbed cores
  - Up to several meters long
  - Can be used in dense materials
  - Can be stored for later examination
  - Slow and cumbersome (set up)
  - Costly equipment
  - Some “collapse” – change in volume
    - Especially with organic rich horizons


Tripod
Trapdoor
2003. 7. 17


Soil Core

Problems with Collapse

- Poor estimate of volume for bulk density measurement
- Only estimates of horizon depth

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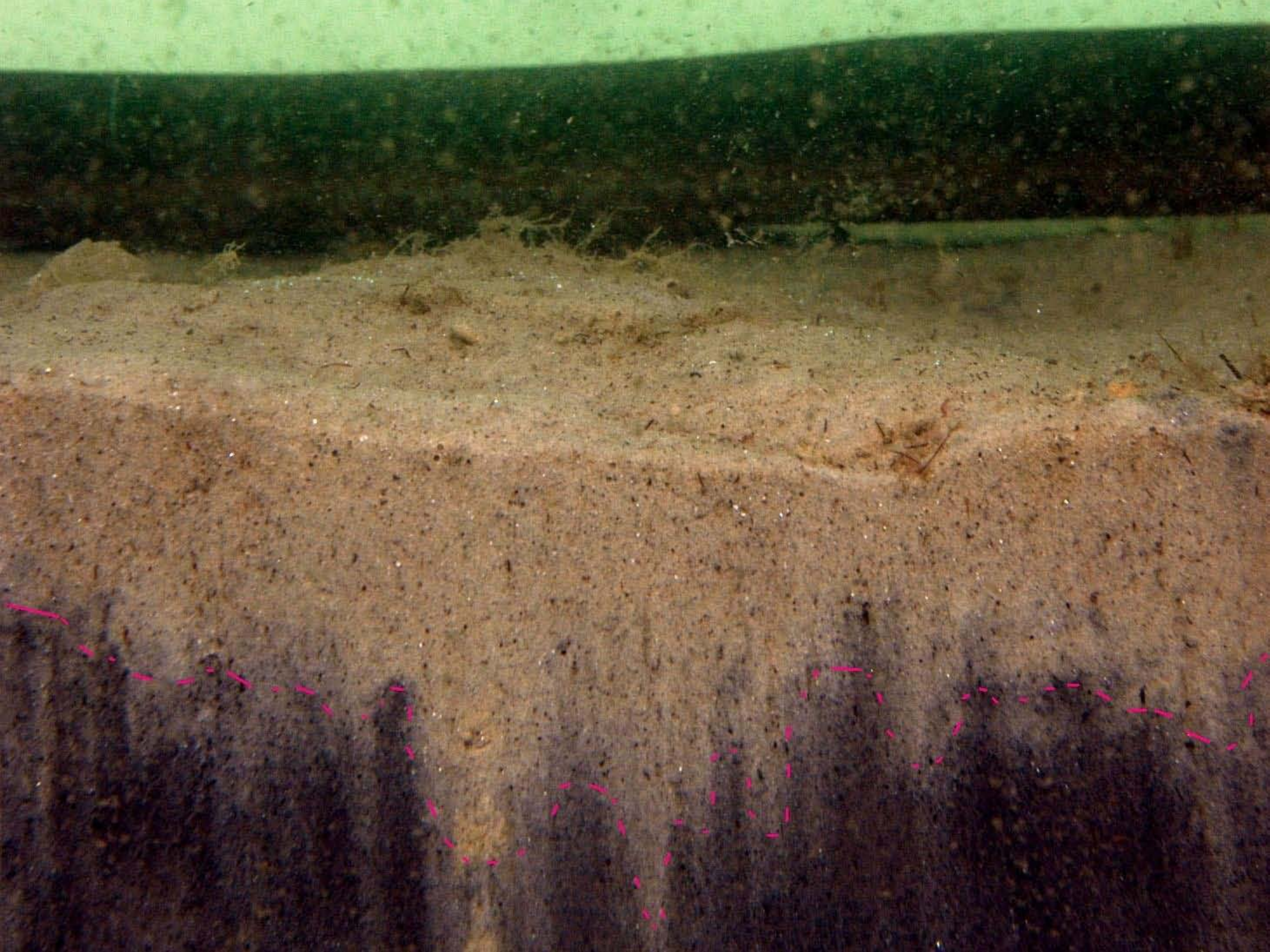
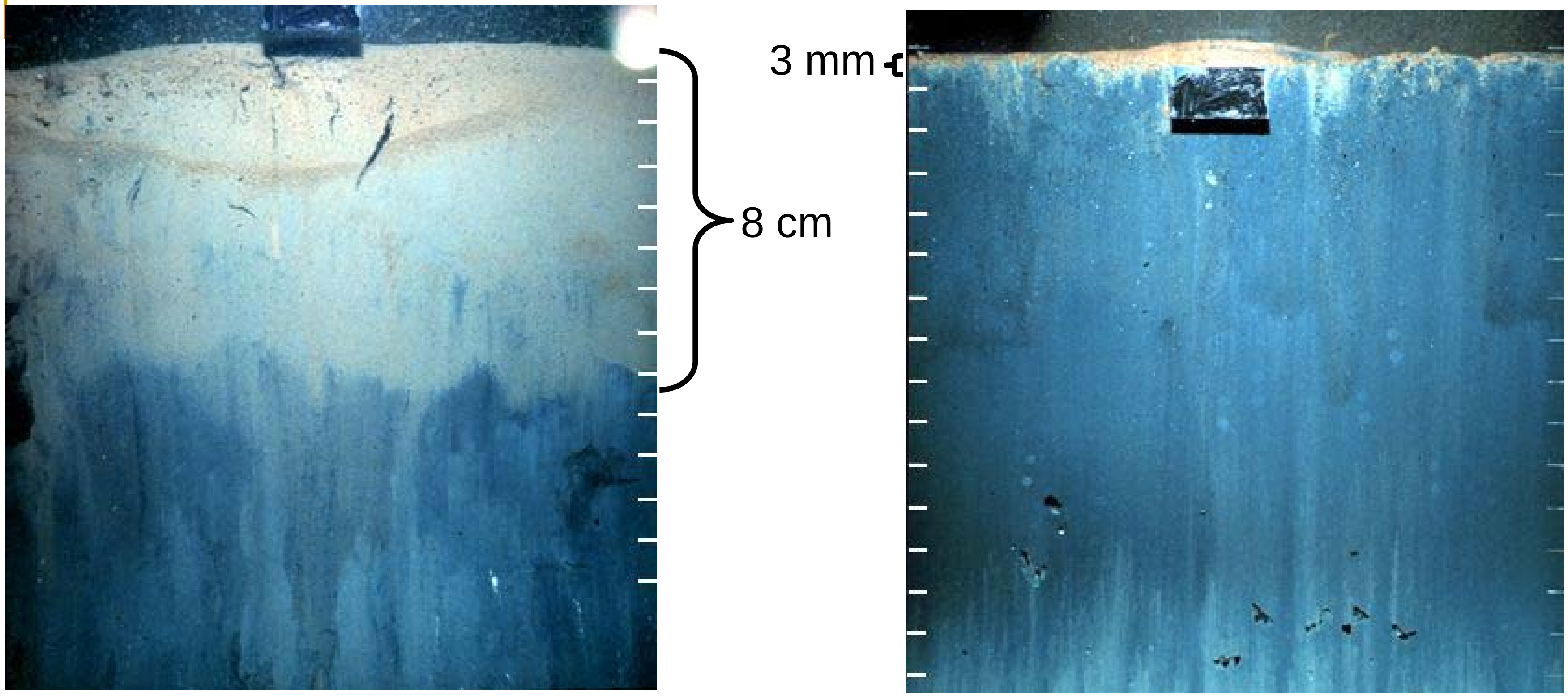
Morphology and Horizons

- Equivalent of "young alluvial soils"
- Commonly are stratified
- Often have only A, C, and transitional (AC) horizons.
- Recognition and importance of the "oxidized" horizon at the surface

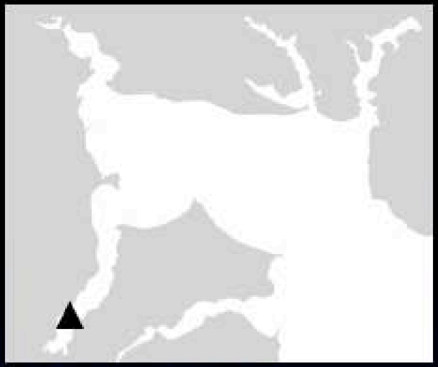


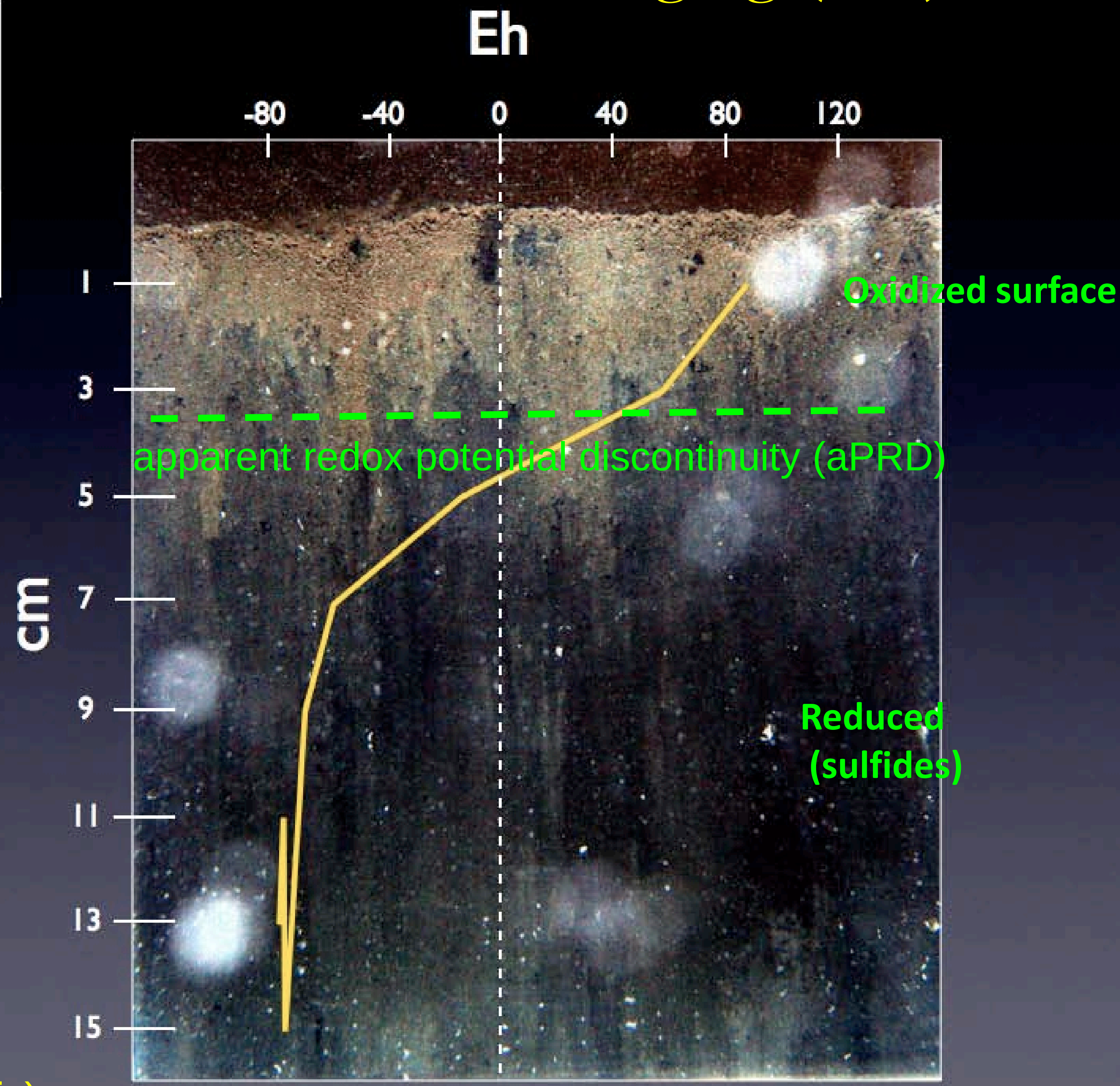


Oxidized Horizon (A)

Forms as a function of bioturbation and diffusion of oxygen

Sediment Profile Imaging (SPI)





(From Payne, MS Thesis)

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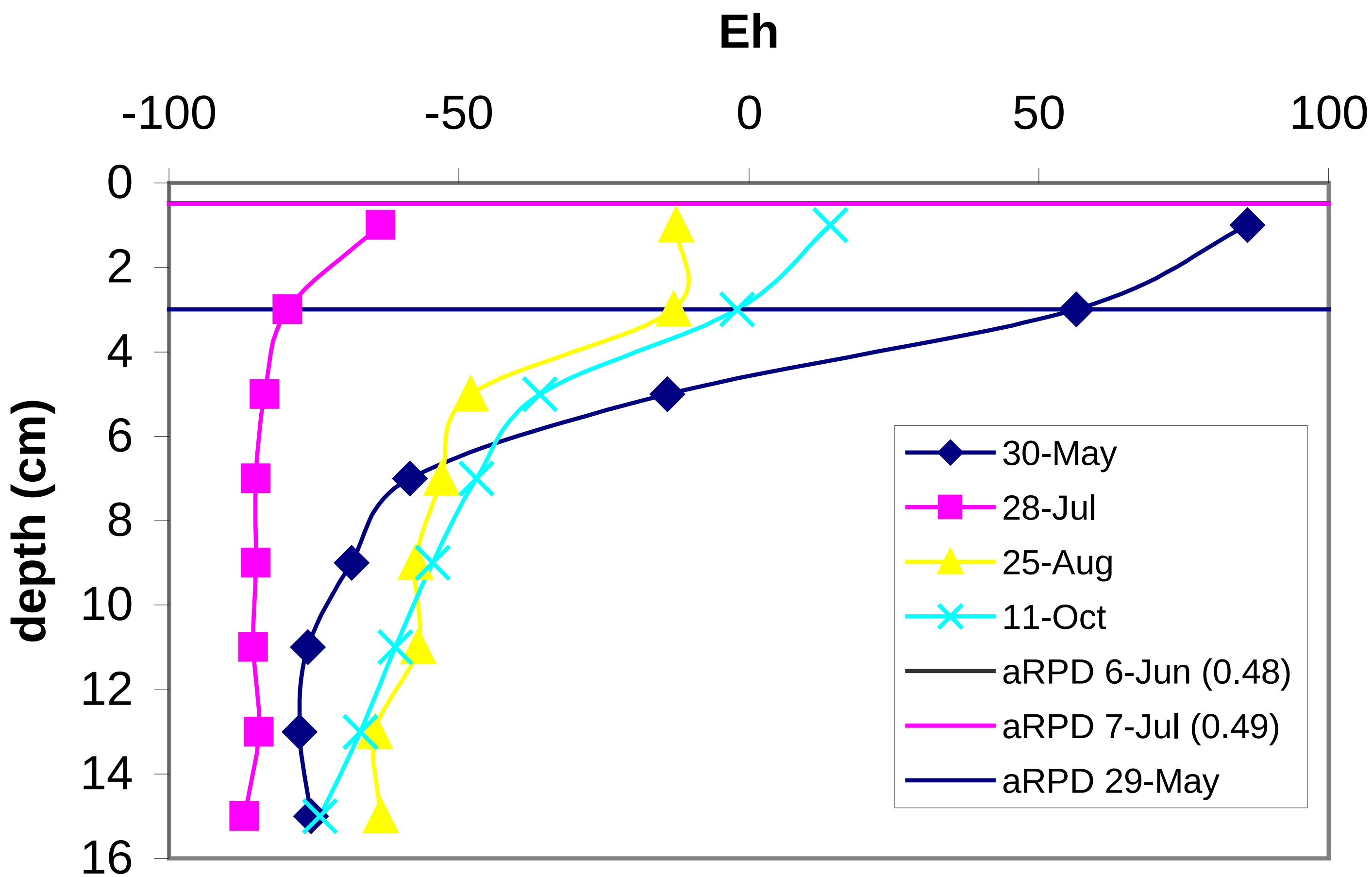
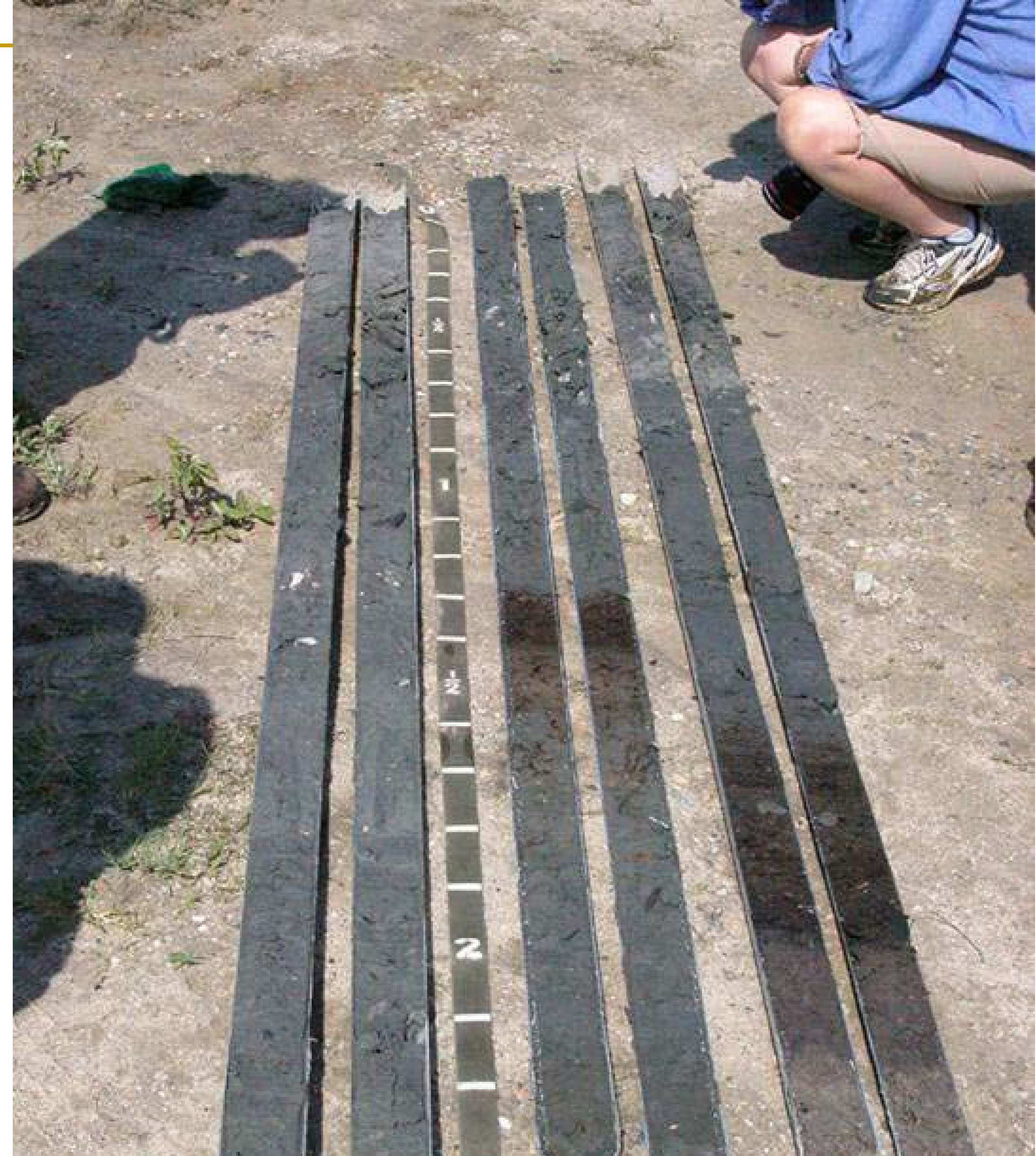
SPI and Redox



Not static – changes over time and with seasons.

Morphology and Horizons

- Equivalent of "young alluvial soils"
- Commonly are stratified
- Often have only A, C, and transitional (AC) horizons.
- Recognition and importance of the "oxidized" horizon at the surface
- Most horizons are depleted (g) or gleyed
  - Some may be "reduced matrices" - especially fresh systems


1
2

Subaqueous Soil Profile Description

Date **Latitude** N 38 **Longitude** W 75 **Water Depth**

Core # **Predicted Tide**

Describers DMB

Time **Depth Inside Core** **Compaction (Depth Outside Core - Depth Inside Core)**

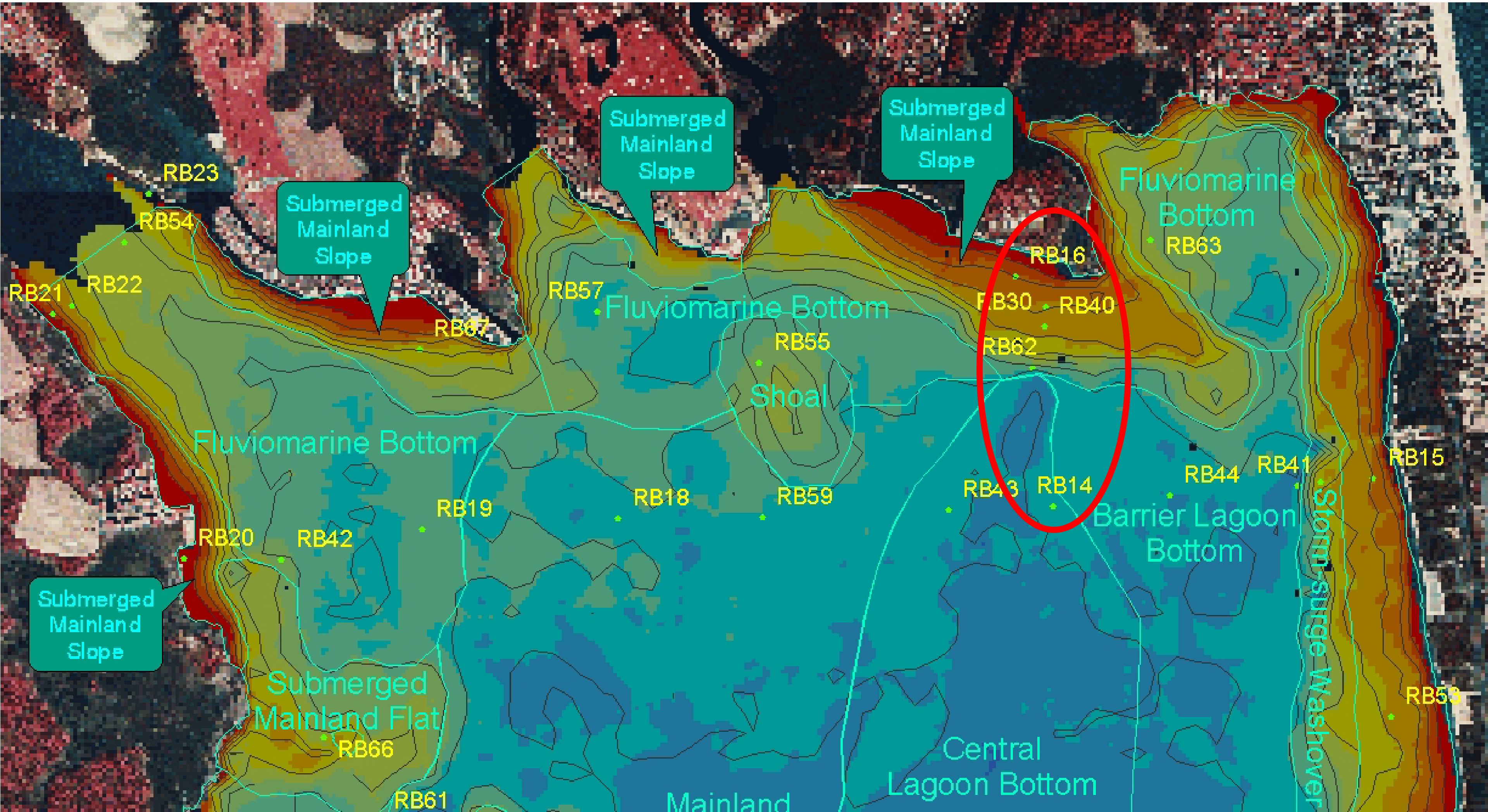
Depth Outside Core **Sampling Method**

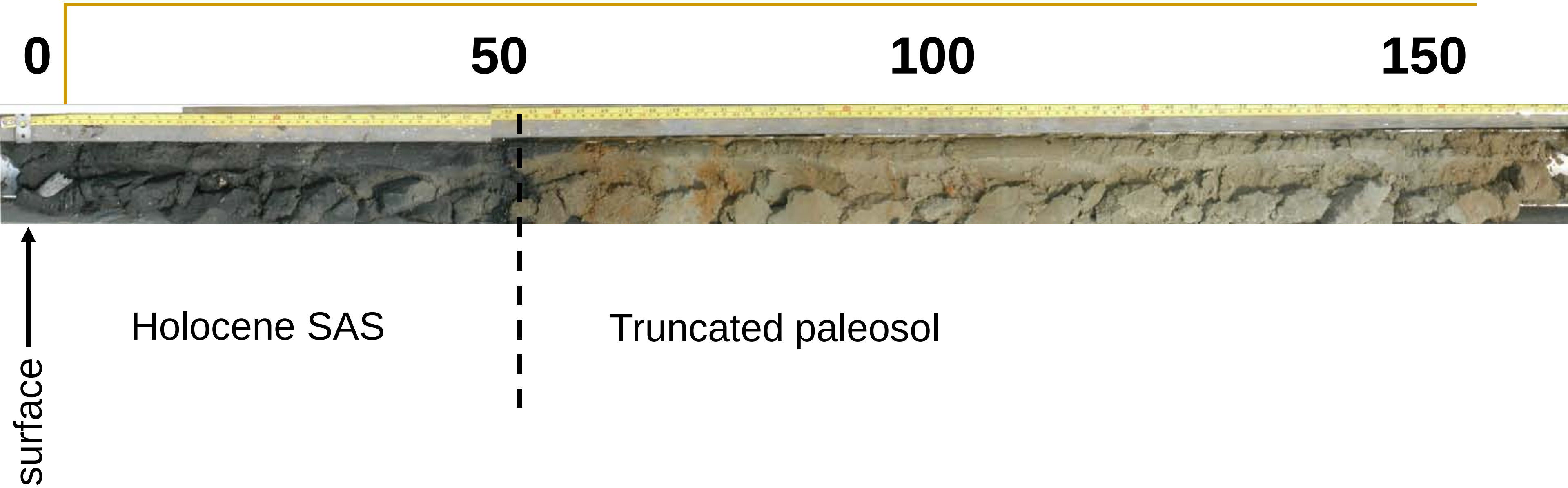
Horizonation	Boundary		USDA Texture		Matrix	Redoximorphic Feat.		Organic Fragments		Structure		Wet	N-Value	Roots	Worm	Shells	Sulfur
	Depth	Dist.	% gravel	Class	Color	Color	Abund/Contr	Abund	Color	Gr	Shape	Consist		%	Tubes	%	Odor

Morphology and Horizons

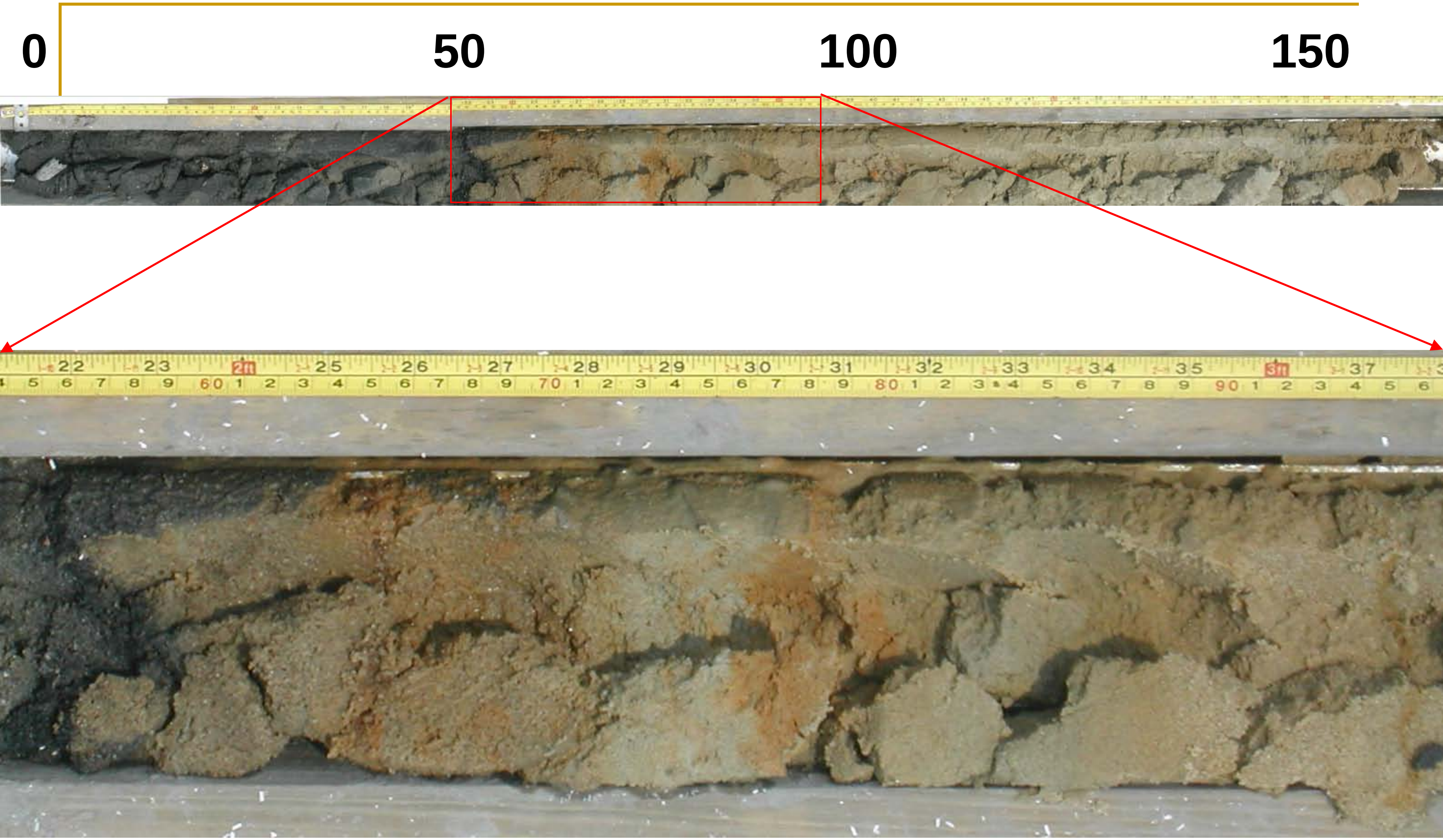
- Sometimes old (or truncated) soils can be buried with a younger Holocene age subaqeous soil.
- Submerged mainland slope landform

Preliminary Digital Elevation Model for Rehoboth Bay Bathymetry August 2003

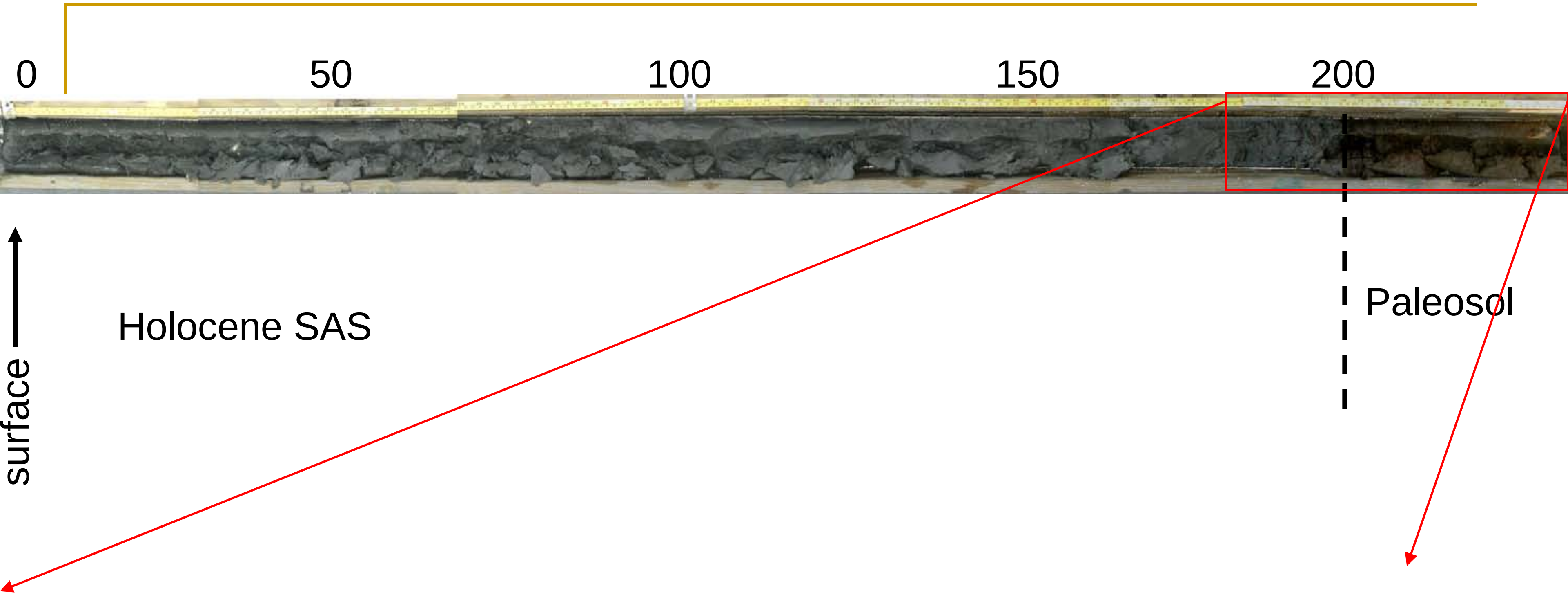




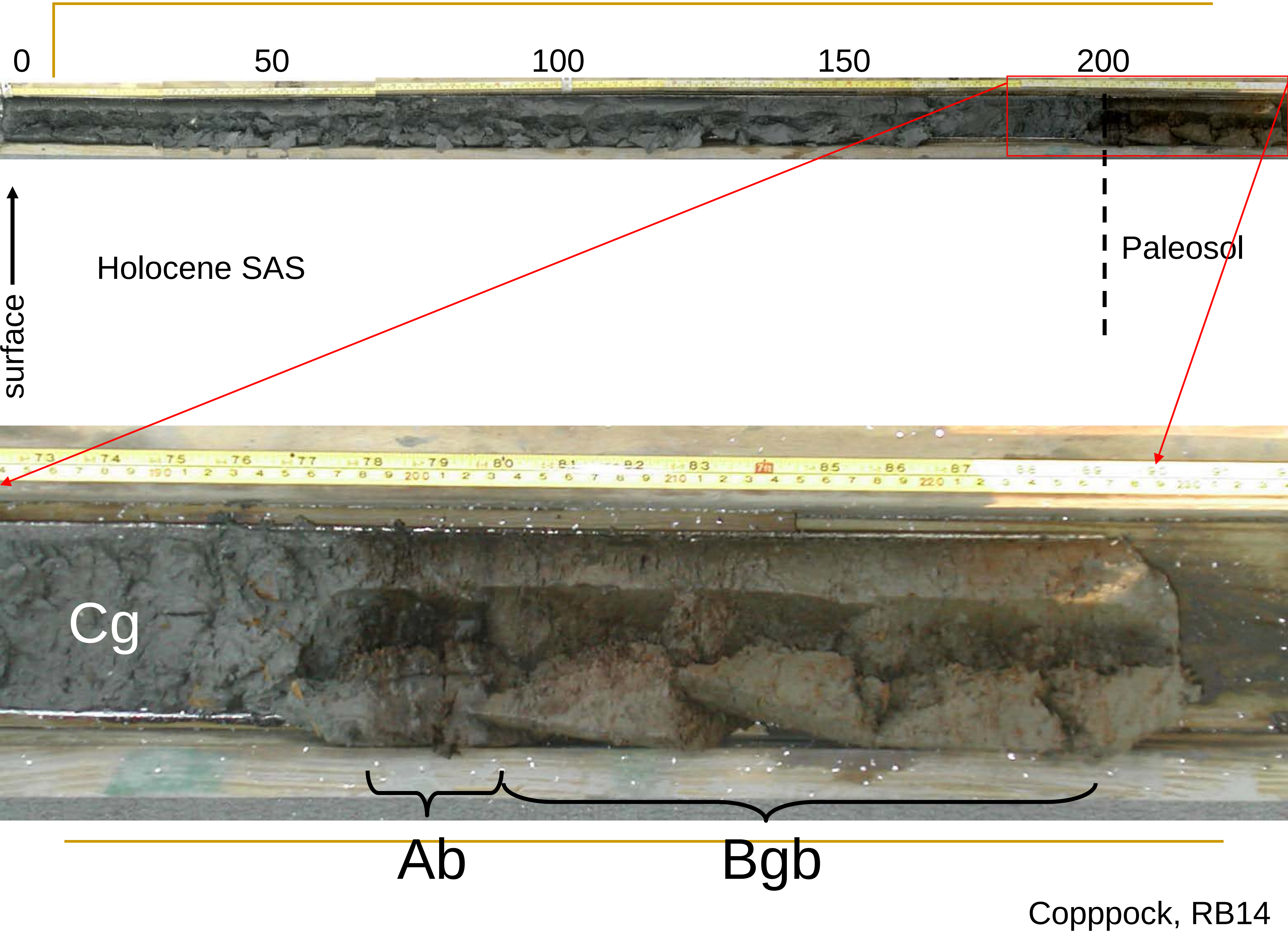
RB16



Relict redoximorphic features from truncated, buried paleosol



Copppock, RB14


0
50
100
150
200
surface
Holocene SAS
Paleosol
Cg
Ab
Bgb
Copppock, RB14

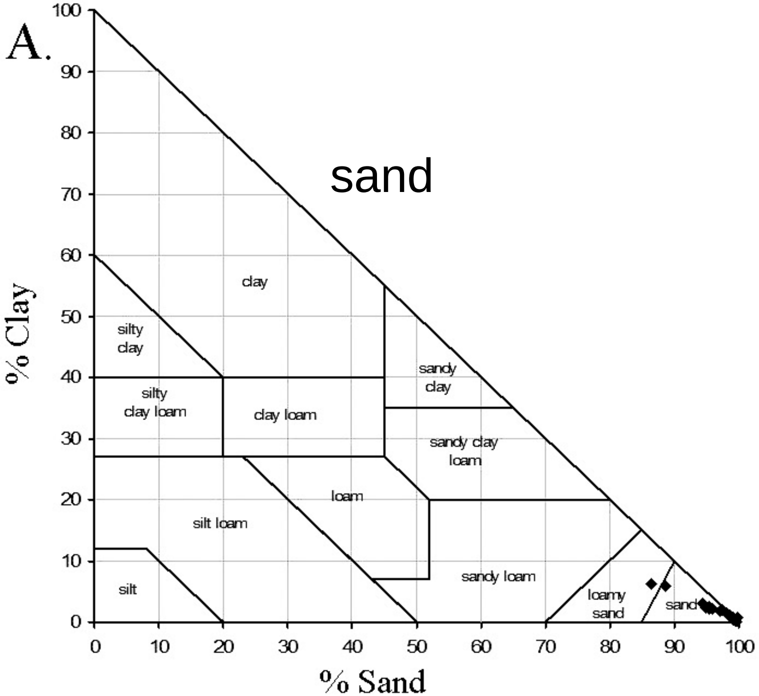
Physical Properties

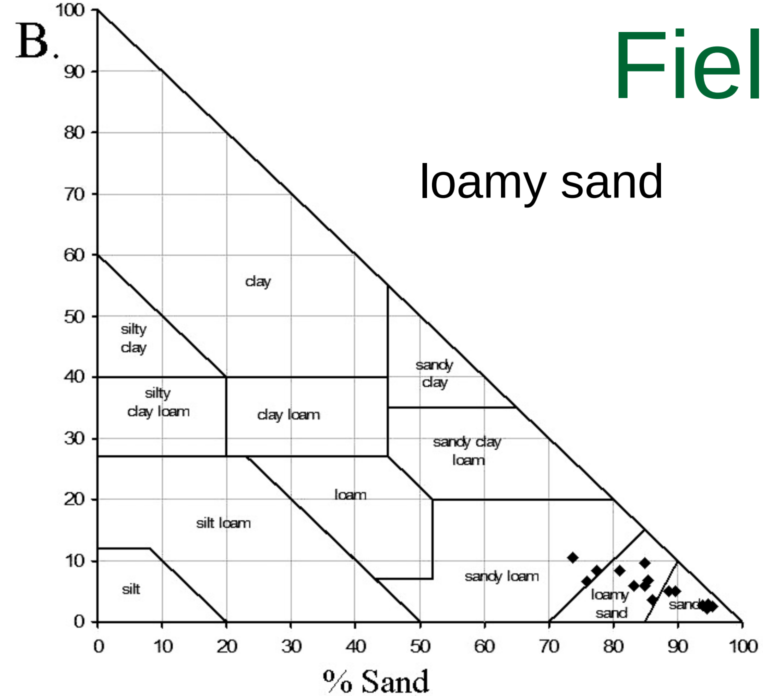
- Particle size – Texture
- n-Value
- Bulk Density

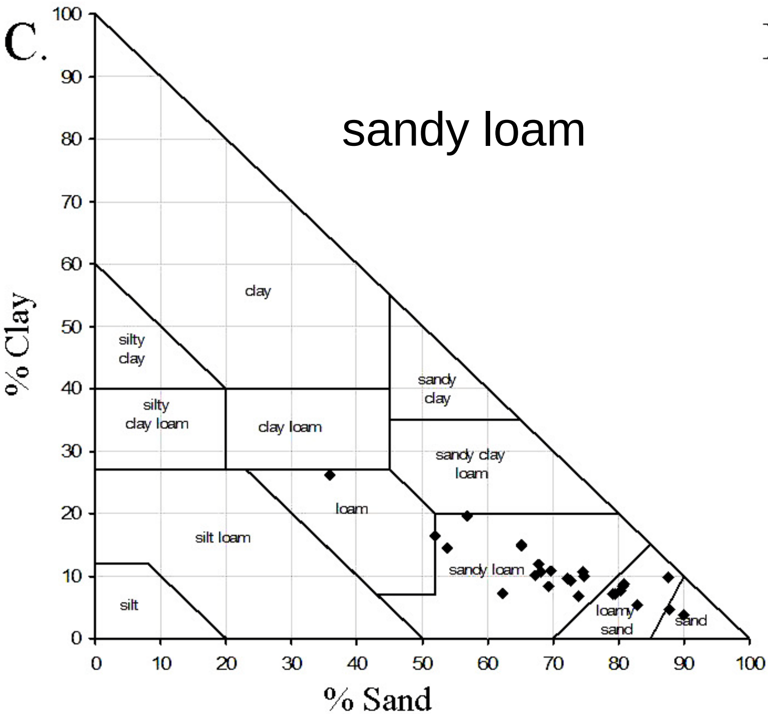
Particle Size

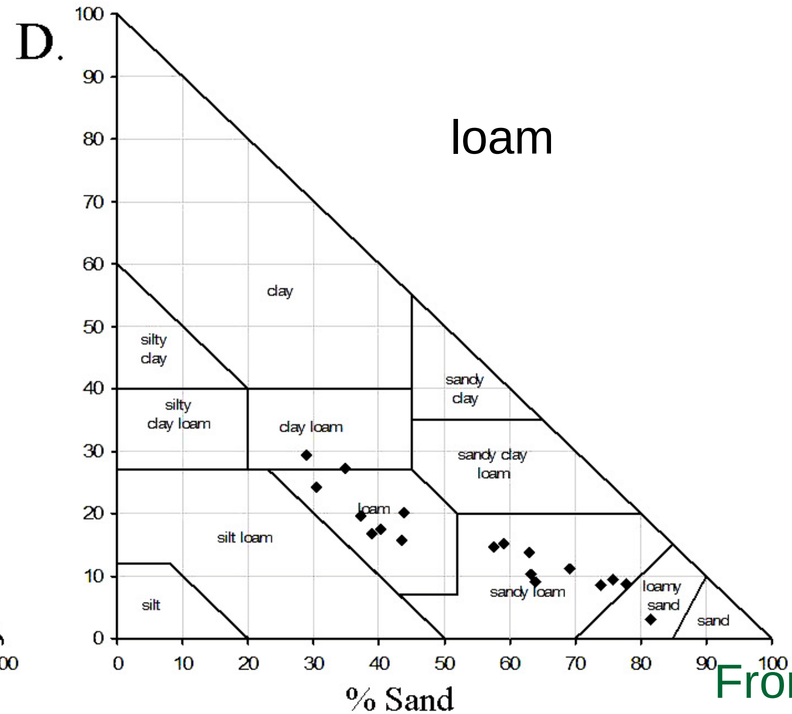
- Lab analyses, may need to first remove salts
  - Chloride salts from sea water
  - Sulfate salts generated during drying – from oxidation of sulfide minerals
- Field texturing – challenging because they are always too wet!

Field vs Lab



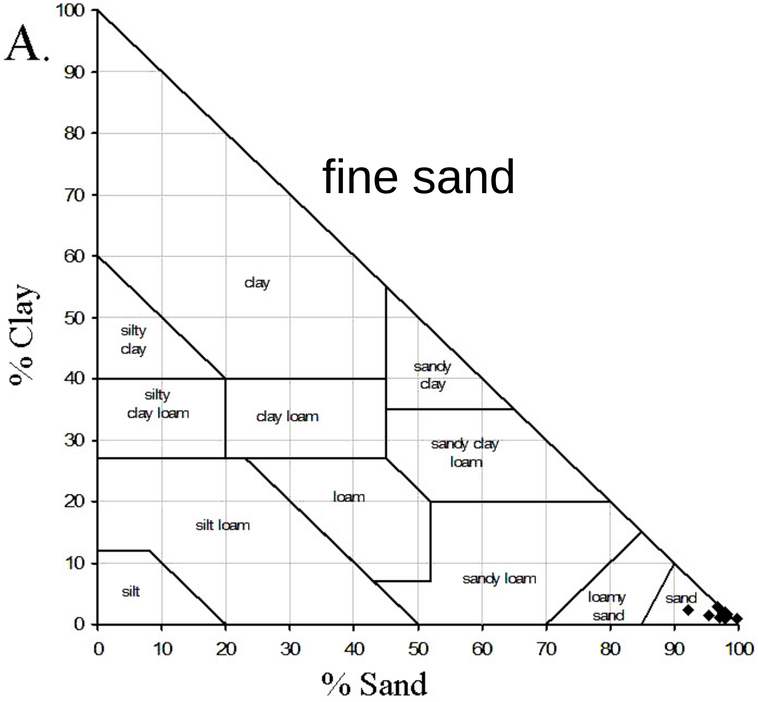


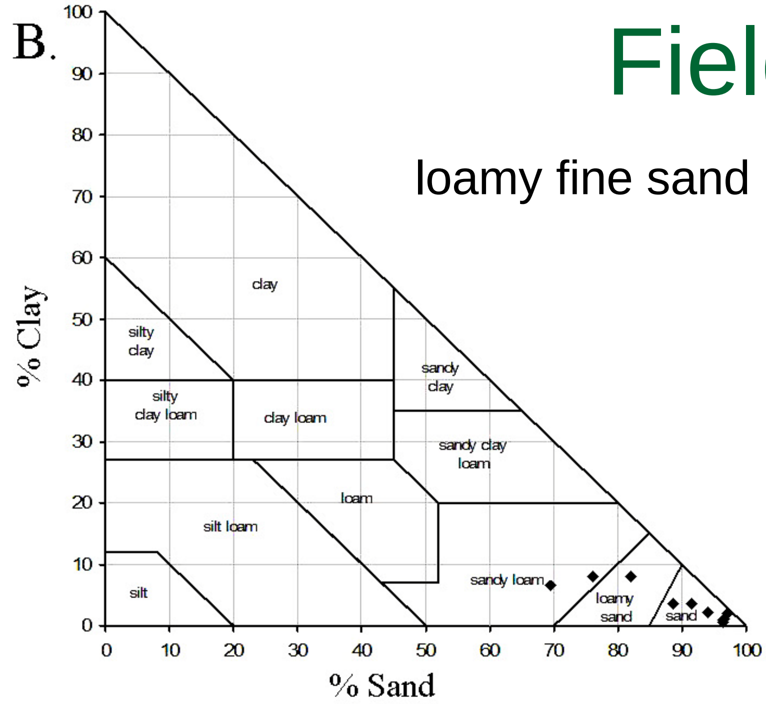


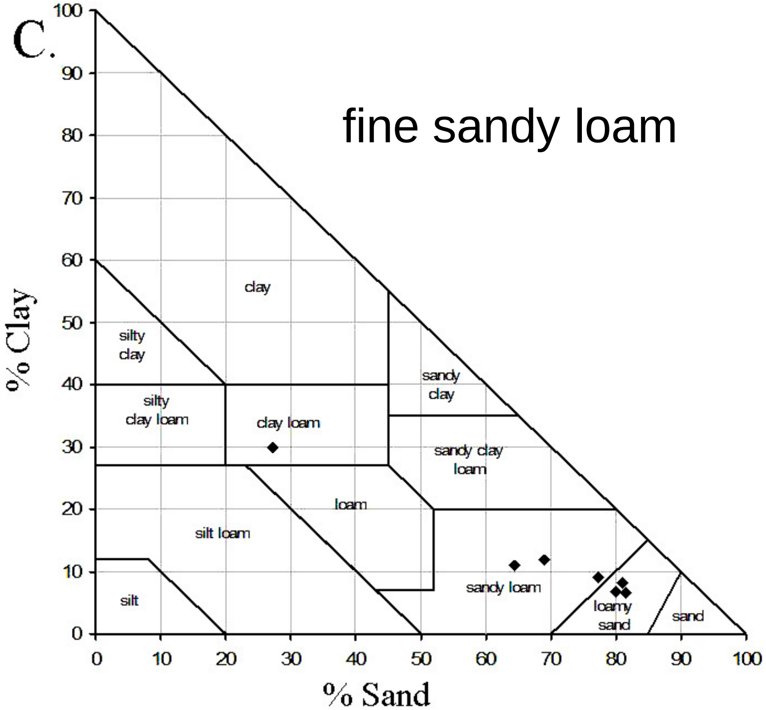


From Balduff (2007)

Field vs Lab







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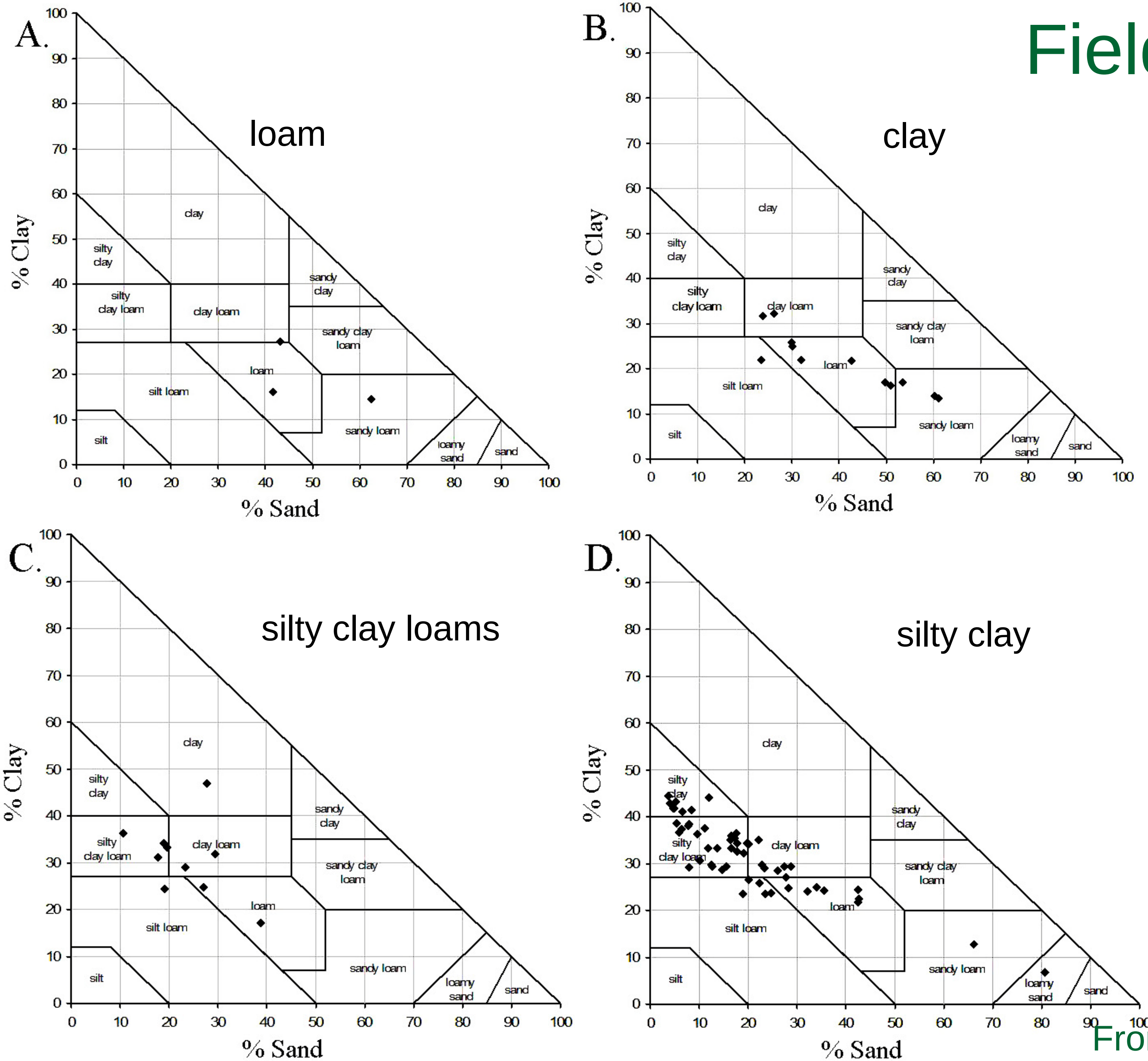

From Balduff (2007)

Comparison of Field and Lab Textures

Balduff (2007)

	Field Textures	Textures Based on Particle-Size Analysis											
n		S	fS	LS	LfS	SL	fSL	vfSL	L	SiL	CL	SiCL	SiC
		--%--											
15	S		87		13								
9	fS		100										
16	LS		38		56		6						
10	LfS		70		20		10						
26	SL		4		35	31	19		12				
7	fSL				43		43				14		
1	SC			100									
18	L				11	11	28	6	33		11		
6	SiL					17					50		33
3	CL					33			33		33		
16	SiCL								13	18	19	50	
49	SiC				2	2			14	8	12	45	16
12	C					8		8	58	8	17		

Comparison of Field and Lab Textures

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n	Field Textures	Textures Based on Particle-Size Analysis											
		S	fS	LS	LfS	SL	fSL	vfSL	L	SiL	CL	SiCL	SiC
		---%---											
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10	LfS		70		20		10						
26	SL		4		35	31	19		12				
7	fSL				43		43				14		
1	SC			100									
18	L				11	11	28	6	33		11		
6	SiL					17					50		33
3	CL					33			33		33		
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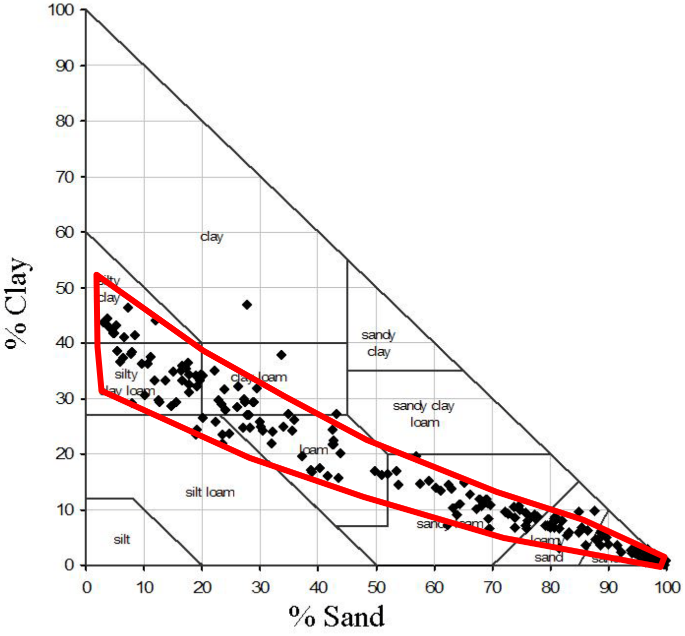
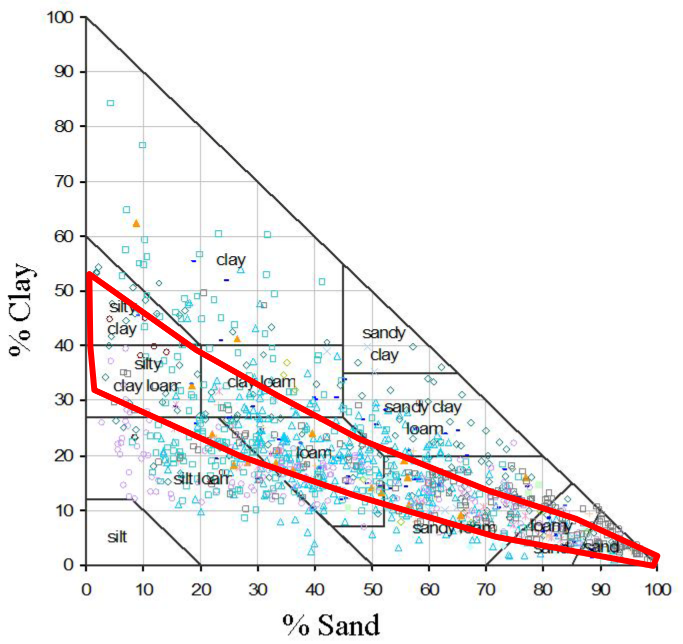


Distribution of particle-size data for 188 subaqueous soil horizons analyzed in Chincoteague Bay.



Distribution of particle-size data for subaerial soils found throughout Maryland (University of Maryland Pedology Lab, 2007). Each marker represents a different county in Maryland.

From Balduff (2007)

n-Value

From Soil Taxonomy (2nd Edition)

- The ***n* value** (Pons and Zonneveld, 1965) characterizes the relation between the percentage of water in a soil under field conditions and its percentages of inorganic clay and humus. The ***n* value** is helpful in predicting whether a soil can be grazed by livestock or can support other loads and in predicting what degree of subsidence would occur after drainage.
- For <u>mineral soil materials</u> that are not thixotropic, the ***n* value** can be calculated by the following formula:

$$n = (A - 0.2R)/(L + 3H)$$

- A = % water (field condition, on a dry-soil basis)
- R = % silt + sand
- L = % clay
- H = %OM

n-Value

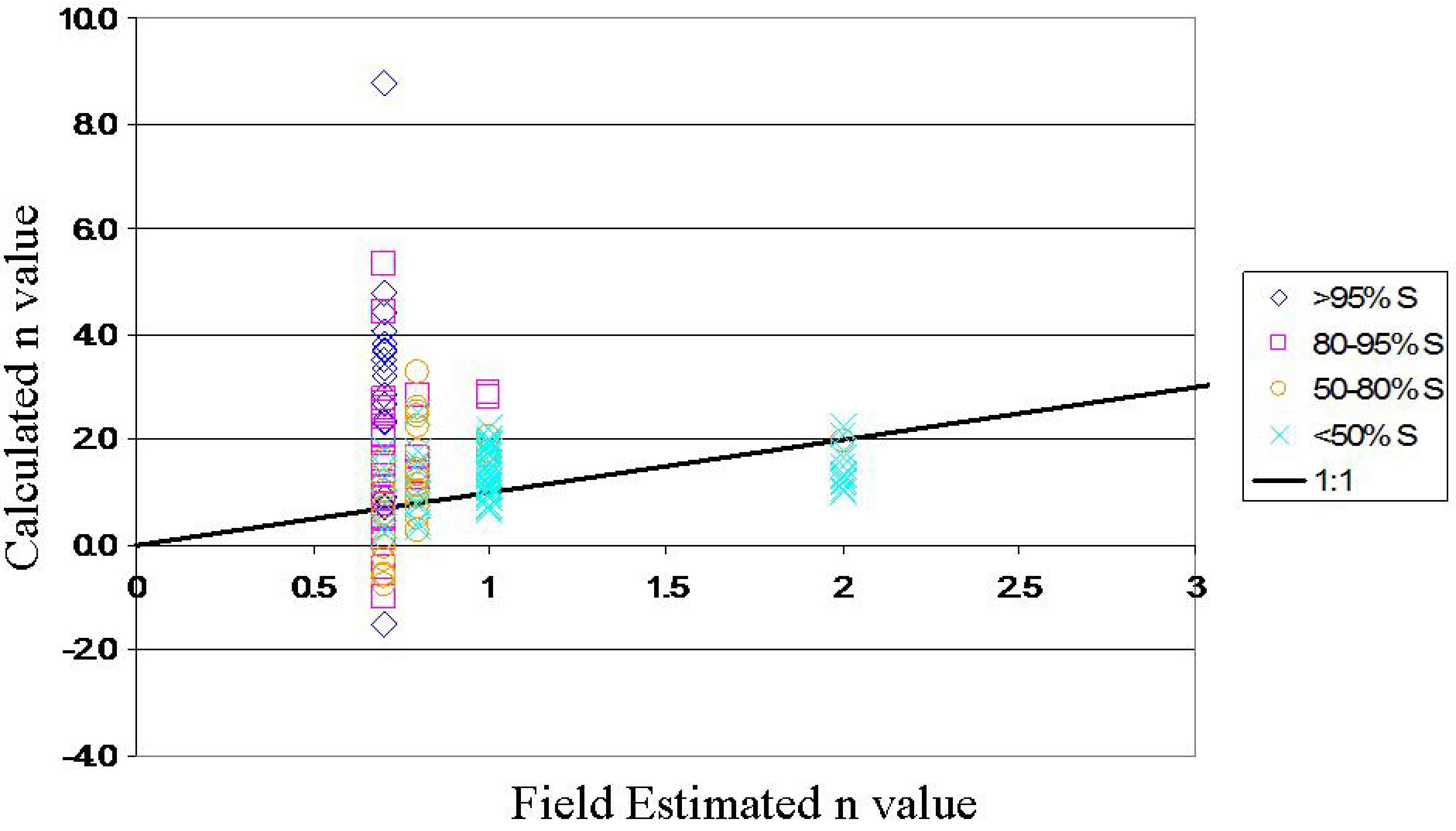
From Soil Taxonomy (2nd Edition)

- ….. but the critical ***n* value** of 0.7 can be approximated closely in the field by a simple test of squeezing a soil sample in the hand.
- If the soil flows between the fingers with difficulty, the ***n* value** is between 0.7 and 1.0 (slightly fluid manner of failure class); …
- … if the soil flows easily between the fingers, the ***n* value** is 1 or more (moderately fluid or very fluid manner of failure class).
- Soils in which the moisture content is periodically reduced below field capacity seldom have an ***n* value** of 0.7 or more. Most of the soils that have been permanently saturated are likely to have a high ***n* value**. Consequently, high ***n* values** are primarily in soils of tidal marshes, swamps, and shallow lakes. The sediments in these areas have never been above the capillary fringe during drought cycles.

… and subaqueous soils!

Cimg0082.mp4

n value >1



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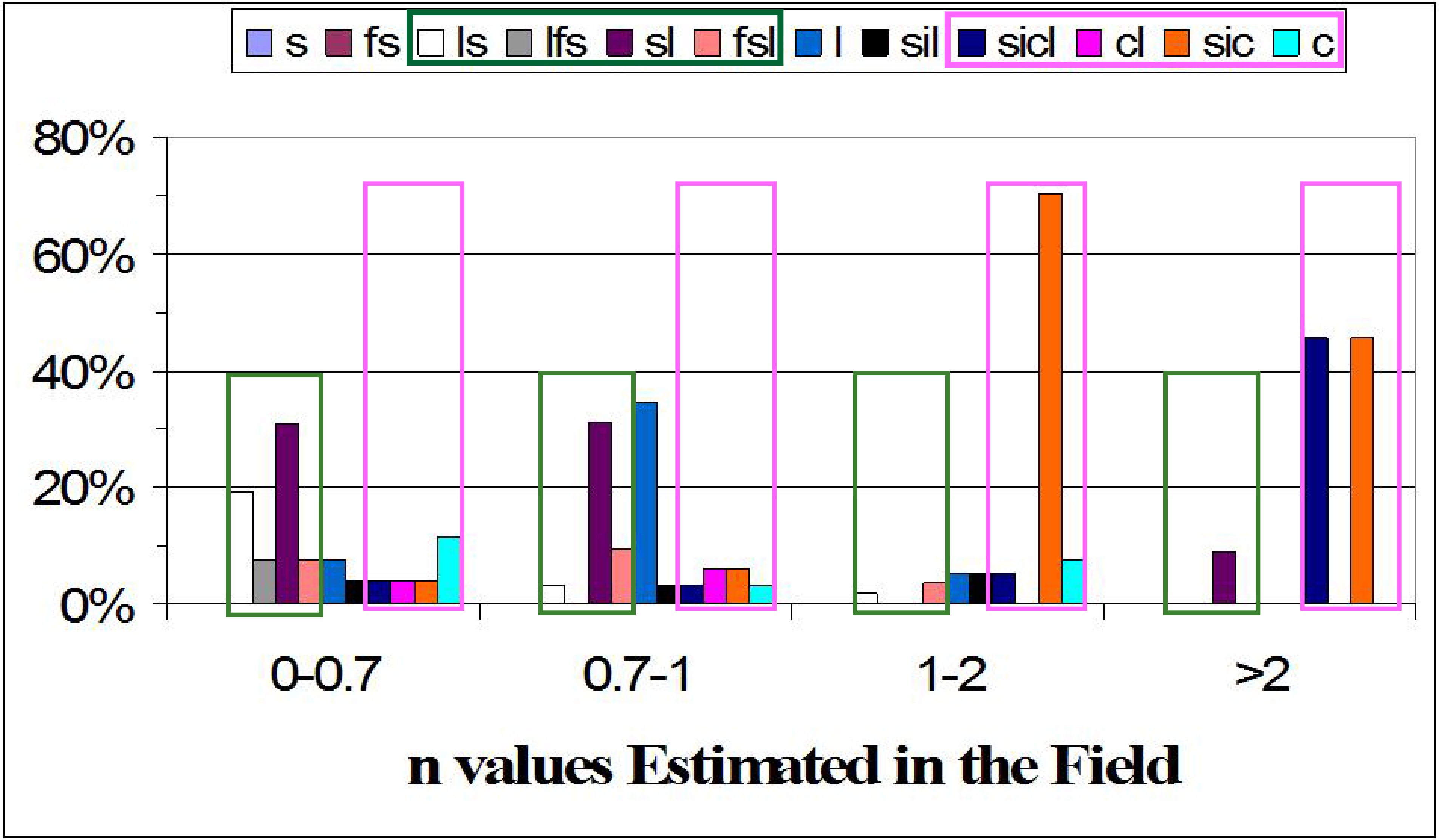


From Balduff (2007)

n-Value

- A useful parameter
  - Estimates bearing capacity
  - Implications for sedimentary environment
- Should be estimated in the field
- Little correspondence between field and lab values
- Lab values have little meaning, while field estimations are useful
- Rather than putting numerical values, should perhaps go with classes from SSM

From the Soil Survey Manual

Table 3-19. Manner of failure classes

Classes	Operation	Test Description Characteristics
Deformable *	Same	Specimen can be compressed to half its original thick- ness without rupture. Radial cracks may appear and extend inward less than half the radius normal compression.
Nonfluid	A handful of soil material is squeezed in the hand.	None flows through the fingers after exerting full compression.
Slightly fluid *	Same	After exerting full compression, some flows through the fingers, but most remains in the palm of the hand.
Moderately fluid *	Same	After exerting full pressure, most flows through the fingers; a small residue remains in the palm of the hand.
Very fluid *	Same	Under very gentle pressure most flows through the fingers like a slightly viscous fluid; very little or no residue remains.

* The approximate equivalent n-values, Pons and Zonneveld (1965), are as follows:

Deformable < 0.7 n-value
Slightly fluid 0.7-1
Moderately fluid -- 1-2
Very fluid- ≥ 2

Bulk Density

- Pretty convenient and easy if sampling with
  - Vibracorer or MacCauley Sampler
  - Cut linear section of core (or half core) and calculate volume.
  - Dry and weight the sample

Bulk Density

- Pretty impossible if sampling with bucket auger

Chemical Properties

- Sample Handling and Storage
  - Physical properties pretty stable
  - Chemical properties highly labile – can change radically!

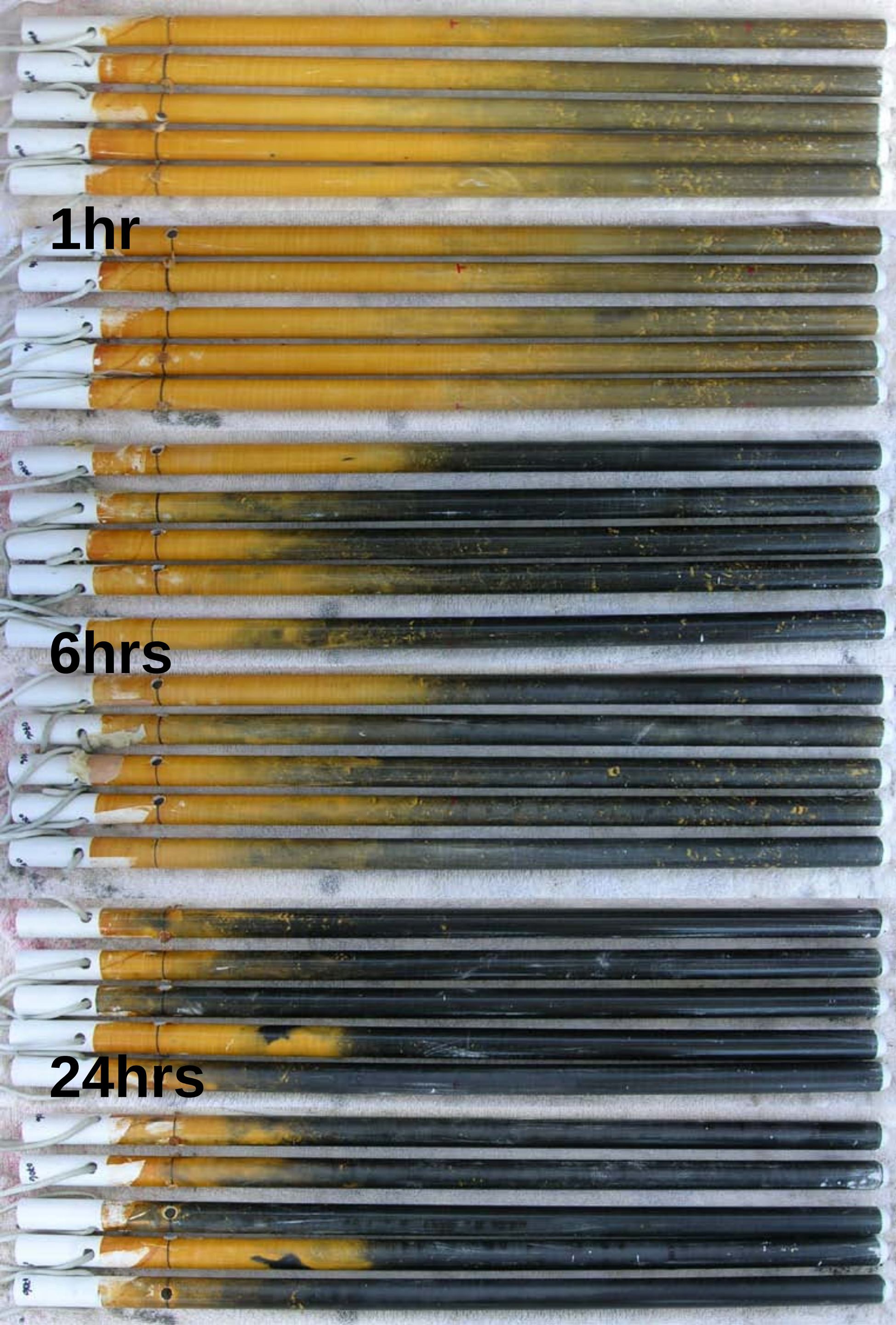
More Labile

More Stable

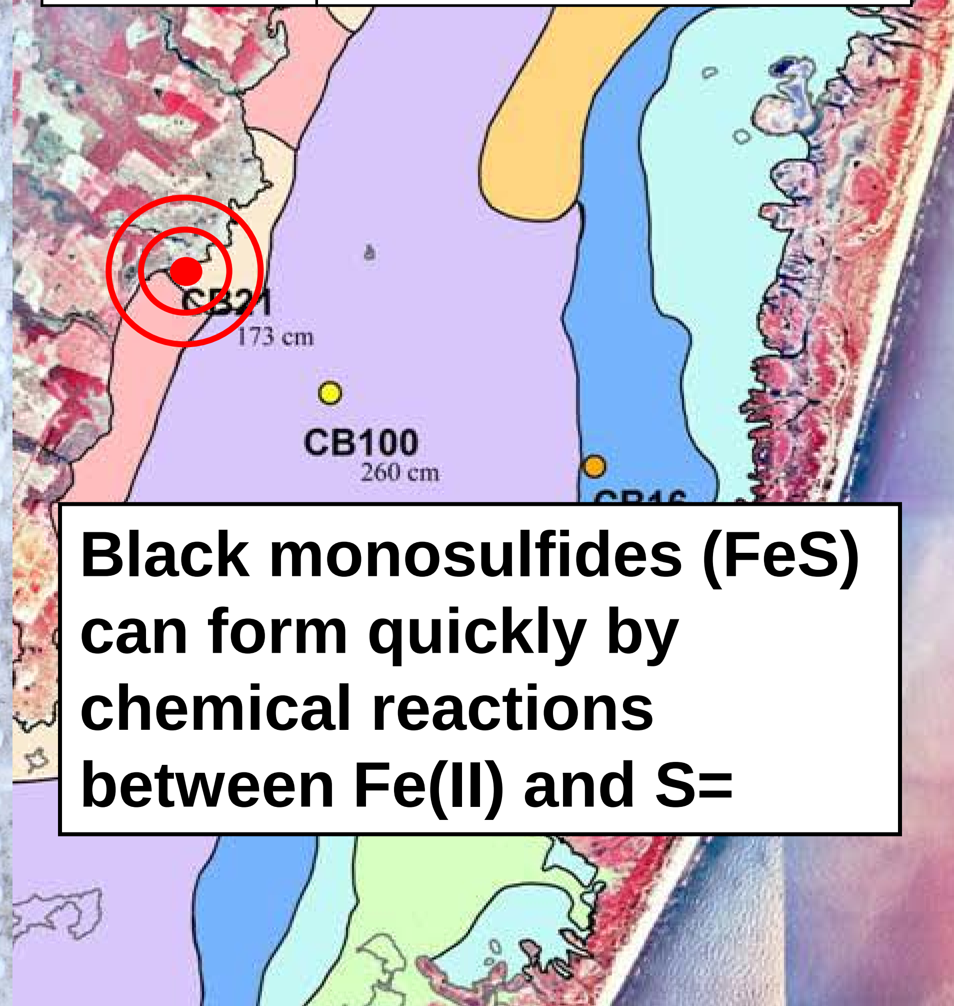
- FeS –minutes to hours
- Pyrite FeS2 – days to weeks
- pH – days to weeks
- Salinity – days to weeks
- Carbonate content – months?
- OM – pretty stable

Sample Storage

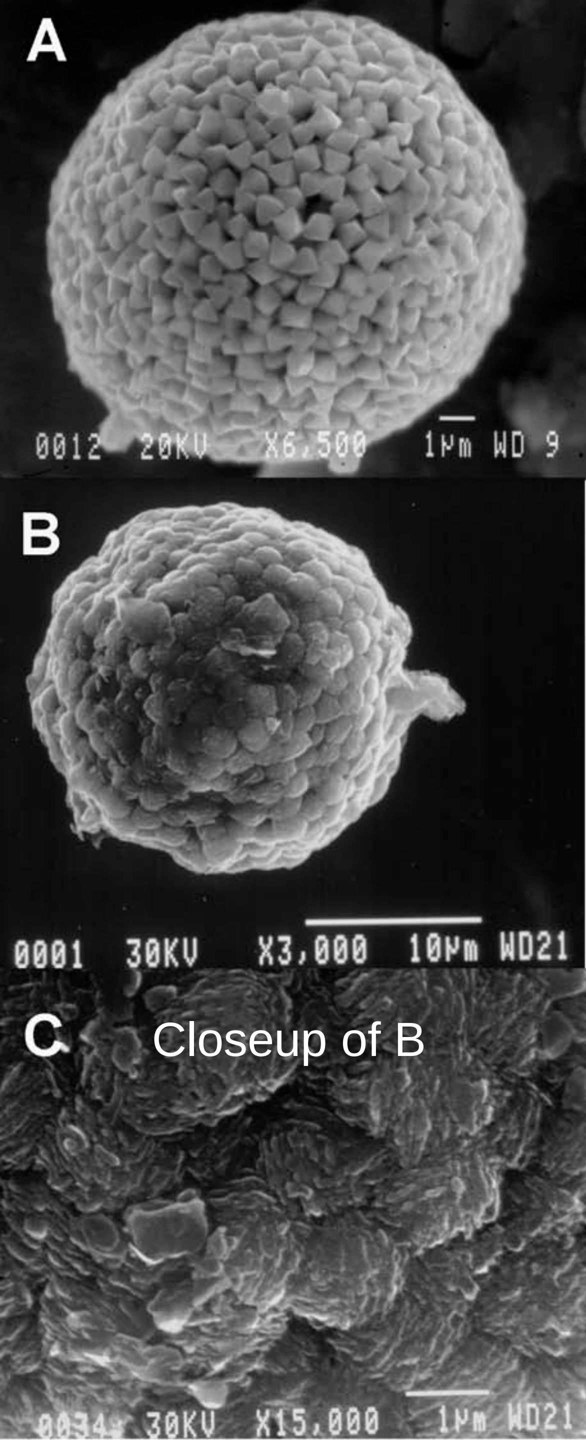
- Bare minimum
  - Store on ice in a cooler
  - Refrigerate and analyze immediately
- Prefered
  - Sparge with N2
  - Then store on ice (or preferably) freeze in the field
  - Store frozen until analyzed
- Slows chemical and microbial oxidation of sulfide minerals



Pedon	CB21
Landform	Submerged wave-cut headland
Soil Map Unit	Spβ
Current Soil Classification	Fine-loamy, Thapto-Histic Sulfaquents
(Proposed Soil Classification)	(Fine-loamy, Thapto-Histic Sulfiwassents)
Series	Southpoint Taxajunct



Black monosulfides (FeS) can form quickly by chemical reactions between Fe(II) and S=



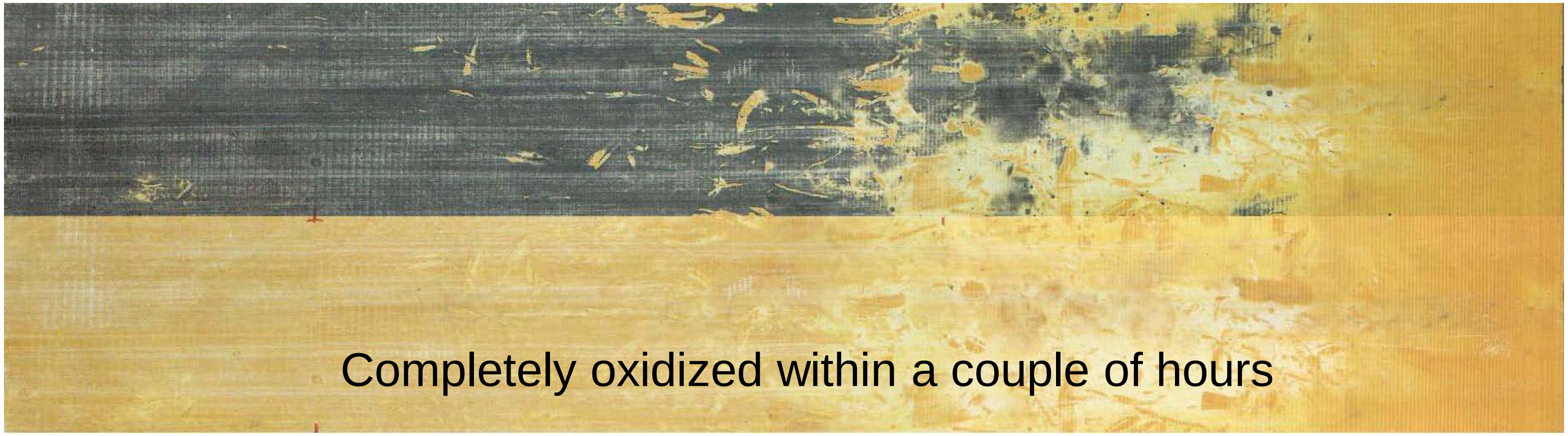
- Well formed and crystalline pyrite framboid

- Pooly formed and poorly crystalline framboid formed within 2 years

Pyrite forms as a result of microbial processes, usually over periods of weeks, months, years or decades.

Oxidation of sulfides

- FeS oxidizes very quickly - chemically



- FeS_2 takes more time to oxidize – microbially mediated reactions.

Oxidation of sulfides

- Overall oxidation and hydrolysis of S and Fe of pyrite

$$FeS_2 + 3\tfrac{3}{4} O_2 + 2\tfrac{1}{2} H_2O \rightarrow FeOOH + 2H_2SO_4$$

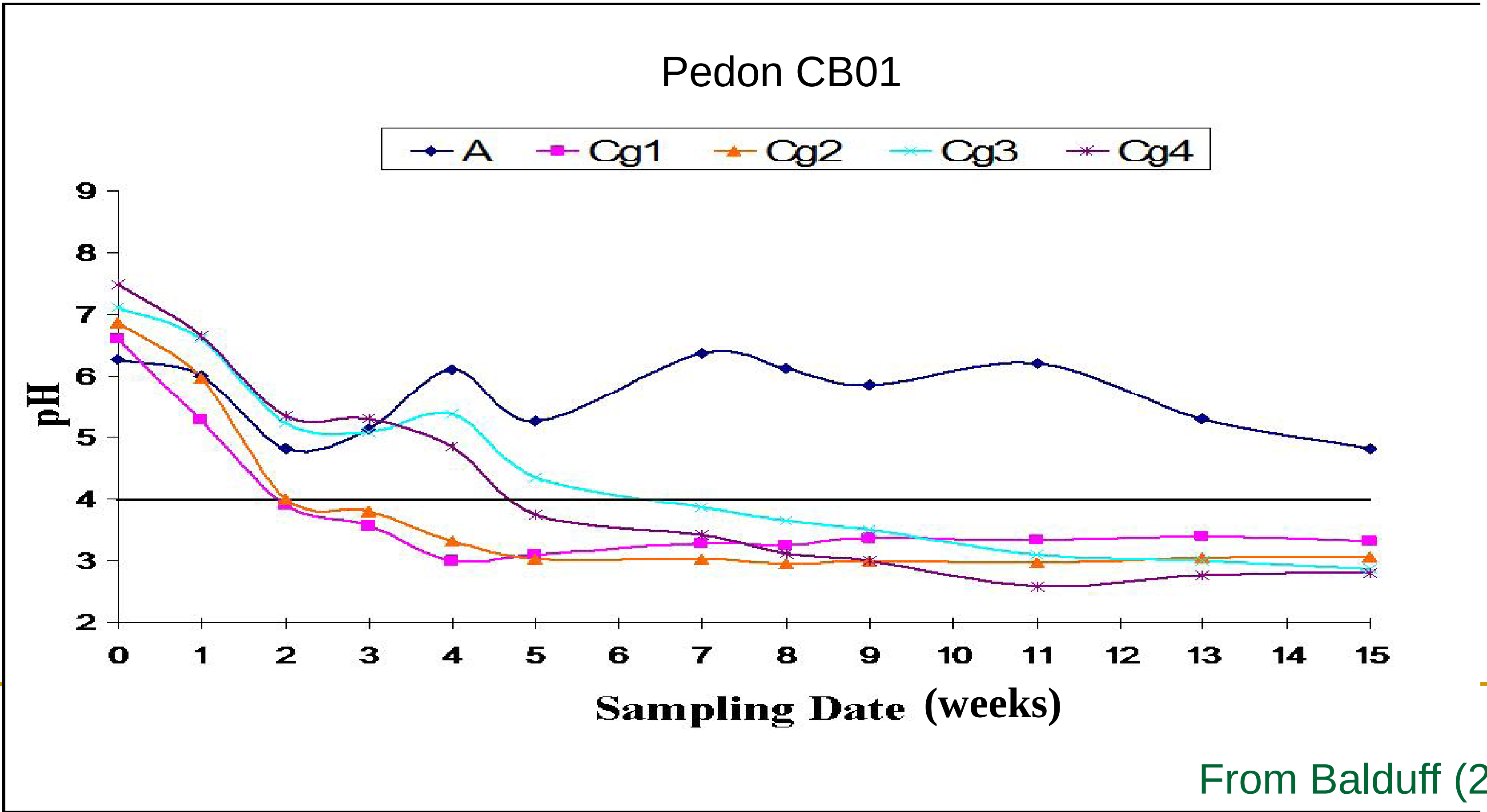
- Sulfuric acid drives down pH
- Acid reacts with other basic compounds generating salts, so salinity goes way up.
- **This is why proper handling and storage are so important!**

Field Measurements

- pH – mostly near neutral
  - can measure with standard field kits (Truog; test strips)
- FeS (acid volatile sulfide) - qualitative
  - Check sample for H_2S odor
  - Add a few drops of 10% HCl and see if you detect increase in H_2S
  - If breezy, place small amount of sample in ziplock bag and add a few drops of HCl. Seal and wait a minute. Open and see if you detect increase in H_2S odor inside the bag.
  - Some experimentation with H_2O_2

Lab Measurements

- Moist, oxidizing, pH Incubation over time
  - Optimizes conditions for microbial oxidation of sulfide minerals and generation of acidity and salts



From Balduff (2007)

pH Incubation – Some samples take longer for pH to drop.

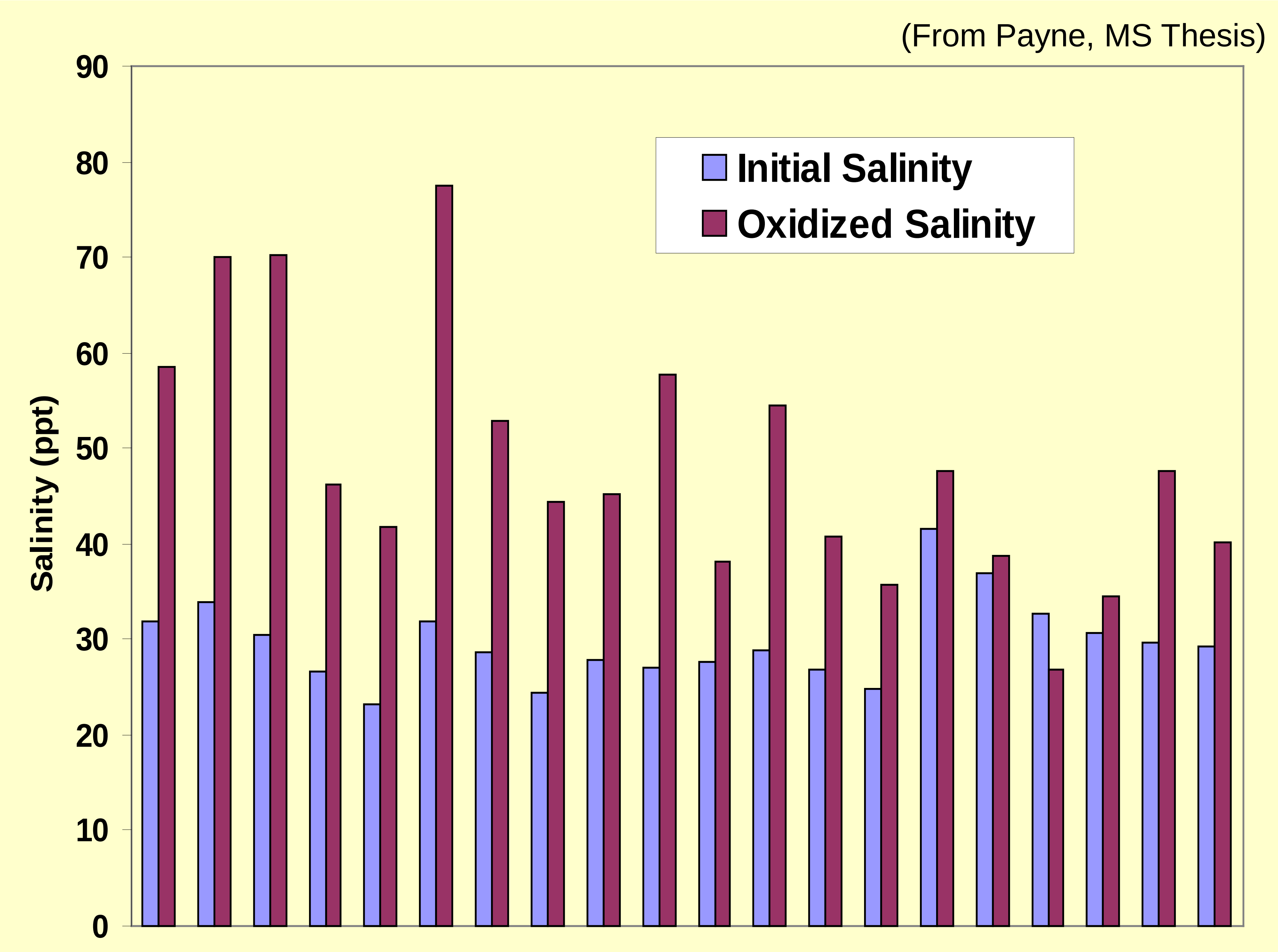
Length of time to drop below pH 4	Number of samples[†]	% of Samples that eventually show a drop in pH<4
4 weeks	25 (16%)	20
8 weeks	73 (45%)	57
12 weeks	104 (64%)	81
16 weeks	117 (72%)	91
20 weeks	125 (77%)	98
24 weeks	128 (78%)	100

† 46 samples were only incubated for 16 weeks

From Balduff (2007)

Lab Measurements

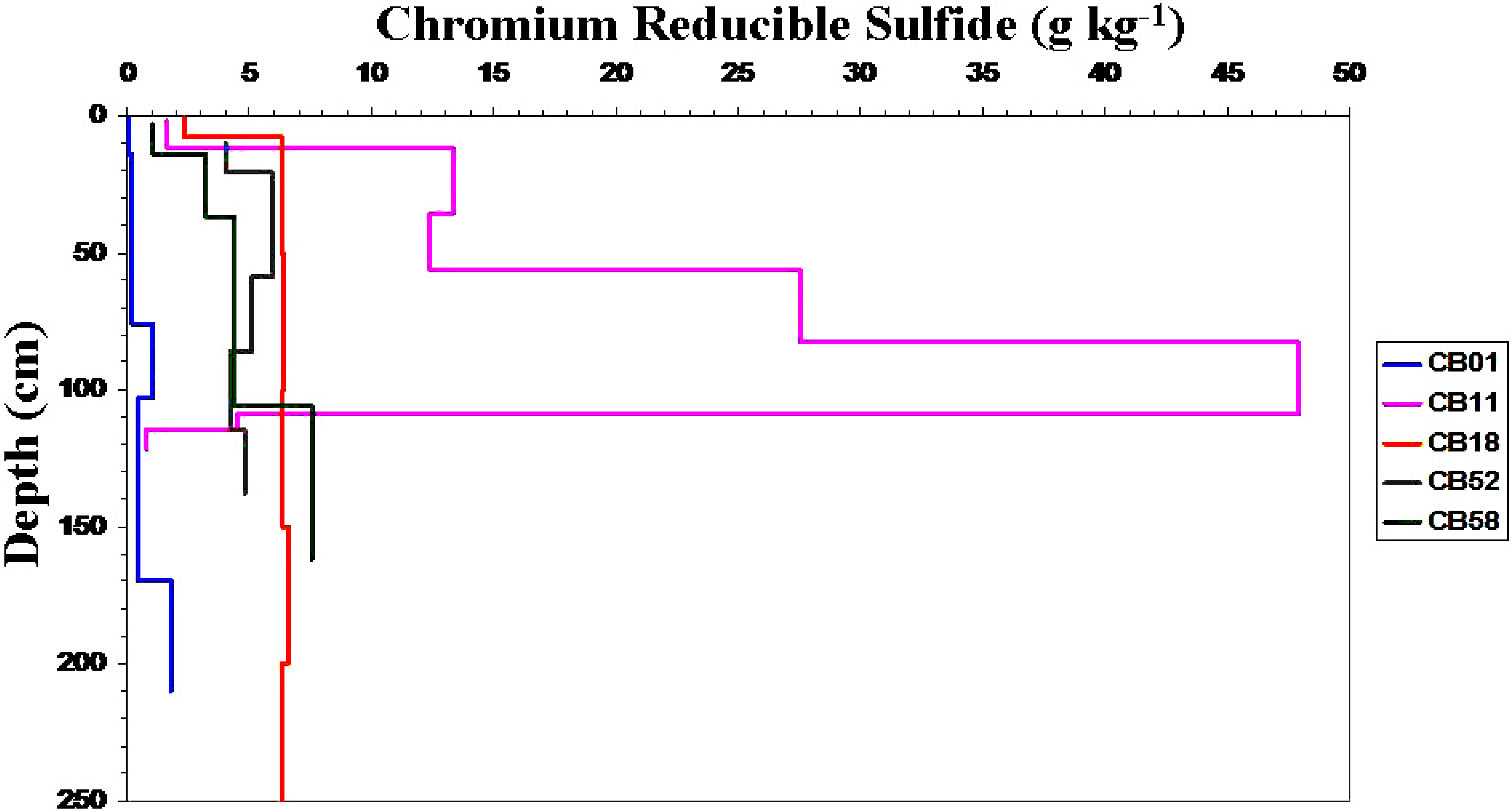
- Salinity
  - Electrical conductivity run on 1:5 extract
  - Much simpler than saturated paste



(From Payne, MS Thesis)
Salinity (ppt)
0
10
20
30
40
50
60
70
80
90
Initial Salinity
Oxidized Salinity

Lab Measurements

- Sulfides – Cr reduction methods
  - Several variations; fairly involved
  - Sample handling critical prior to analysis
  - Can distinguish between FeS (Acid Volatile Sulfide - AVS) and Pyrite (Cr reducible Sulfide - CRS) if needed



Usually, AVS (FeS) is MUCH LESS than CRS (FeS_2), typically (only a few % of CRS).

From Balduff (2007)

Lab Measurements

- **Carbonates** – Qualitative
  - Add drop of 10% HCl to soil while examining under stereo microscope

Class	Reaction	$CaCO_3$ ($g\ kg^{-1}$)	
		Mean	Range
non-effervescent (NE)	no reaction	0	
very slightly effervescent (VS)	one or two bubbles	3.2	0.0 to 17
slightly effervescent (SL)	few bubbles	7.4	0.0 to 30
strongly effervescent (ST)	many bubbles		18 to 370
violently effervescent (VE)	low foam		

From Balduff (2007)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