Sedimentation Dynamics and Stratigraphy of the Middle Breton Sound Estuary, Southeastern Louisiana: Spatiotemporal Evidence for Subdeltaic Evolution

Edwin J. Bomer IV[1], Samuel J. Bentley[1,2], Kehui Xu[2,3], and Qin Chen[4]

[1]Department of Geology and Geophysics, Louisiana State University, Baton Rouge, Louisiana 70803

[2]Coastal Studies Institute, Louisiana State University, Baton Rouge, Louisiana 70803

[3]Department of Oceanography and Coastal Sciences, Louisiana State University, Baton Rouge, Louisiana 70803

[4]Department of Civil and Environmental Engineering, Louisiana State University, Baton Rouge, Louisiana 70803

GCAGS Explore & Discover Article #00053*
http://www.gcags.org/exploreanddiscover/2016/00053_bomer_et_al.pdf
Posted September 13, 2016.

*Article based on an extended abstract published in the *GCAGS Transactions* (see footnote reference below), which is available as part of the entire 2016 *GCAGS Transactions* volume via the GCAGS Bookstore at the Bureau of Economic Geology (www.beg.utexas.edu) or as an individual document via AAPG Datapages, Inc. (www.datapages.com), and delivered as an oral presentation at the 66th Annual GCAGS Convention and 63rd Annual GCSSEPM Meeting in Corpus Christi, Texas, September 18–20, 2016.

EXTENDED ABSTRACT

Subsurface core borings have provided a fundamental understanding of stratigraphic architecture and depositional processes in the Mississippi River Delta. Careful observation of lithostratigraphic successions has led to the realization that delta plain construction is marked by a cyclic repetition of depositional events that occur in a consistent temporal manner. Crevasse splay-generated subdeltas are a primary driver of sedimentation in the modern Balize delta, and it is postulated that older lobes operated in a similar fashion. This study aims to determine the depositional processes that govern the middle Breton Sound estuary, an area within the geographic framework of the Plaquemines delta lobe, and to temporally constrain their occurrence through stratigraphic analysis and radiometric dating.

Twenty-five vibracores, up to ~5 m long, were collected from the study area and underwent whole-core density, grain size, and loss-on-ignition analyses. To provide age control, ten samples from the cores were chosen for radiocarbon dating. Grain size analyses of 252 downcore samples demonstrated that silt is the dominant grain size, a finding consistent with that of other receiving basins in the area (Fig. 1). Loss-on-ignition testing revealed that organic-rich sediments are primarily concentrated in the first meter of the vertical profile with smaller yet appreciable peaks between two and three meters depth (Fig. 2). Five lithofacies were identified based on physical properties and correlated to distinct subdeltaic depositional environments. ^{14}C dating of in situ bivalve shells and the base of surficial peat yielded calibrated ages of ~1150 and ~350 calendar years B.P., respectively.

...

Originally published as: Bomer, E. J., IV, S. J. Bentley, K. Xu, and Q. Chen, 2016, Sedimentation dynamics and stratigraphy of the middle Breton Sound estuary, southeastern Louisiana: Spatiotemporal evidence for subdeltaic evolution: Gulf Coast Association of Geological Societies Transactions, v. 66, p. 695–696.

Sedimentation Dynamics and Stratigraphy of the Breton Sound Estuary, Southeastern Louisiana: Spatiotemporal Evidence for Subdeltaic Evolution

Edwin J. Bomer[1]
Samuel J. Bentley[1,2]
Kehui Xu[2,3]
Qin Chen[4]

(1) Department of Geology and Geophysics, Louisiana State University
(2) Coastal Studies Institute, Louisiana State University
(3) Department of Oceanography and Coastal Sciences, Louisiana State University
(4) Department of Civil and Environmental Engineering, Louisiana State University

THE WATER INSTITUTE OF THE GULF

LSU Coastal Studies Institute

CPRA

Overview

- Scientific Objectives
- Introduction / Previous Work
- Study Area
- Hypotheses
- Methodology
  - Field Work
  - Grain Size Analysis
  - Loss-on-Ignition (LOI)
- Results
  - Bulk Granulometry and LOI
  - Lithofacies Succession
- Discussion and Interpretations
- Conclusions

Scientific Objectives

- Ascertain the deposition processes that govern Breton Sound estuary using grain size trends and stratigraphic analysis from core borings

- Constrain relevant chronostratigraphic boundaries and delta-building events using AMS ^{14}C dating

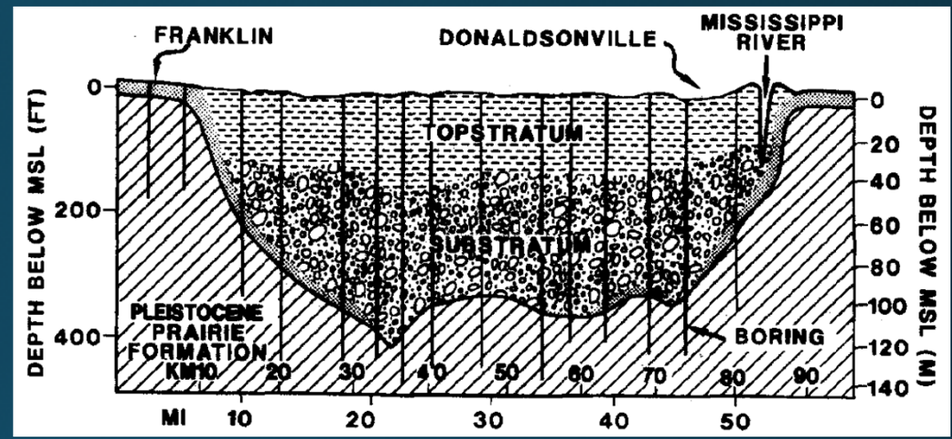
Introduction

Previous Work – Early Studies

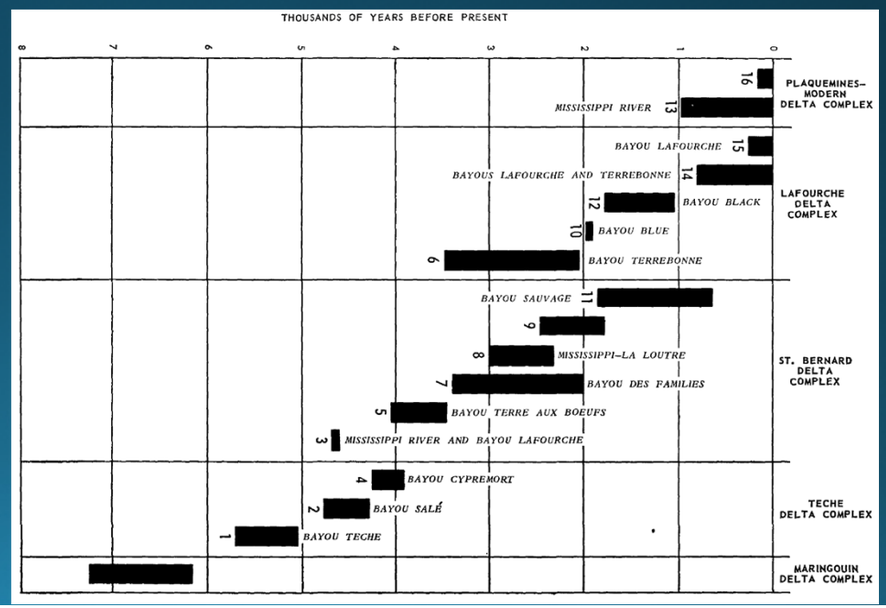
Mississippi River Delta (MRD) geomorphic studies
- Trowbridge (1930)
- Russell (1936)
- Russell and Russell (1939)

MRD subsurface studies
- Fisk (1944)
- Coleman and Gagliano (1964)

MRD geochronology studies
- McIntire (1954)
- Frazier (1967)



Fisk (1944)



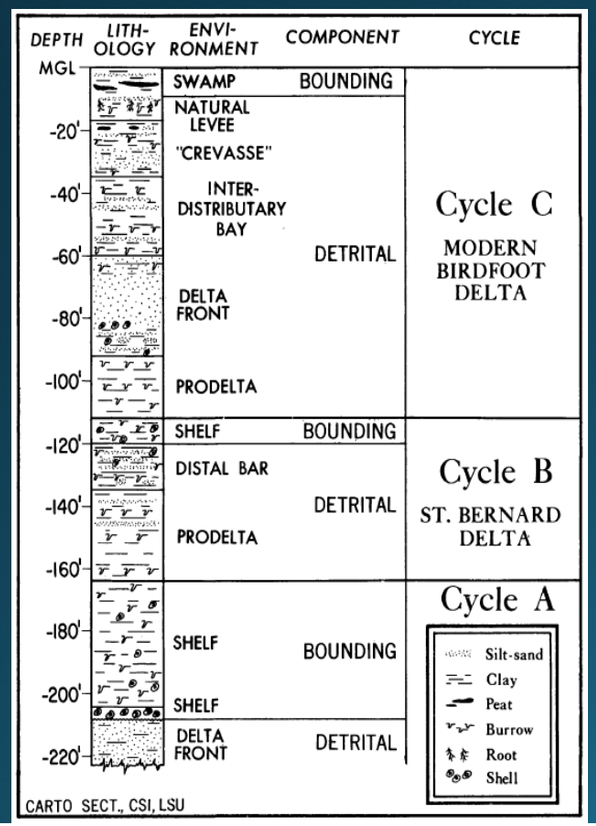
Frazier (1967)

Previous Work

Cyclicity of deltaic sedimentation occurs on multiple temporal scales

Delta lobe

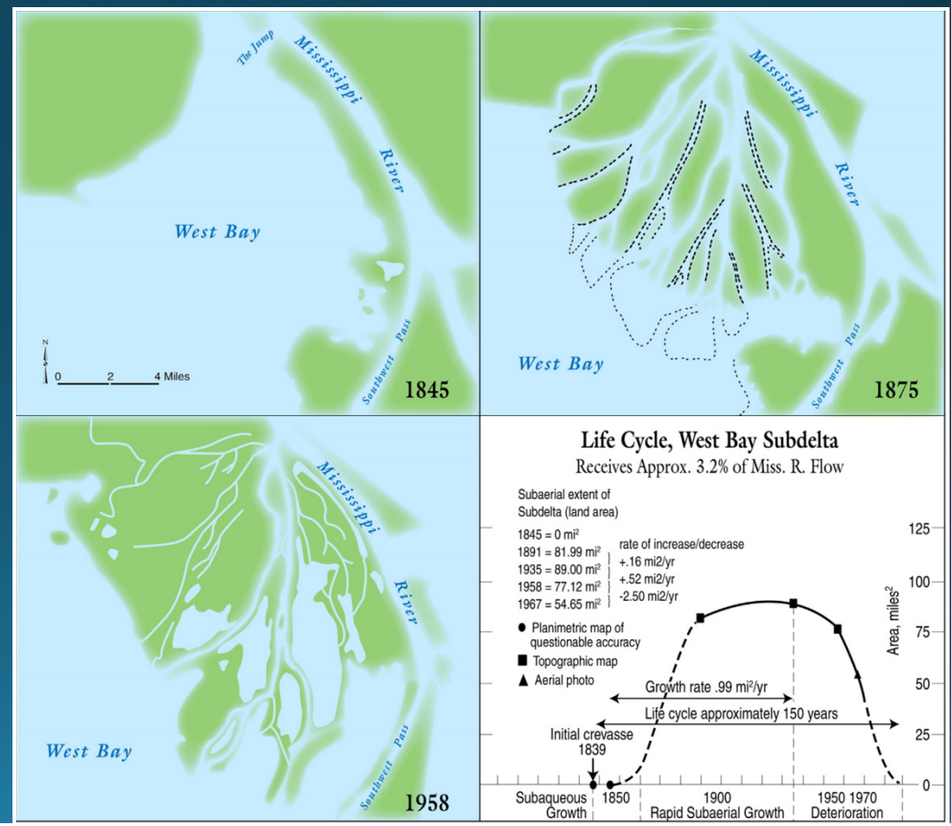
1000 – 2000 years



Coleman and Gagliano (1964)

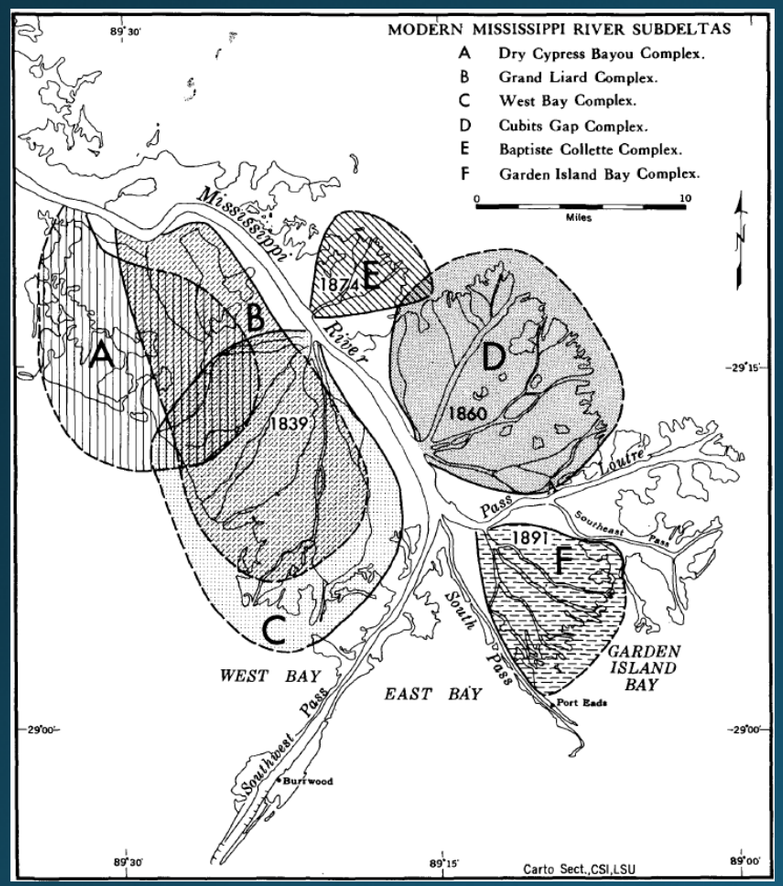
Subdelta

100-200 years

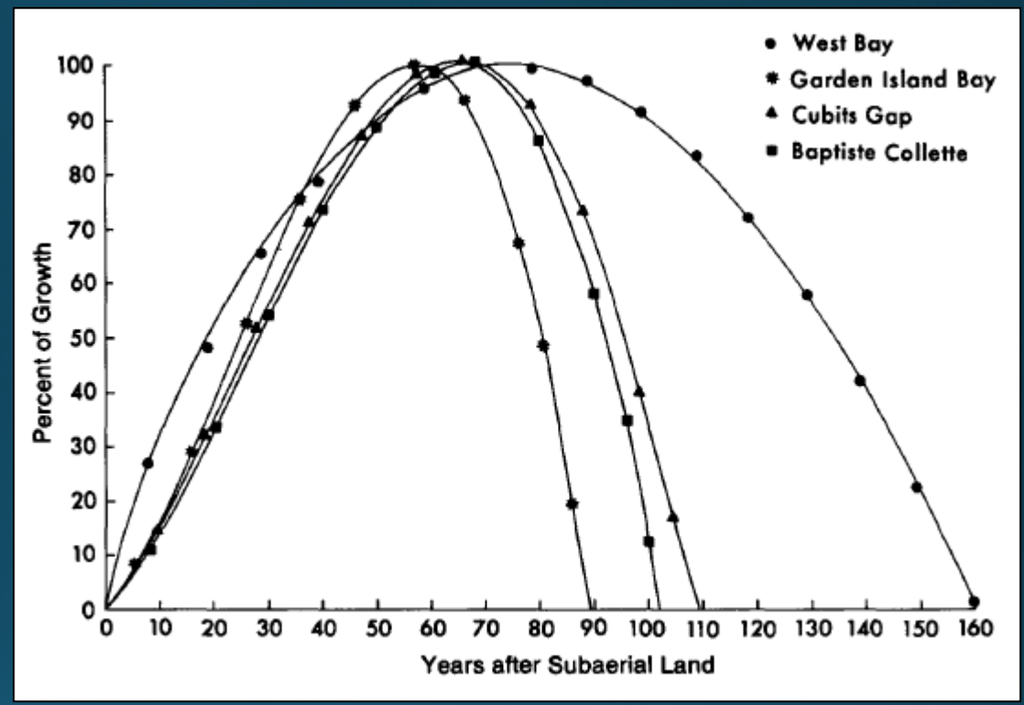


Bentley et al. (2015)

Previous Work



Coleman and Gagliano, 1964



Coleman, 1988

Crevasse splay deposits

- Form from a break in the natural levee
- Sediment rapidly infills open bay

Subdelta evolution

- Consistent development sequence
- Life span of 100 – 200 years
- Responsible for >80% of land growth in Balize delta (Davis, 1993)

Study Area

Middle Breton Sound (MBR)

Hypotheses

- Hypothesis I
  - The stratigraphy in the upper reaches of Breton Sound is composed of:
    - Fluvial sands and muds deposited by crevasse splays during the Plaquemines delta phase (ca. 1000-500 years BP)
    - Peat and mud deposited by non-fluvial processes like organic growth and storm-driven flooding after the delta prograded downstream to its present location
- Hypothesis II
  - The base of peat age is coincident with the onset of sediment bypassing and Balize delta lobe progradation (ca. 500 years BP)

Methodology

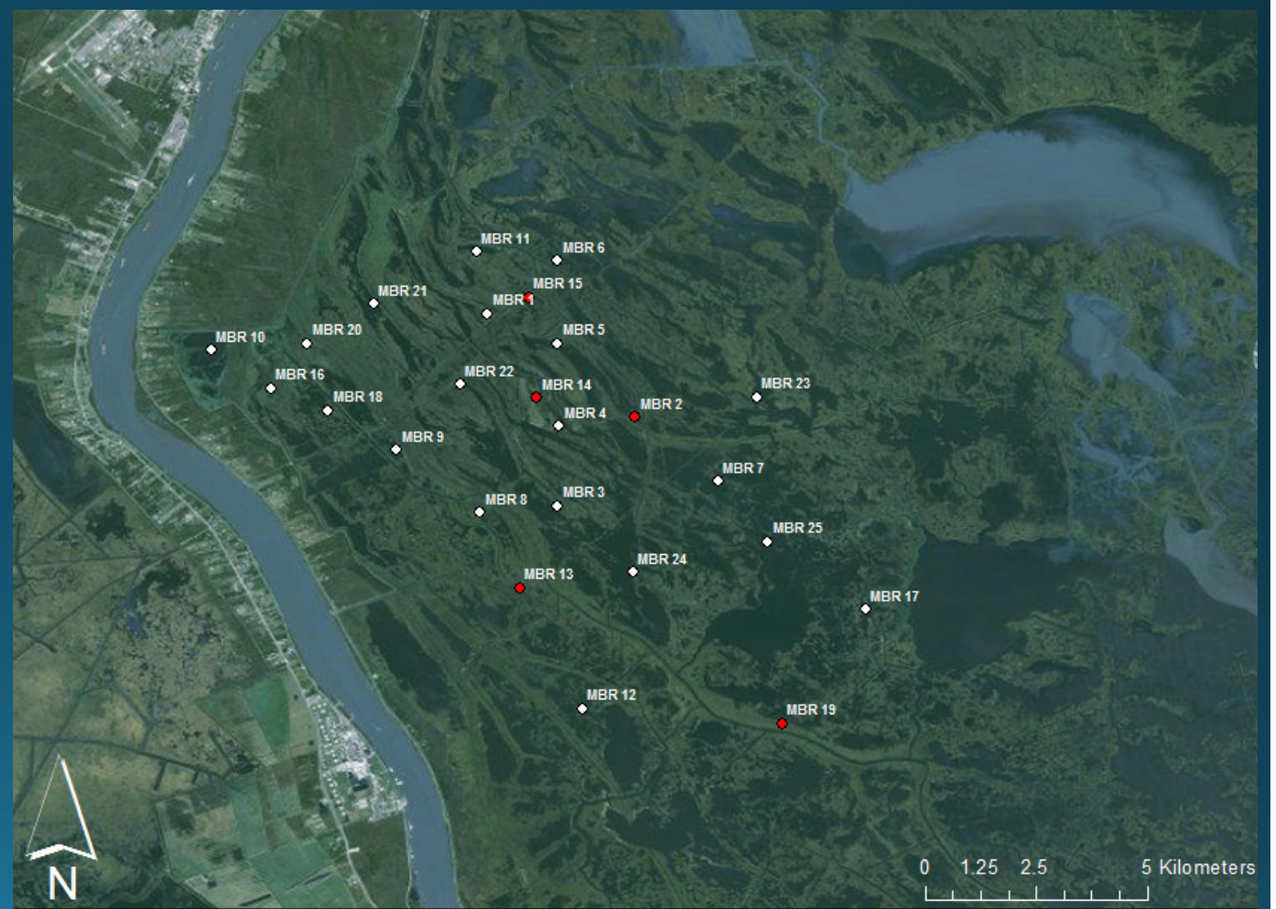
Field Work

Coring locations

- Situated such that they encompass a spatial area indicative of the receiving basin

Data collection

- Vibracores (n=25)
  - 6 m penetration
- Piston cores (n=25)
  - 1 m penetration
- Vane shear stress (n=100)
  - Measurements taken every 50 cm to a depth of 2.5 m
  - Performed by LSU Department of Civil and Environmental Engineering



Granulometry

Original sediment sample

↓ Mixed with ~5 ml of NaH_2PO_4 and poured through 850 µm sieve

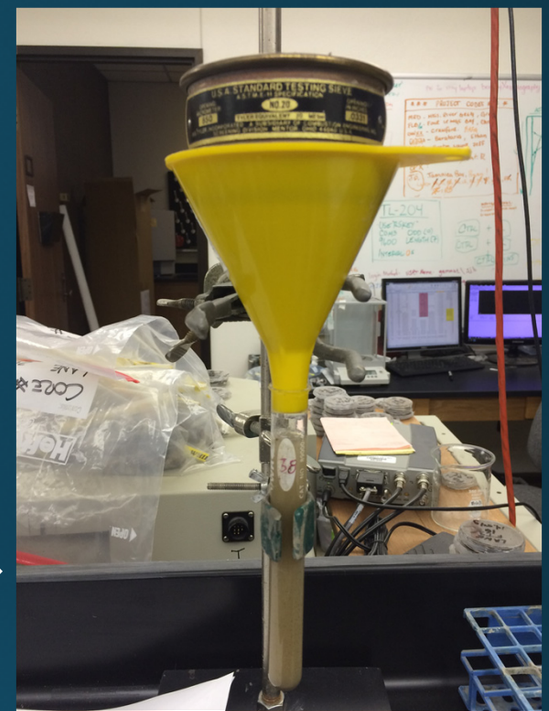
Sieved sediment

↓ Add ~5 ml of 30% H_2O_2 and place in hot bath at 60°C for 6 hrs

Digested sediment

↓ Add ~40 ml of NaH_2PO_4 and disperse in Particle Size Analyzer

Relative grain size abundance



Sieved sediment sample

Hot bath

Laser diffraction particle size analyzer

Loss-on-Ignition

Wet sediment (~94 g)

Heated at 60°C for
72 hrs in drying oven

Dehydrated sediment (~26 g)

Homogenized with
mortar and pestle

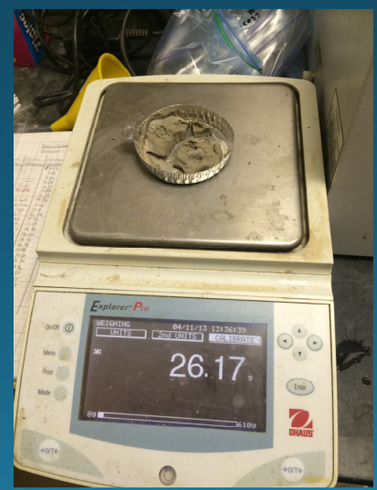
Ground sediment (~26 g)

Combusted at 550°C for
2 hrs in muffle furnace

Mineral remnants (~20 g)

Wet sediment

Drying sediment

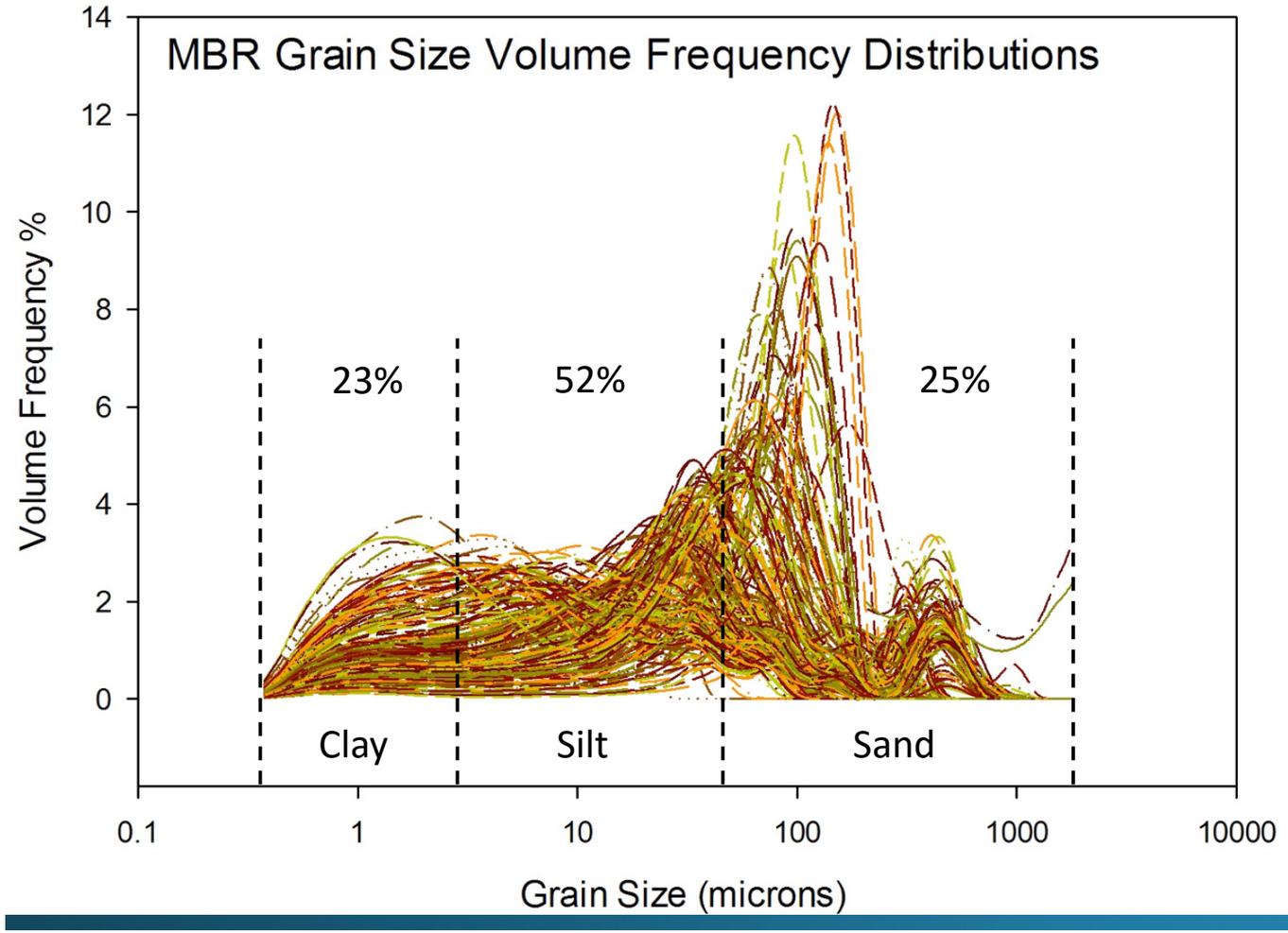


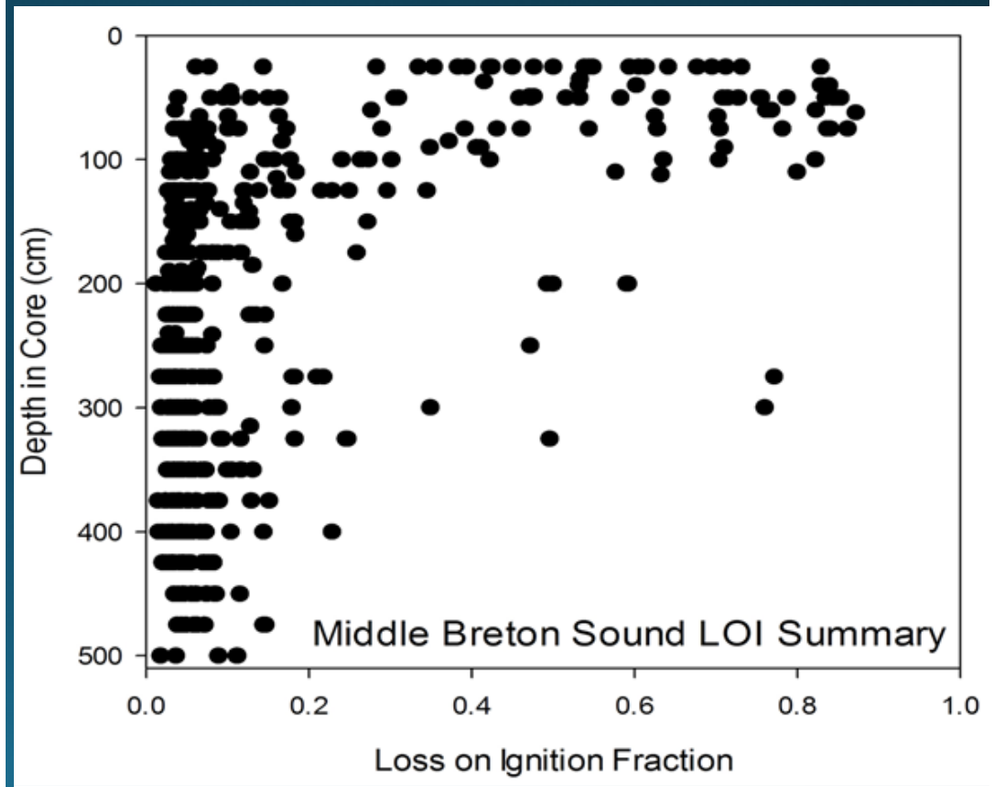
Dehydrated sediment

Mineral remnants

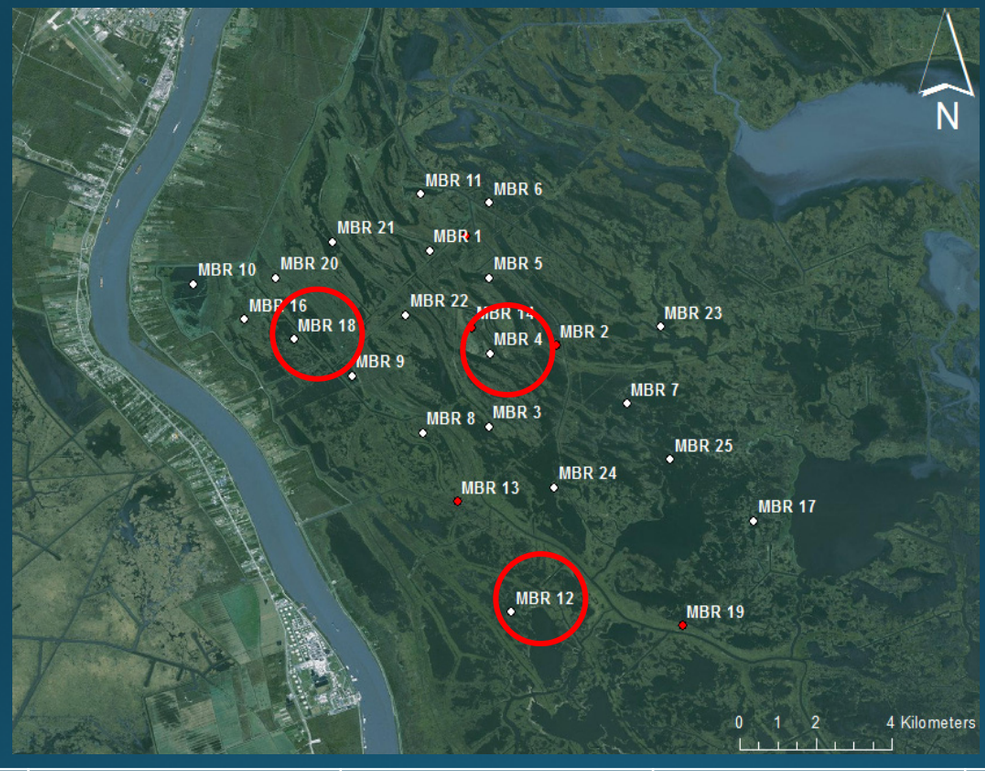
Results

MBR Grain Size and Loss-on-Ignition Results





^{14}C Results – Basal Peats

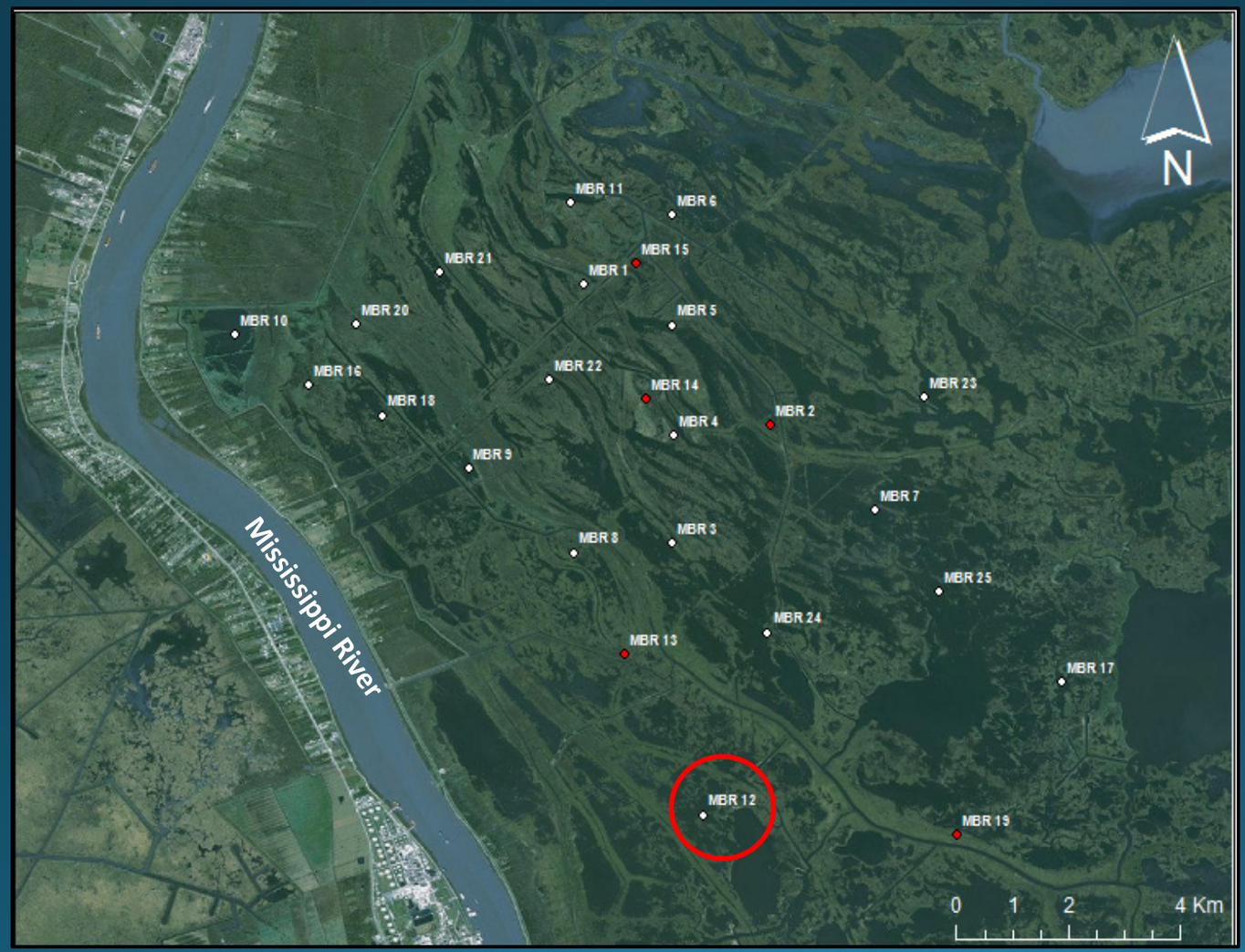


Core	Depth (cm)	Uncalibrated Age (^{14}C ybp)	Median Calib. Age (cal ybp)	Standard Deviation (yrs)
MBR 18	43-44	420	470	± 40
MBR 4	54-55	250	298	± 18
MBR 12	105-106	210	285	± 20
MBR 4	381-382	2970	3203	± 66

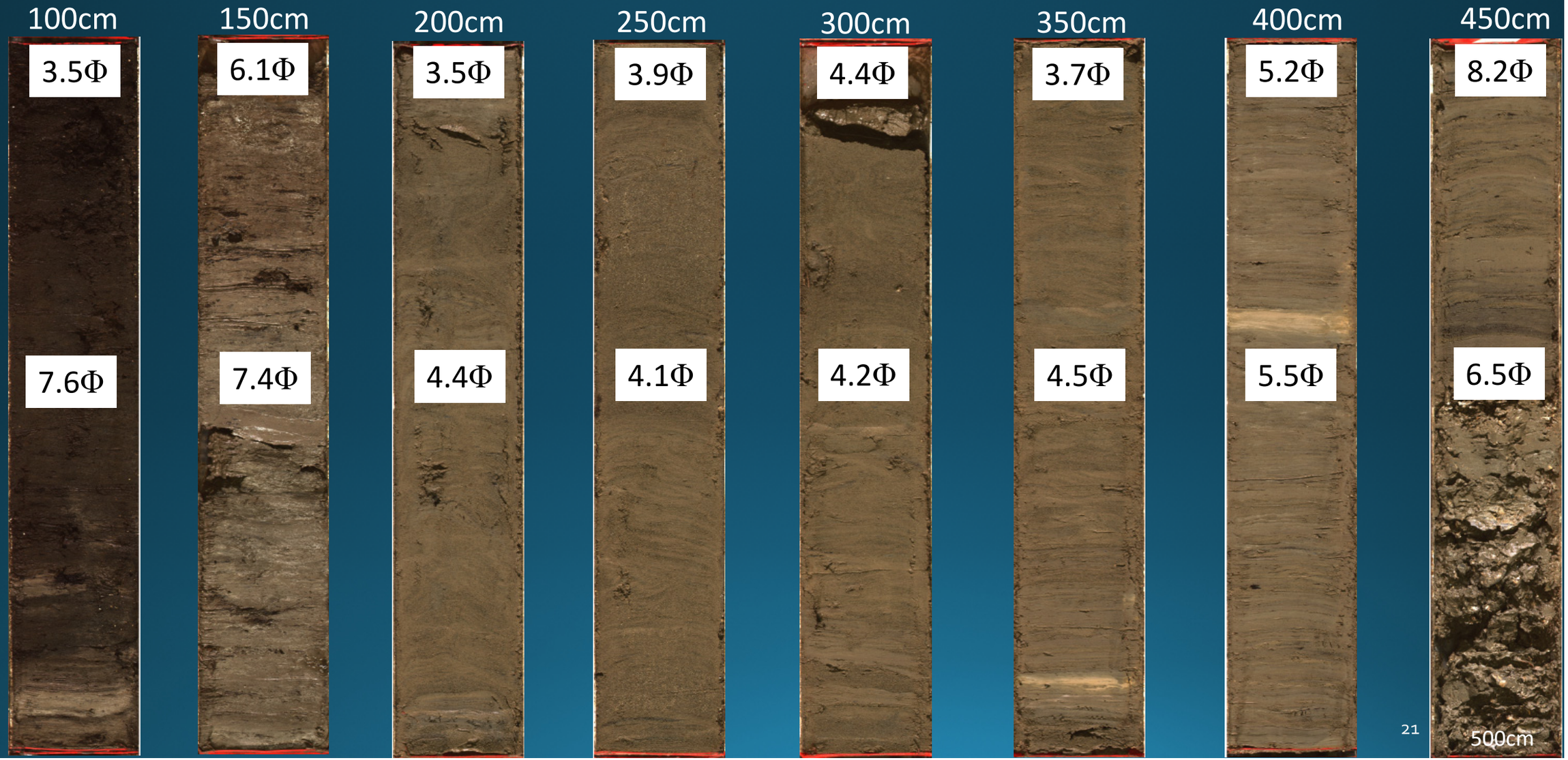
^{14}C Results – *In situ* Bivalve Shells

Core	Depth (cm)	Uncalibrated Age (^{14}C ybp)	Median Calib. Age (cal ybp)	Standard Deviation (yrs)
MBR 18	385-386	2000	1248	± 62
MBR 12	473-474	2070	1055	± 100

Lithofacies Succession in MBR 12

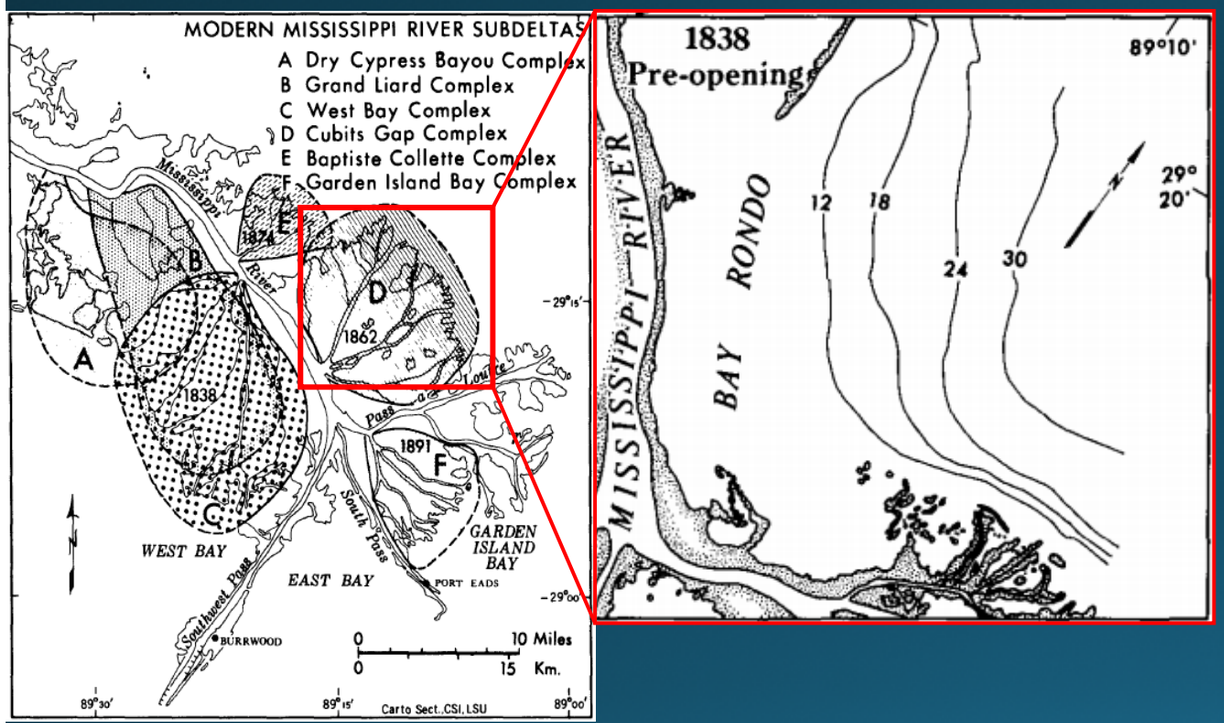


Lithofacies Succession in MBR 12



Discussion and Interpretations

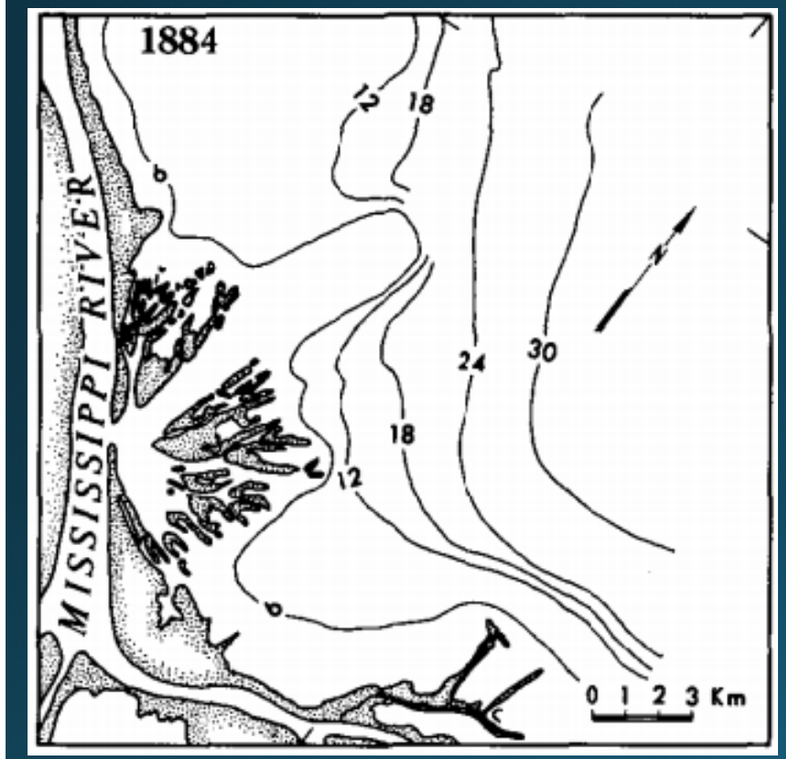
Lithofacies 1 (F1): Shell-rich open bay clay



Depositional and facies model - Cubit's Gap subdelta (Coleman, 1988)

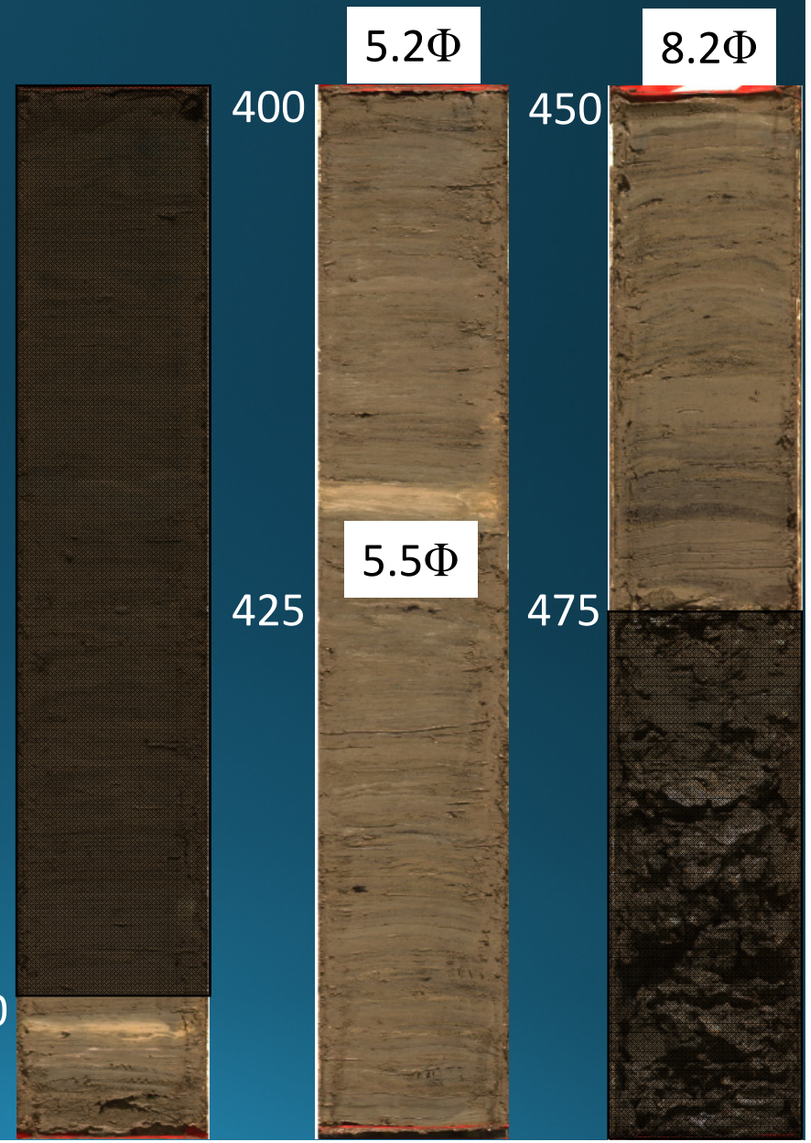
- Highly bioturbated gray clay
- Presence of *Rangia* shells indicates a shallow (<6 m) open bay environment
- Bulk density
  - Variable due to shell content, but in general, 1.5 – 2 g/cc

Lithofacies 2 (F2): Prodelta silts and clays



(Coleman, 1988)

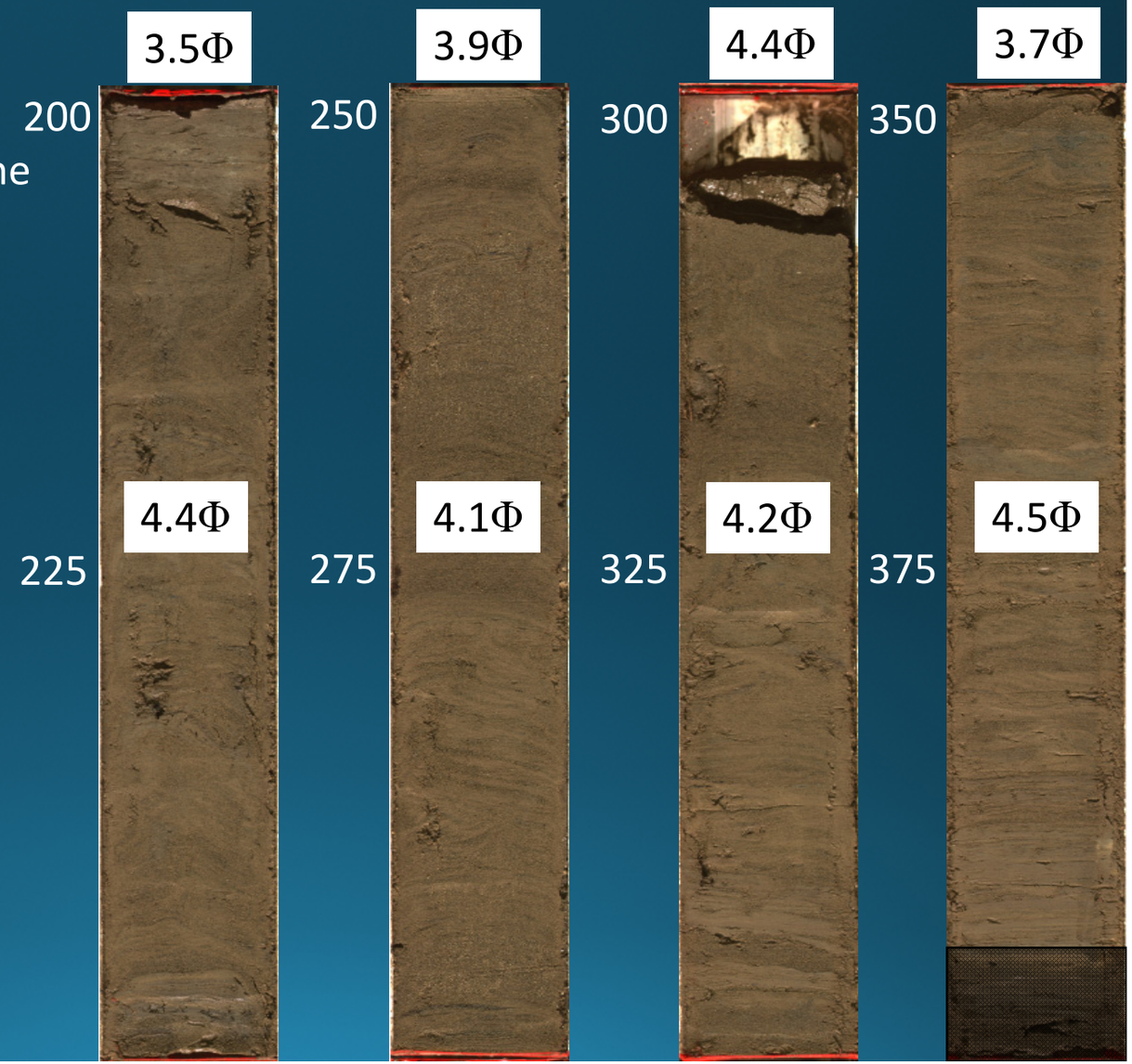
- Massive clay grades upward into well laminated interbedded silts and clays
- Often can be calcareous
  - Siderite horizons
- Represents the initial subaqueous fill after crevasse breakthrough
- Bulk density
  - 1.5 – 2 g/cc



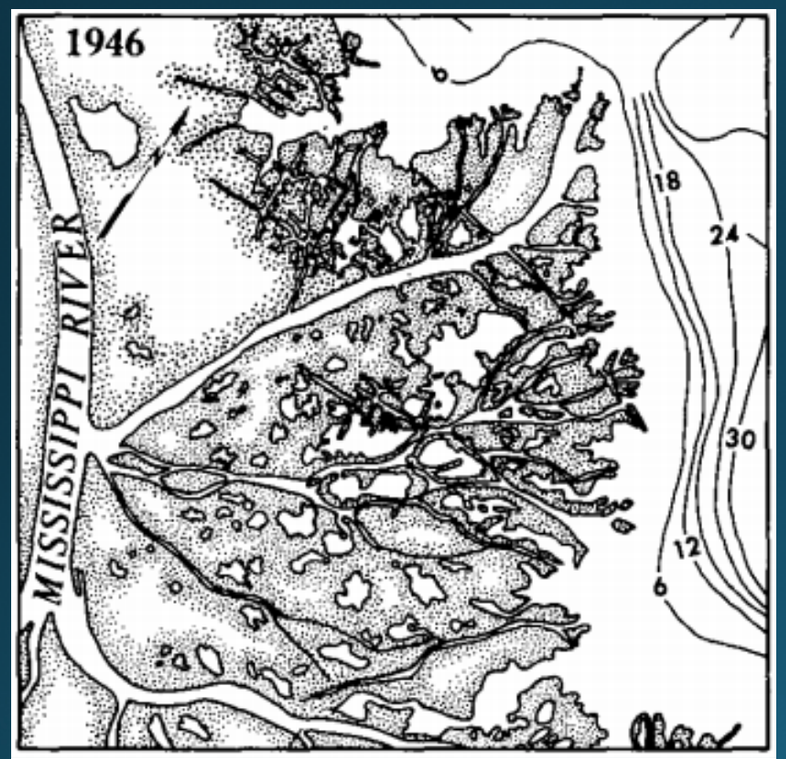
Lithofacies 3 (F3): Distributary channel sands and silts

(Coleman, 1988)

- Alternating sands and silts
  - Sand packages become thicker and more prominent upsection
- Diagnostic feature is the presence of sedimentary structures
  - Current ripple lamination
  - Convolute lamination
- Represents maximum hydraulic efficiency
- Bulk density
  - 1.75 – 2.25 g/cc

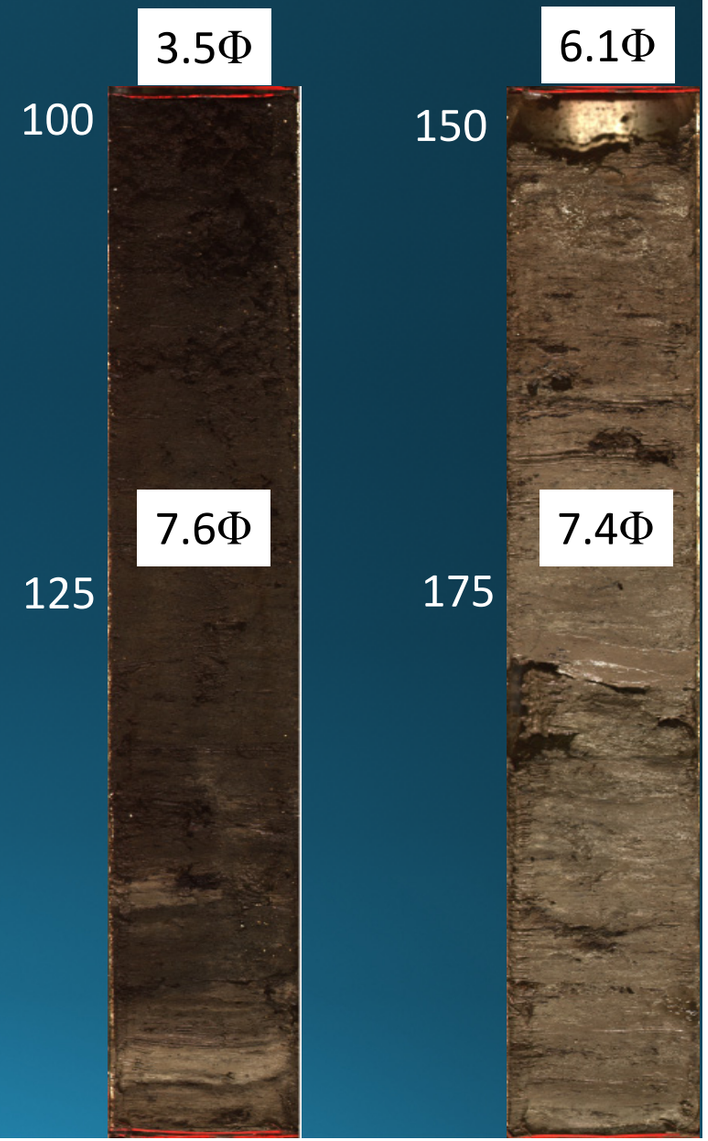


Lithofacies 4 (F4): Interdistributary bay silts and clays



(Coleman, 1988)

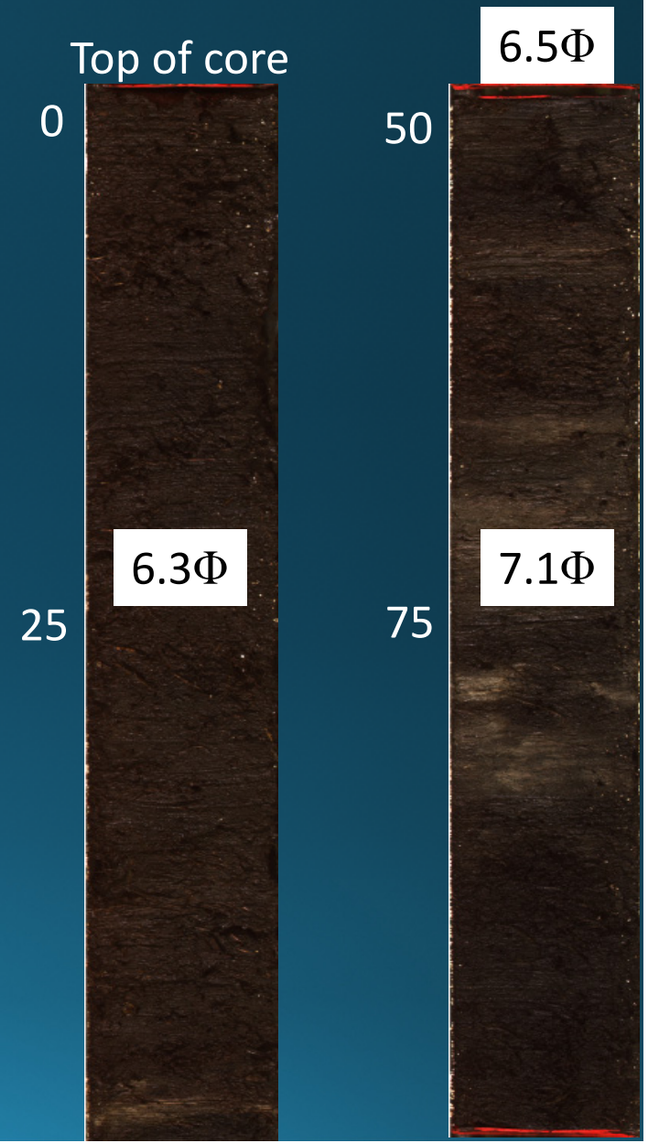
- Silts and clays that become organic-rich upsection (LOI > 30%)
- Sediment deposited by distributary overbank flooding
- Homogeneous texture suggests extensive bioturbation
- Bulk density
  - 1.5 g/cc



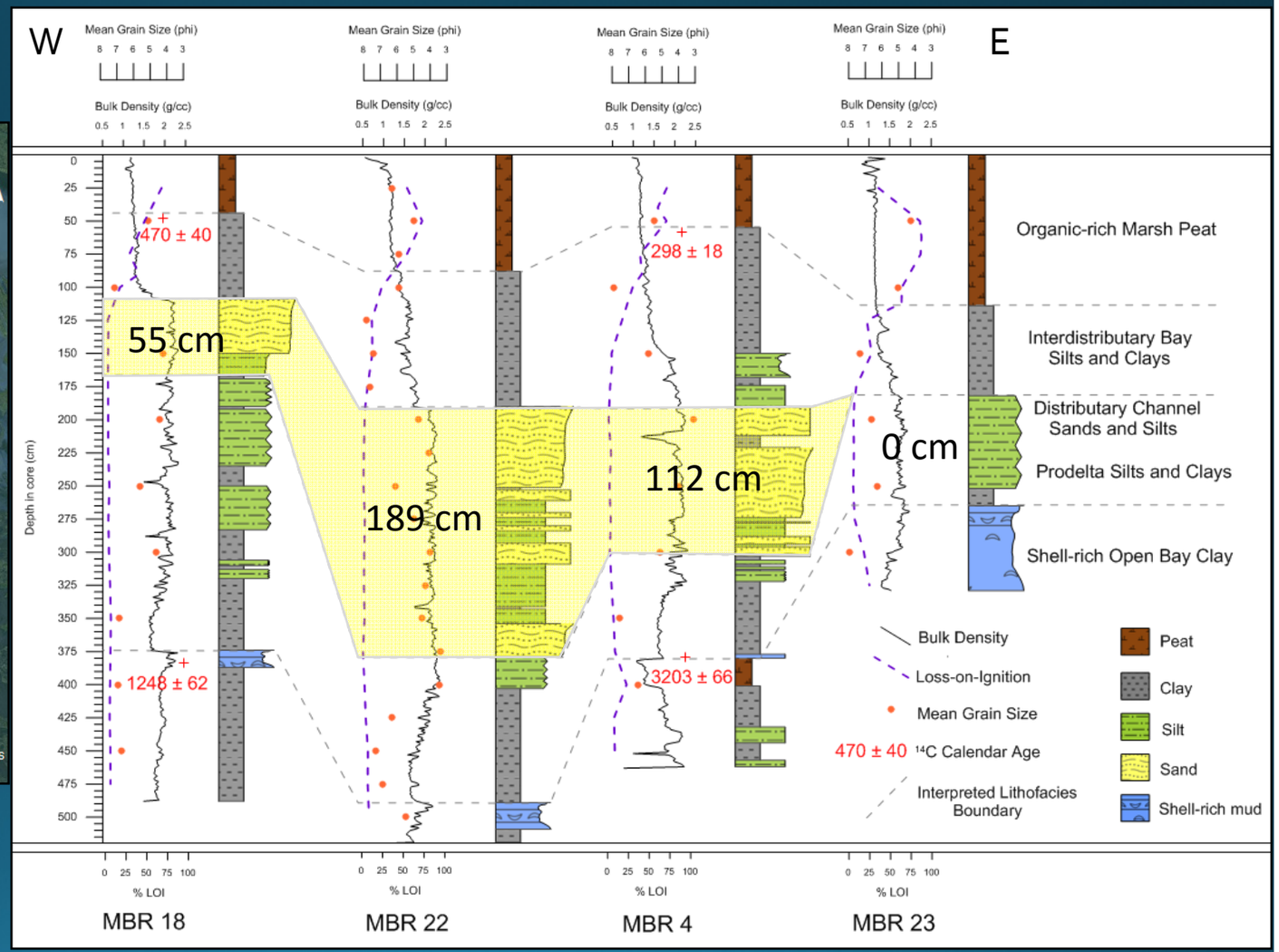
Lithofacies 5 (F5): Organic-rich marsh peat

(Coleman, 1988)

- Dark brown, fibrous, organic-rich peat with minor amounts of detrital material
- *In situ* carbonaceous material and LOI > 60%
- Clay stringers represent local flood and/or storm events
- Bulk density
  - 1 – 1.5 g/cc

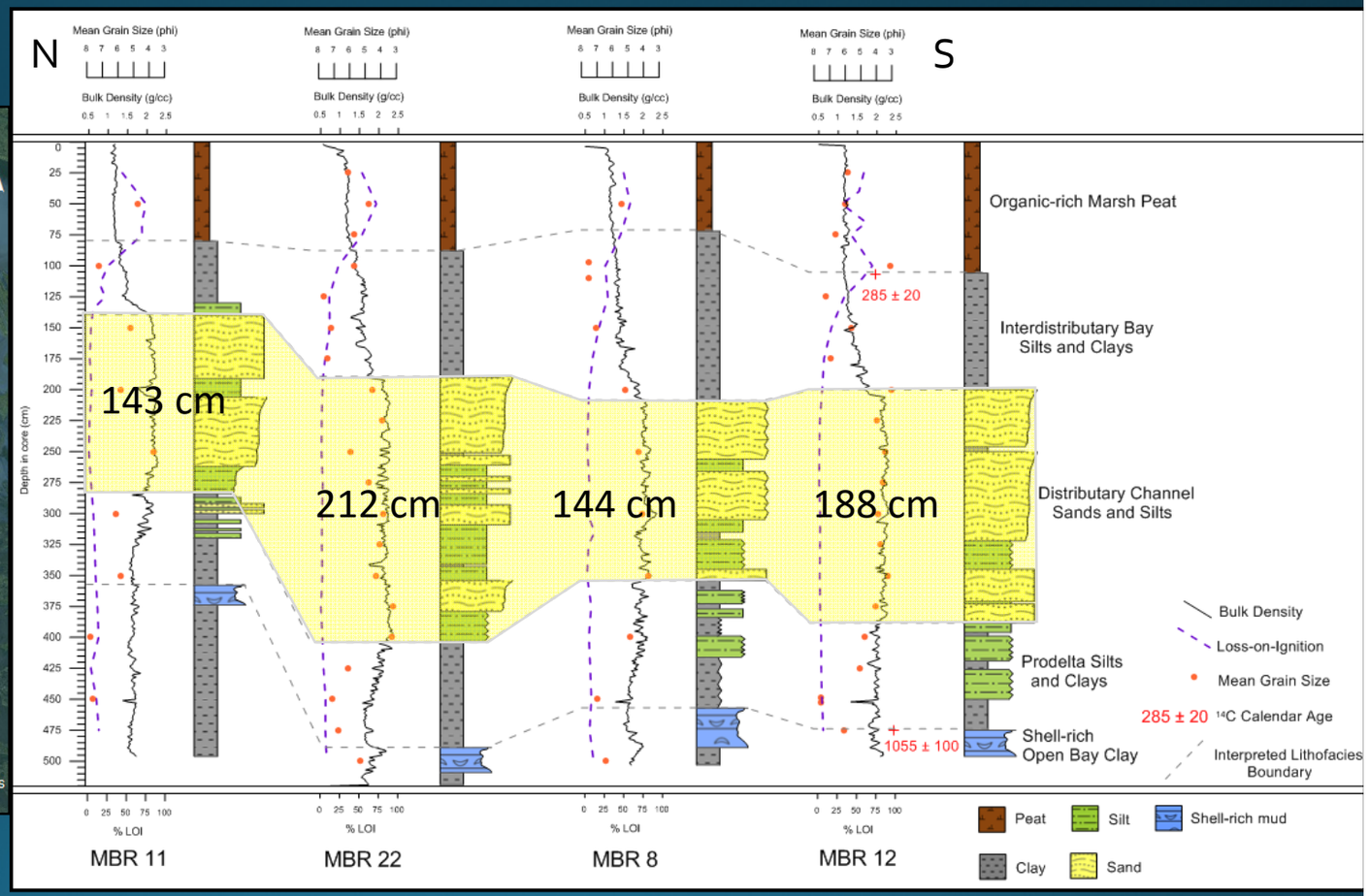


West-East Cross Section and Lithostratigraphy



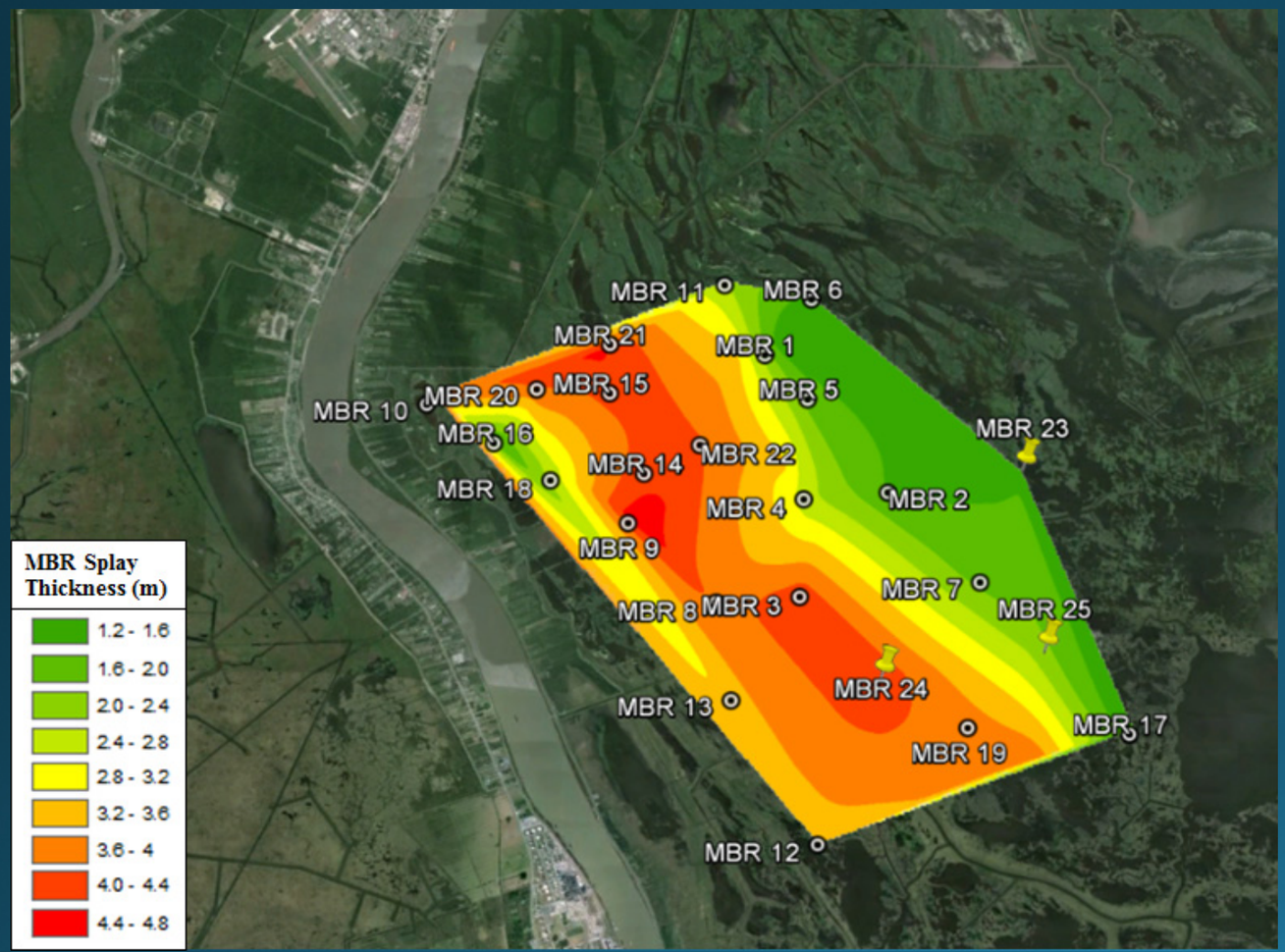
Average distributary channel lithofacies thickness = 89 cm

North-South Cross Section and Lithostratigraphy



Average distributary channel lithofacies thickness = 172 cm

Splay Isopach Map



Natural neighbor interpolation

Average MBR vibracore compaction = 24%

- Actual splay thickness could be >6 m near point source
- Consistent with Coleman and Prior (1982) and Coleman (1988)

Conclusions

- The lithostratigraphic succession observed in MBR cores is consistent with that of modern crevasse splay deposits (e.g. Coleman and Prior, 1982; Coleman, 1988)
- Splay thickness spatial distributions suggest that a levee breach occurred north of the study area and distributaries propagated in a south to southeast direction
- ^{14}C ages of basal peats indicate that the onset of subdeltaic activity occurred no later than 470 ± 40 years B.P.
- ^{14}C ages of bivalve shells indicate that an open bay environment occupied MBR ~950 to 1310 years B.P.

Acknowledgments

Advisory Committee:

- Dr. Sam Bentley
- Dr. Carol Wicks
- Dr. Kevin Xu

Funding Sources:

THE WATER INSTITUTE OF THE GULF

CPRA

LSU Geology & Geophysics

bp

Lab Assistance:

- Patrick Baudoin
- Ryan Clark
- Daniela Colmenares
- Frances Crawford
- Abigail Heath
- Ethan Hughes
- Bryan Mogrovejo
- Rodney Stieffel

Field Assistance:

- Bill Gibson
- Brittany Gregory
- Ray Inaray
- Greg Keller
- Meg O'Connor
- Charlie Sibley
- James Smith
- Crawford White

References

Bentley, S.J., Blum, M.D., Maloney, J., Pond, L., and Paulsell, R., 2015. The Mississippi River Source-to-Sink System: Perspectives on Tectonic, Climatic, and Anthropogenic Influences, Miocene to Anthropocene. *Earth-Science Reviews*, **151**, 36 pp.

Boyer, M.E., Harris, J.O., and Turner, R.E., 1997. Constructed Crevasse and Land Gain in the Mississippi River Delta. *Restoration Ecology*, **5**, p. 85-92.

Coastal Protection and Restoration Authority of Louisiana (CPRA) 2012. Integrated ecosystem restoration and hurricane protection: Louisiana's comprehensive master plan for a sustainable coast, Baton Rouge, LA.

Coleman, J.M. and Gagliano, S.M., 1964. Cyclic Sedimentation in the Mississippi River Deltaic Plain. *Transactions – Gulf Coast Association of Geological Societies*, **14**, p. 67-80.

Day, J. W., Cable, J.E., Lane, R.R., and Kemp, G.P., 2016. Sediment Deposition at the Caernarvon Crevasse during the Great Mississippi Flood of 1927: Implications for Coastal Restoration. *Water*, **8**, p. 1-12.

Davis, D.W., 1993. Crevasses on the Lower Course of the Mississippi River. *Coastal Zone '93*, p. 360–378.

Delaune, R., Baumann, R., and Gosselink, J., 1983. Relationships among Verical Accretion, Coastal Submergence, and Erosion in a Louisiana Gulf Coast Marsh. *Journal of Sedimentary Petrology*, **53**, 147-157.

Fisk, H.N., 1944. Geological Investigation of the Alluvial Valley of the Lower Mississippi River. In: Miss. River Comm., Vicksburg, MS.

Frazier, D.E., 1967. Recent Deltaic Deposits of the Mississippi River, their Development and Chronology. *Transactions – Gulf Coast Association of Geological Societies*, **17**, p. 287-315.

Gagliano, S.M., Light, P., and Becker, R.E., 1973. Controlled Diversions in the Mississippi River Delta System: An Approach to Environmental Management. Coastal Resource Unit, Center for Wetland Resources, Louisiana State University, Baton Rouge.

Gagliano, S.M., Meyer-Arendt, K.J., and Wicker, K.M., 1981. Land Loss in the Mississippi River Deltaic Plain. *Transactions – Gulf Coast Association of Geological Societies*, **31**, p. 295-300.

Kosters, E.C., 1998. Organic-Clastic Facies Relationships and Chronostratigraphy of the Barataria Interlobe Basin, Mississippi Delta Plain. *Journal of Sedimentary Petrology*, **59**, p. 98-113.

Kraus M.J., and Gwinn B. 1997. Facies and facies architecture of Paleogene floodplain deposits, Willwood Formation, Bighorn Basin, Wyoming, USA. *Sedimentary Geology*, **114**, p. 33–54

Lanesky, D.E., Logan, B.W., Brown, R.G., and Hine, A.C., 1979. A New Approach to Vibracoring Underwater and on Land. *Journal of Sedimentary Petrology*, **49**, p. 654-657.

Lankford, R.R. and Shepard, F.P., 1960. Facies Interpretation in Mississippi Delta Borings. *Geology*, **68**, p. 408-426.

Meade, R.H. and Moody, J.A. (2010). Causes for the decline of suspended-sediment discharge in the Mississippi River system, 1940-2007. *Hydrological Processes*, **24**, pp. 35-49.

Morton, R.A., and White, W.A., 1997. Characteristics of and Correction for Core Shortening in Unconsolidated Sediments. *Journal of Coastal Research*, **13**, p. 761-769.

Morton, R.A., Tiling, G., and Ferina, N.F., 2003. Primary Causes of Wetland Loss at Madison Bay, Terrebonne Parish, Louisiana. U.S. Geological Survey Open File Report 03-60, 44 pp. Saucier, R.T., 1968. Recent Geomorphic History of the Pontchartrain Basin. Louisiana State University Press, Baton Rouge, 114 pp.

Slingerland, R., and Smith, N.D., 2004. River Avulsions and their Deposits. *Annual Review of Earth and Planetary Sciences*, **32**, p. 257-285.

Tornqvist, T.E., Kidder, T.R., Autin, W.J., van der Borg, K., de Jong, A.F.M., Klerks, C.J.W., Snijders, E.M.A., Storms, J.E.A., van Dam, R.L., and Wiemann, M.C., 1996. A Revised Chronology for Mississippi River Subdeltas. *Science*, **273**, p. 1693-1696.

Wells, J.T. and Coleman, J.M., 1987. Wetland Loss and the Subdelta Life Cycle. *Estuarine, Coastal, and Shelf Science*, **25**, p. 111-125.

Wilson, C.A. and Allison, M.A., 2008. An Equilibrium Profile Model for Retreating Marsh Shorelines in Southeast Louisiana. *Estuarine, Coastal, and Shelf Science*, **80**, p. 483-494.

Questions?