Extreme Events on a Low-Gradient River and Delta: Evidence for Sediment Mass Movements on the Subaqueous Delta and a Mechanism for Creating Hyperpycnal Flow in the Lower River*

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Abstract

The Brazos River empties into the Gulf of Mexico (Gulf of Mexico) forming a wave-influenced delta dominated by a muddy subaqueous portion. Recent work in the lower river and subaqueous delta (SAD) however, have discovered evidence for sedimentary processes more often associated with higher sediment discharge rivers and/or high-gradient rivers. These studies utilized high-resolution geophysics on the SAD and water-column profiling in the lower river to investigate the transfer to and fate of fluvial sediment on the shelf. From the SAD results showed the eastern portion was dominated by high side scan sonar backscatter features, an erosional scarp along the upper shoreface, and a thinning of the Holocene sediment package immediately downslope of the scarp. The thickness of the Holocene sediment package increased in deeper water. These features suggest sediment mass wasting events on the delta front. After rapidly prograding during the early and mid 20th century, reductions in sediment load, and a shift in the primary depocenter lead to erosion on these abandoned portions of the delta. The result is the erosional scarp upslope of the high backscatter features representing exposed relict consolidated sediments. In the lower river, we observed a separate extreme event. During an elevated fluvial discharge event, data from the lower river showed an anomalously high-suspended sediment layer. This fluid mud layer was >1 m thick in areas, and located along a 6 Km span of the river ~ 2 Km upstream from the mouth. The location corresponded to a reach of the river impacted by salt-water intrusions from the GOM. This salt-water intrusion was shown to inhibit sediment export from the river to the GOM, and facilitate deposition of fine-grained sediment in the lower river. Based on our observations we believe that this is a mechanism for the development of hyperpycnal flow in the river. The mud layer in the lower river builds during moderate and low discharge

periods and remobilized during increased discharge. We observed suspended sediment concentrations up to 100 g/l in the fluid mud layer during this event. While our observations did not capture the transition from fluid mud to hyperpycnal flow, we believe that with persistent increased discharge the fluid mud layer could transition to hyperpycnal flow. These results highlight the potential for sedimentary processes not typically associated with a river in this environmental setting.

References Cited

Carlin, J., T. Dellapenna, K. Strom, and C. Noll, 2015, The influence of a salt wedge intrusion on fluvial suspended sediment and the implications for sediment transport to the adjacent coastal ocean: A study of the lower Brazos River TX, USA: Marine Geology, v. 359/1, p. 134-147.

Warrick, J.A., J. Xu, M. Noble, and H.J. Lee, 2008, Rapid formation of hyperpycnal sediment gravity currents offshore of a semi-arid California river: Continental Shelf Research, v. 28, p. 991-1009.

EXTREME EVENTS ON A LOW-GRADIENT RIVER AND DELTA: EVIDENCE FOR SEDIMENT MASS MOVEMENTS ON THE SUBAQUEOUS DELTA AND A MECHANISM FOR CREATING HYPERPYCNAL FLOW IN THE LOWER RIVER

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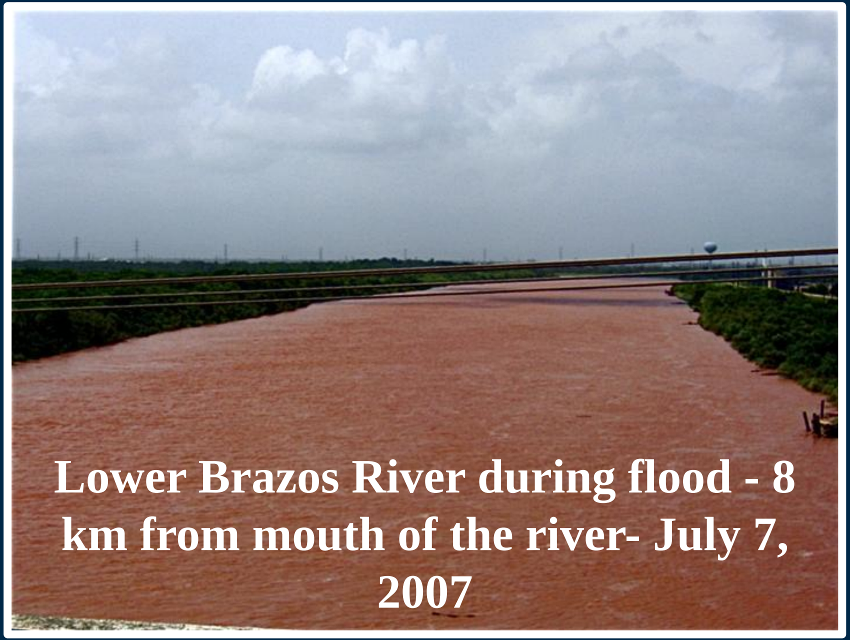
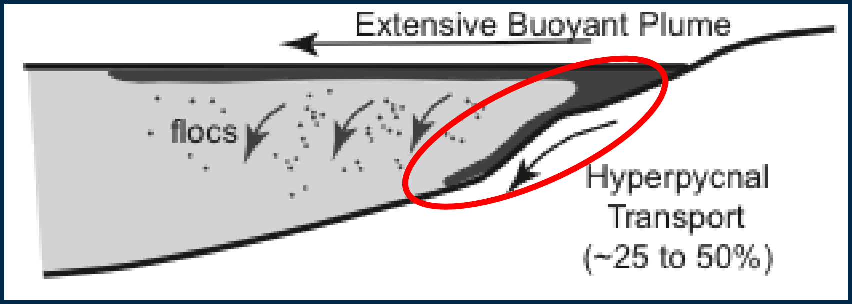
GALVESTON CAMPUS

Overview: A case study of the Brazos River and Delta (TX, USA)

- **Results from an investigation of modern sedimentary process related to extreme events in the lower river and subaqueous delta**
- **Better understanding of how these events shape the deltaic sedimentary record on this muddy, low-gradient fluvial-deltaic system**
- Brazos River Background
- Methodologies
- Mechanism to Generate Hyperpycnal Flow
  - Fluvial sediment plume flowing along the seabed
  - Suspended Sediment Concentrations (SSC) ≥ ~ 40 g/l
  - Brazos River – 100 year event (Mulder and Syvitski, 1995)
- Sediment Mass Movements and other Post-Depositional Alterations on the Subaqueous Delta
- Conclusions, Implications, and Future Questions



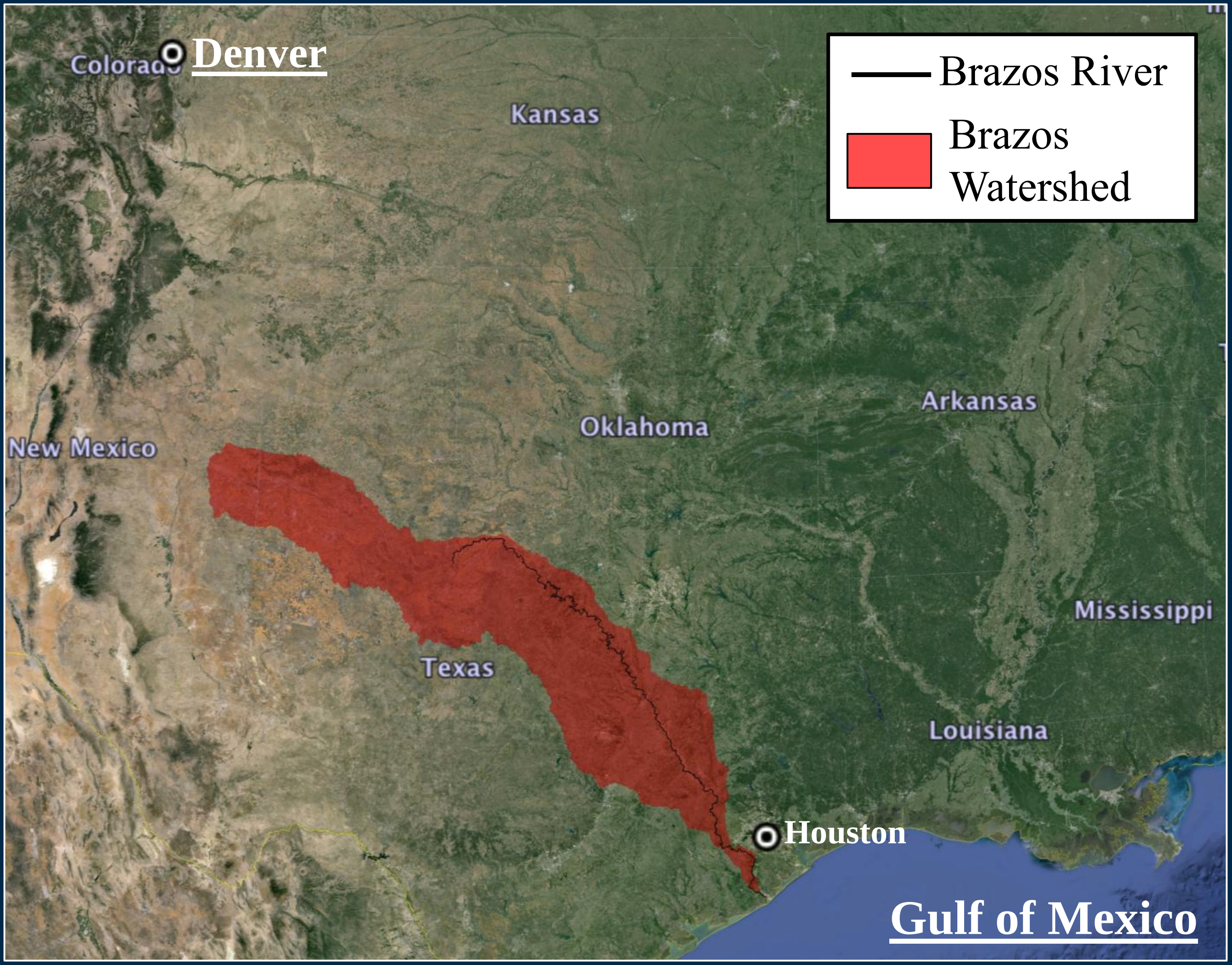
Lower Brazos River during flood - 8 km from mouth of the river- July 7, 2007



(after Warrick et al., 2008)

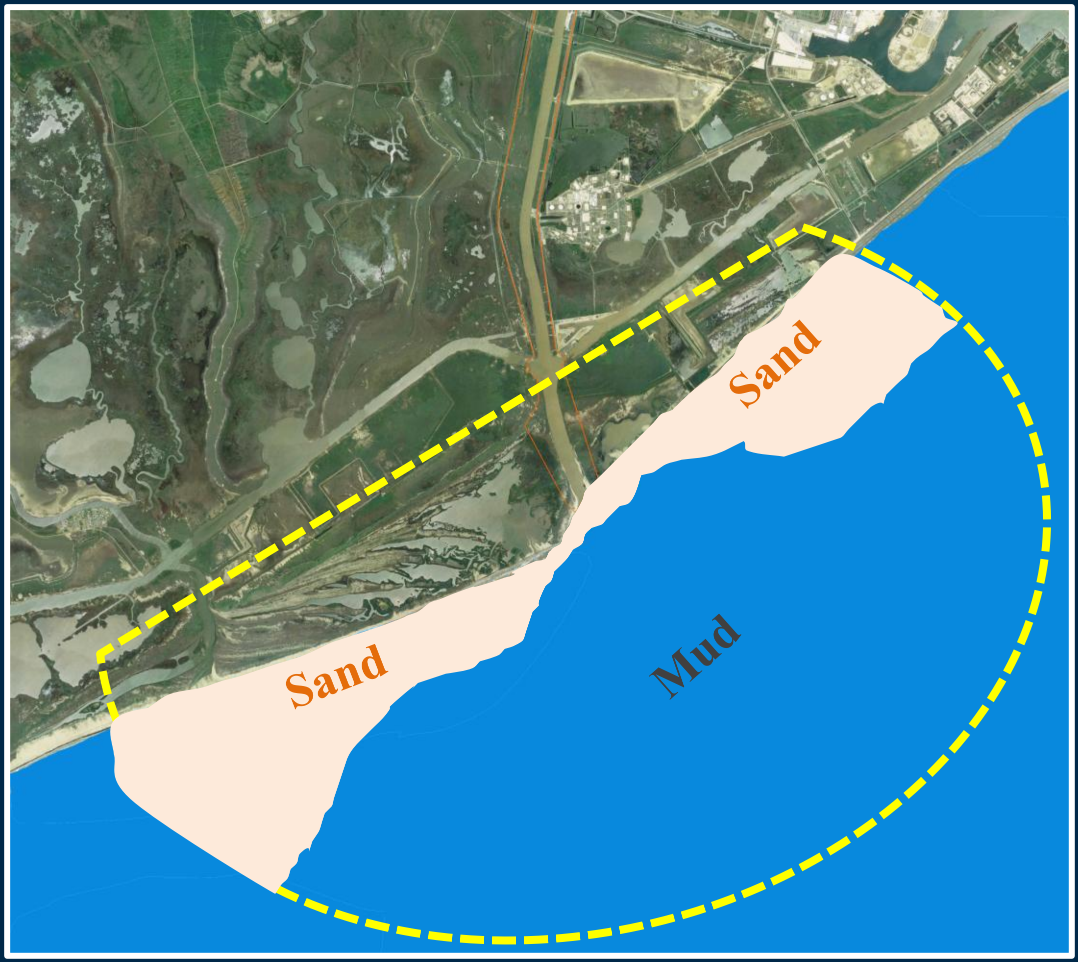
Brazos River

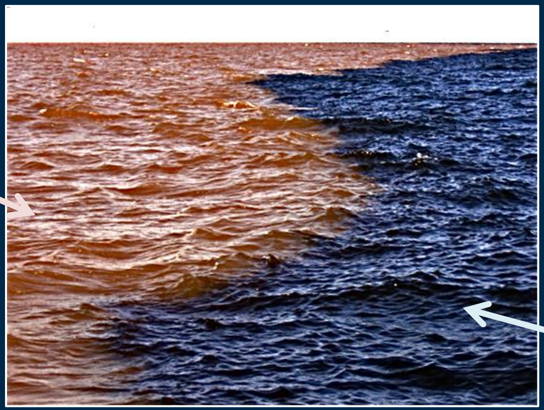
- 11^{th} longest river in the US - 118,000 km^2 watershed
- 2^{nd} largest sediment discharge to the Gulf of Mexico
- 10 – 16 Mt/yr average annual sediment load – avg. water discharge ~ 215 m^3/s



Brazos River Delta

- 35 km^2 delta with approx. 70% being subaqueous
- 130 km shelf width
- 0.5 m tidal range and 1.1 m mean wave height
- Dominant wind and wave from the SE
- For most of the year net longshore drift is from NE to SW, reversal in the summer
- Asymmetric delta (morphology and facies dist.)
- Dominated by mud with a characteristically red color (Triassic Red-Beds)





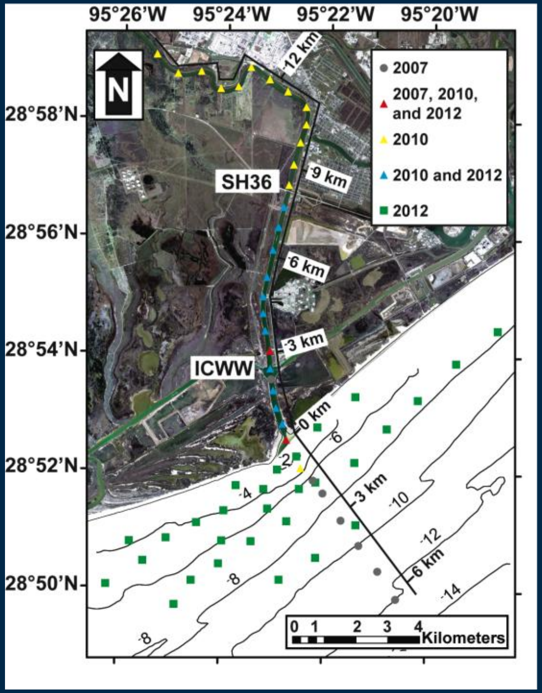
Methodologies

Seabed Mapping and High-Resolution Seismic Reflection

- **Spring and Summer 2011: Map the inner subaqueous delta**
  - **Side scan sonar and swath bathymetry: Teledyne Benthos C3D-LPM**
  - **CHIRP Subbottom Profiling (seismic reflection)**
    - Edgetech® 216 Full Spectrum Subbottom CHIRP seismic sonar system
    - 2 – 16 kHz frequency range
    - Vert. Resolution: 6 -10 cm
    - Seabed Penetration: 6 – 80 m depending on bottom type

Sediment Cores and Short-Lived Radioisotopes

- Determine depositional and erosional areas

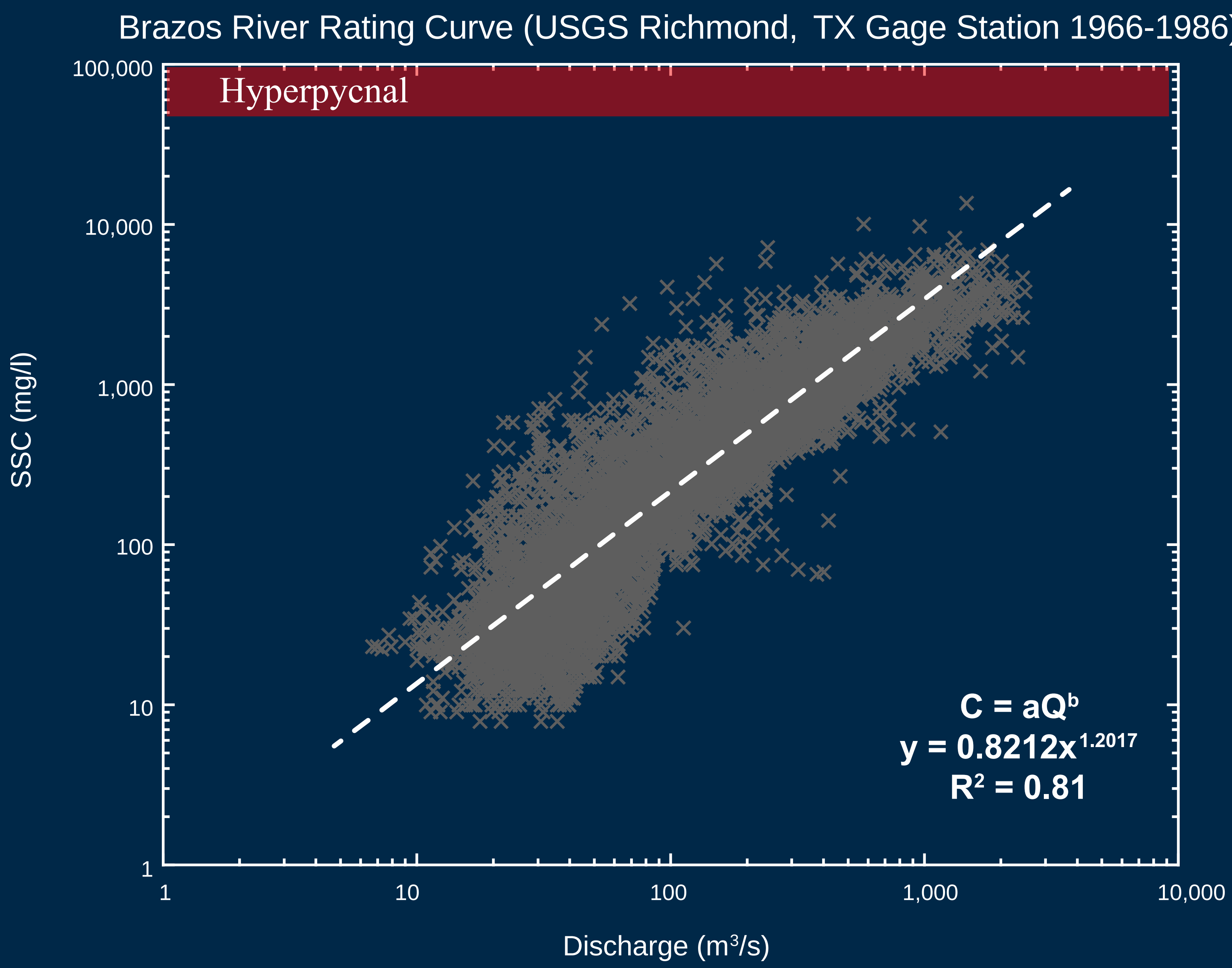


(Carlin et al., 2015)

Suspended Sediment Measurements

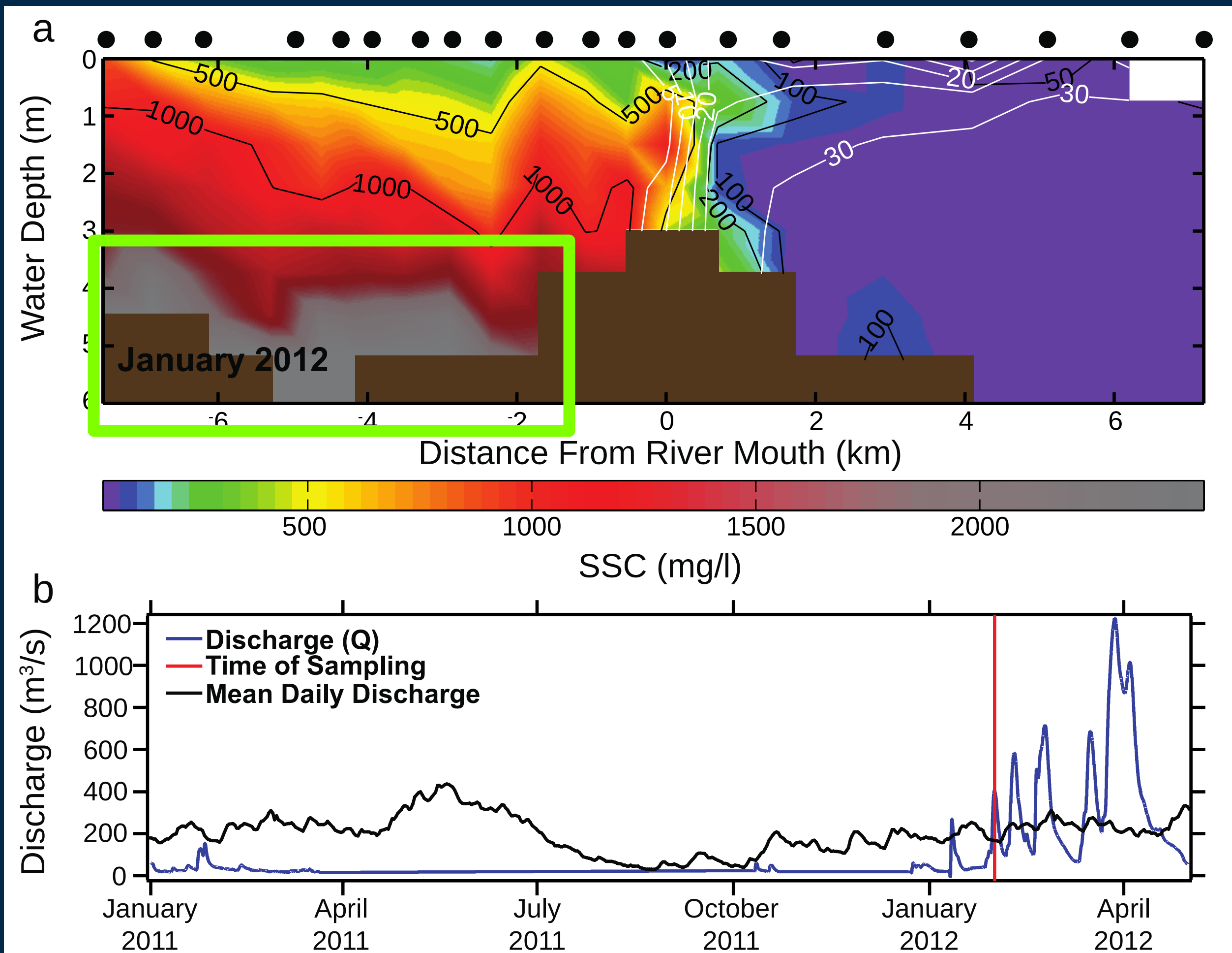
- **Summer 2007 – March 2015 over various river discharges**
- **Water column profiles SSC, Salinity, and Depth using CTD – OBS**
  - **OBS – SSC 10's mg/l - ~ 2 g/l**
- **Sampling stations every 0.5 km in the lower ~ 15 km of the river (and throughout the subaqueous delta)**
- **Collected near-bed water samples**

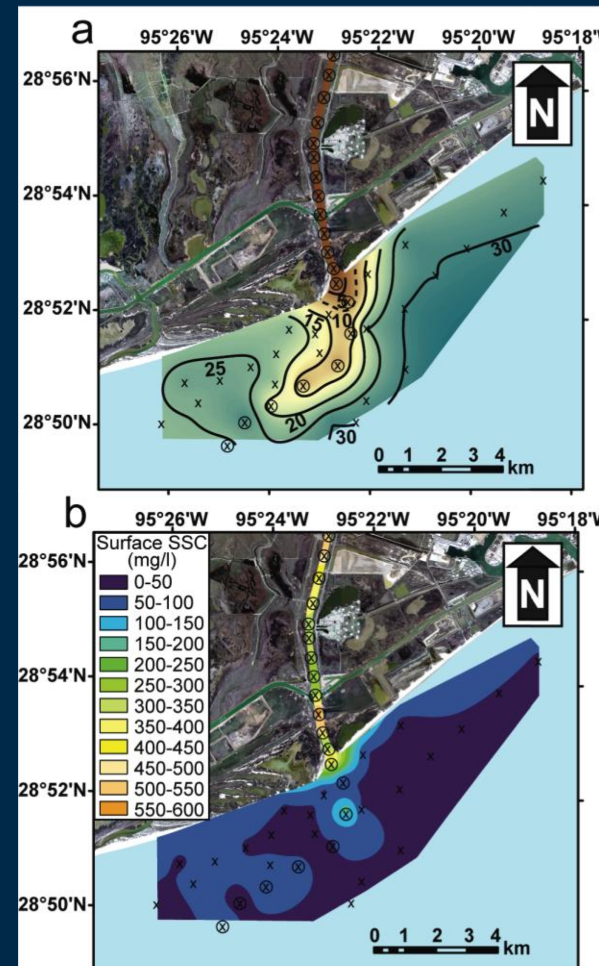
Mechanism to Generate Hyperpycnal Flow



Mechanism to Generate Hyperpycnal Flow

River | River Mouth | Offshore





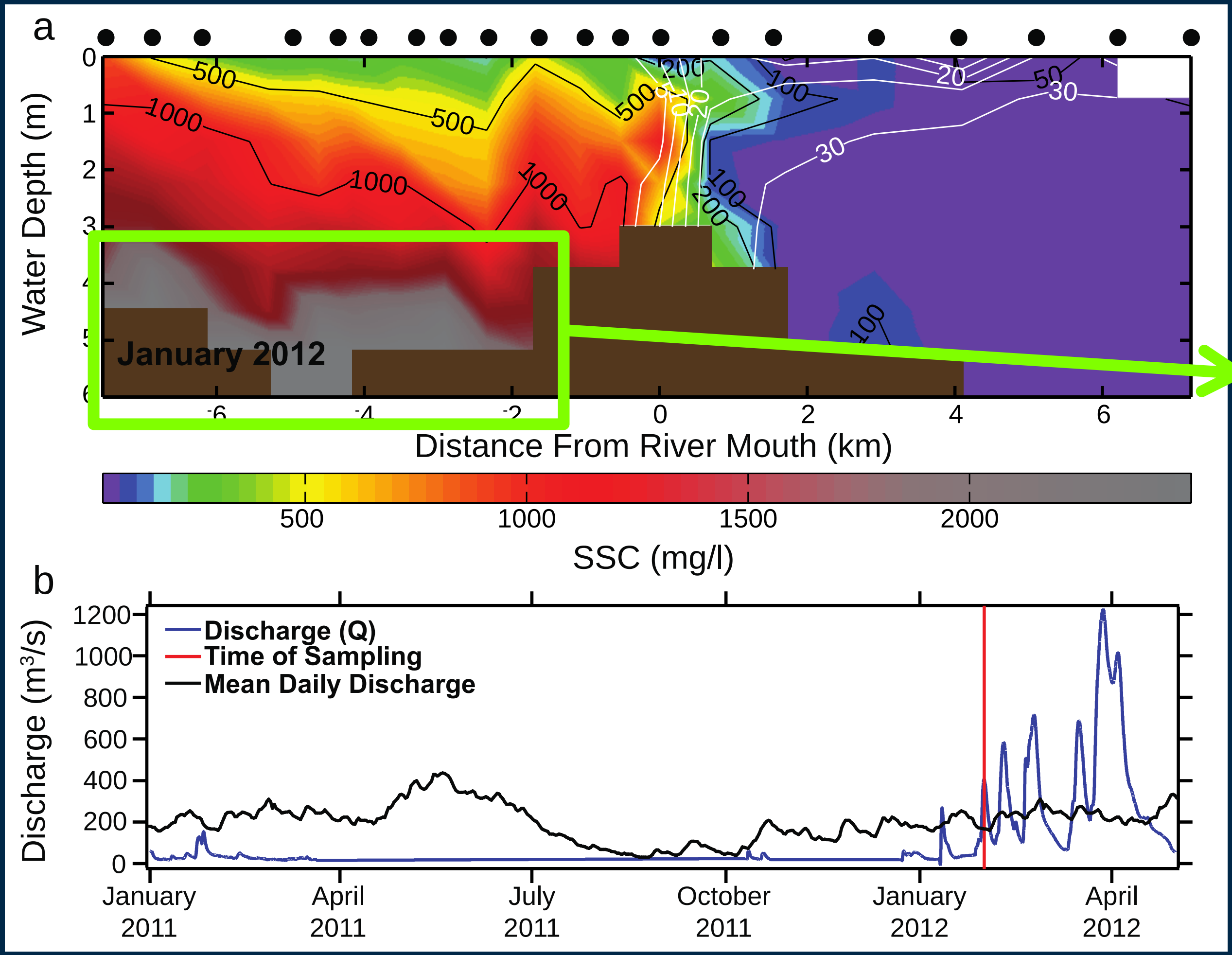
(Carlin et al., 2015)

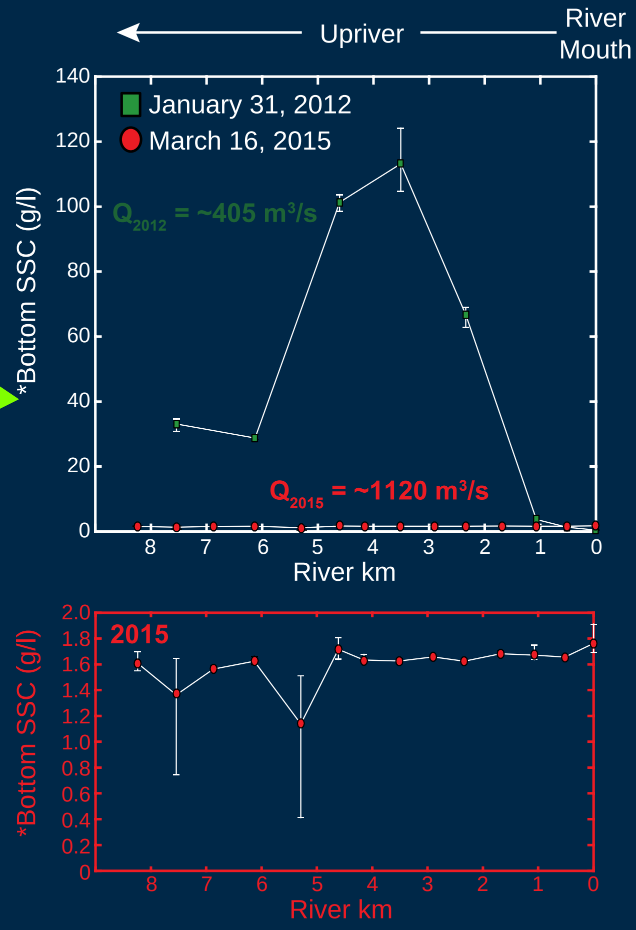
Mechanism to Generate Hyperpycnal Flow

River

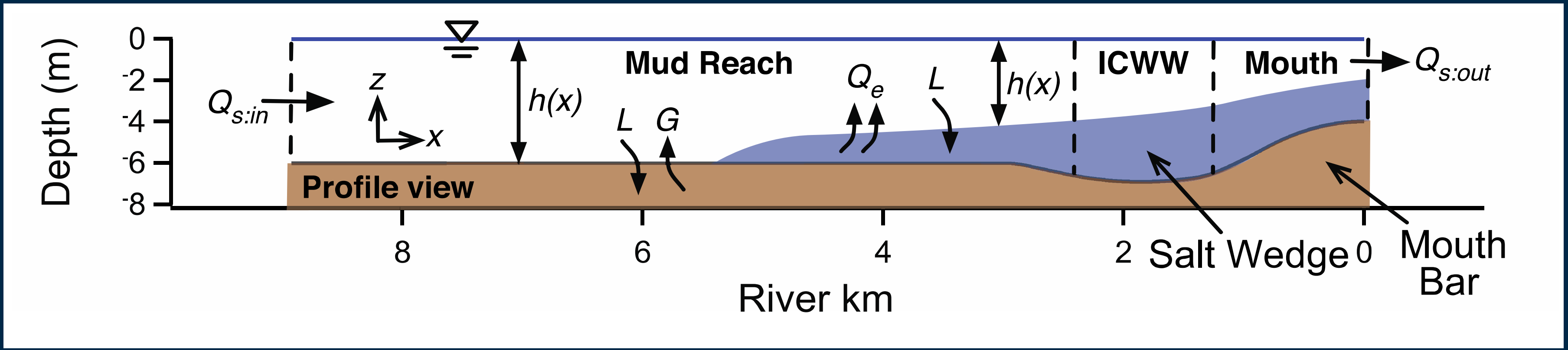
River Mouth

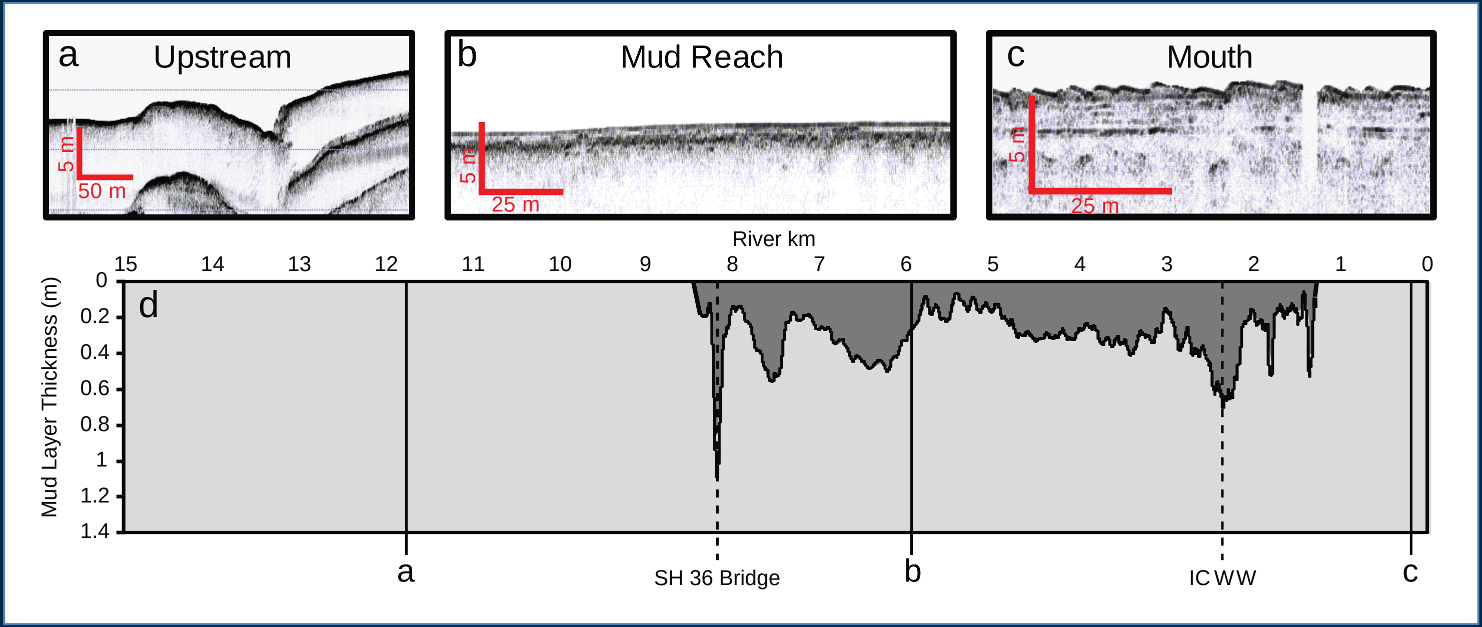
Offshore





Mechanism to Generate Hyperpycnal Flow

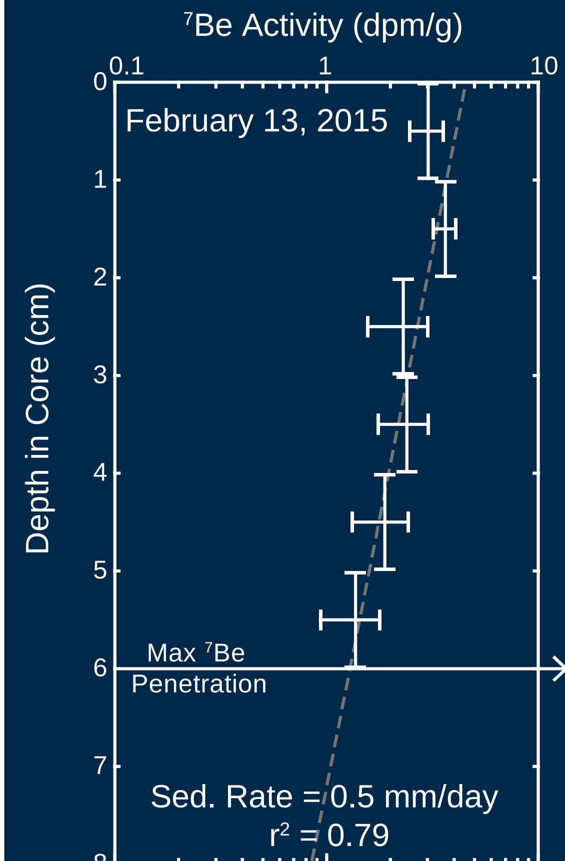




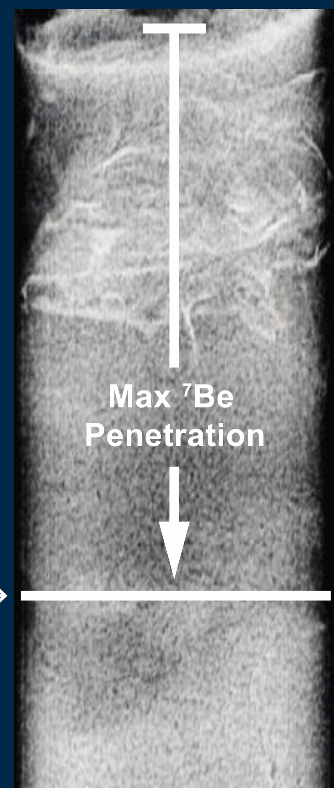
(Carlin et al., 2015)

Mechanism to Generate Hyperpycnal Flow

River km 3.5



February 13, 2015



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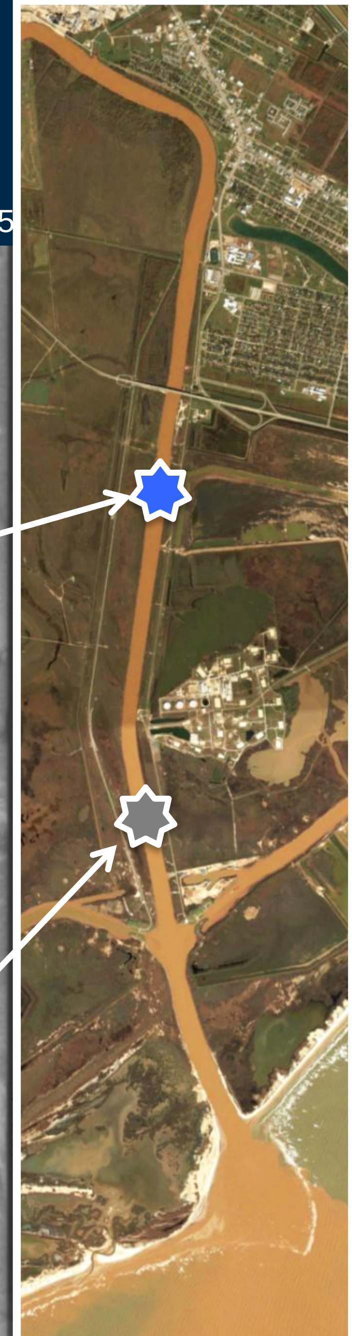


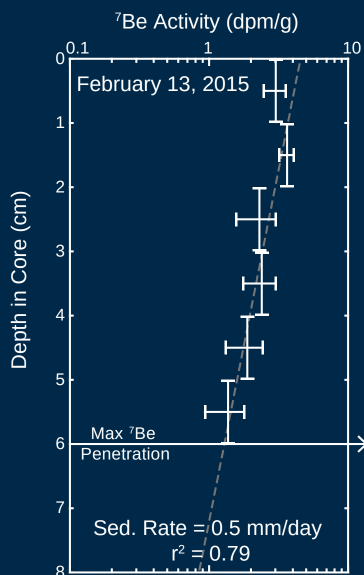
Discharge USGS Station 08116650 Rosharon, TX

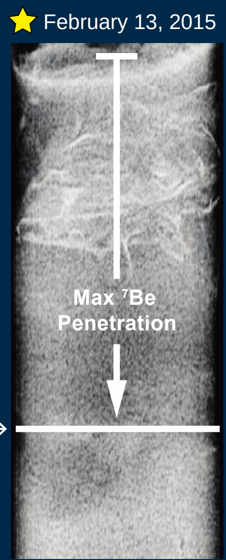
1200
1000 Salt Wedge Absent
800
600 Q_{cr}
Transitional
400
Salt Wedge Present
Discharge (m^3/s)
Erosional
Erosional
Hyperpycnal?

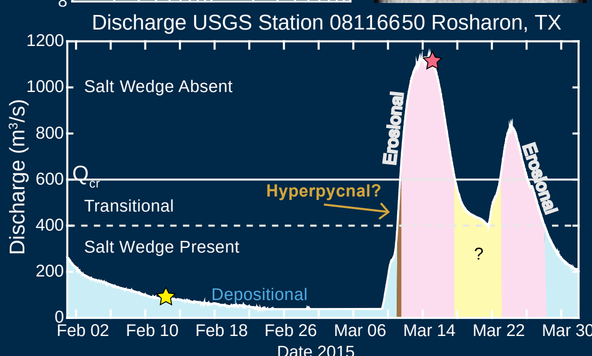
River km 6.5

No Recent Deposition

Mechanism to Generate Hyperpycnal Flow

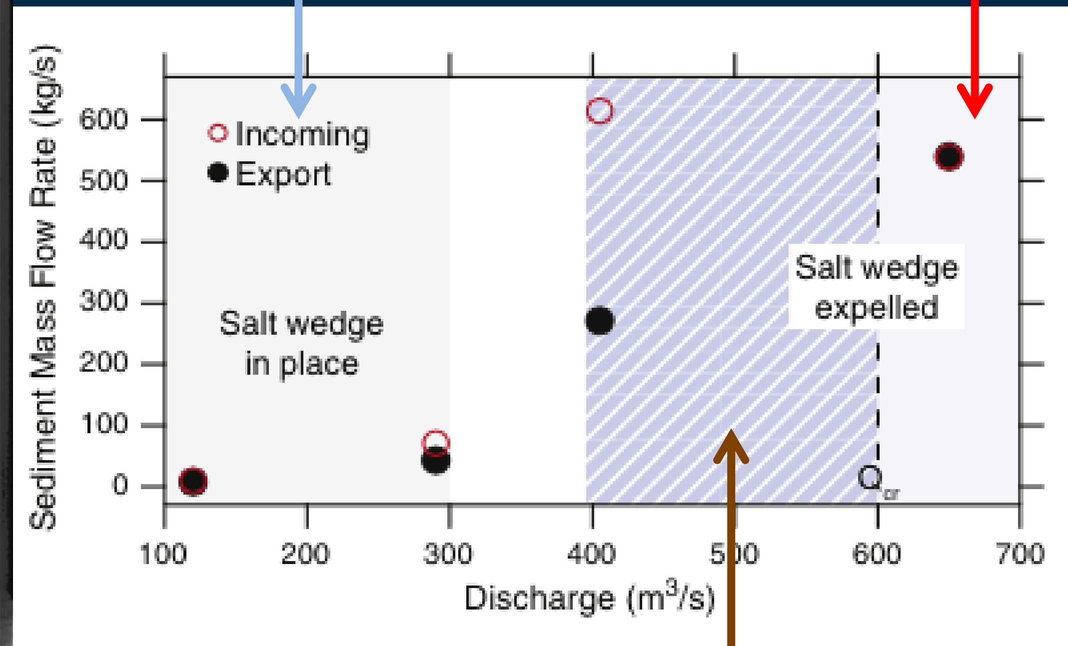


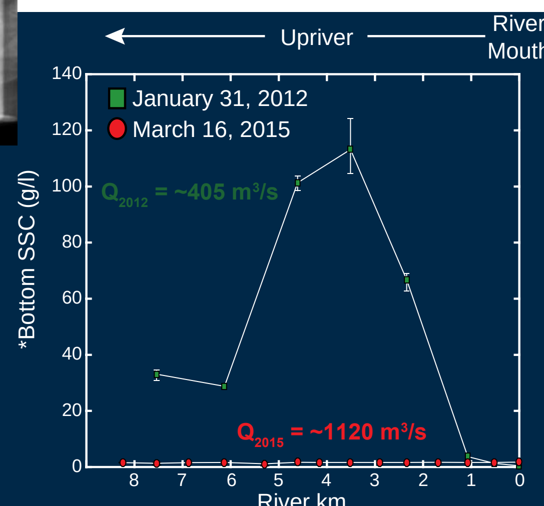




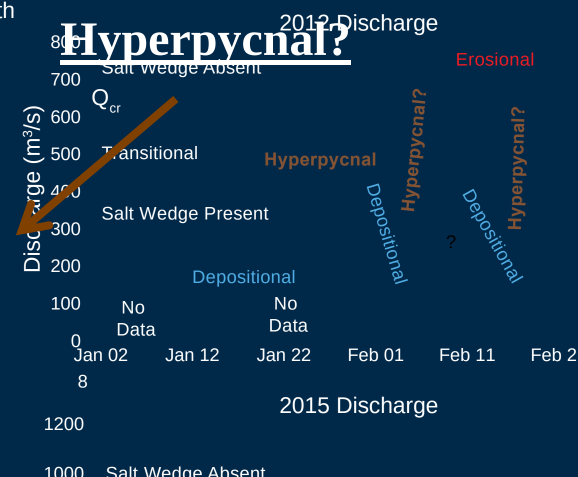
Depositional

Non-depositional/ Erosional

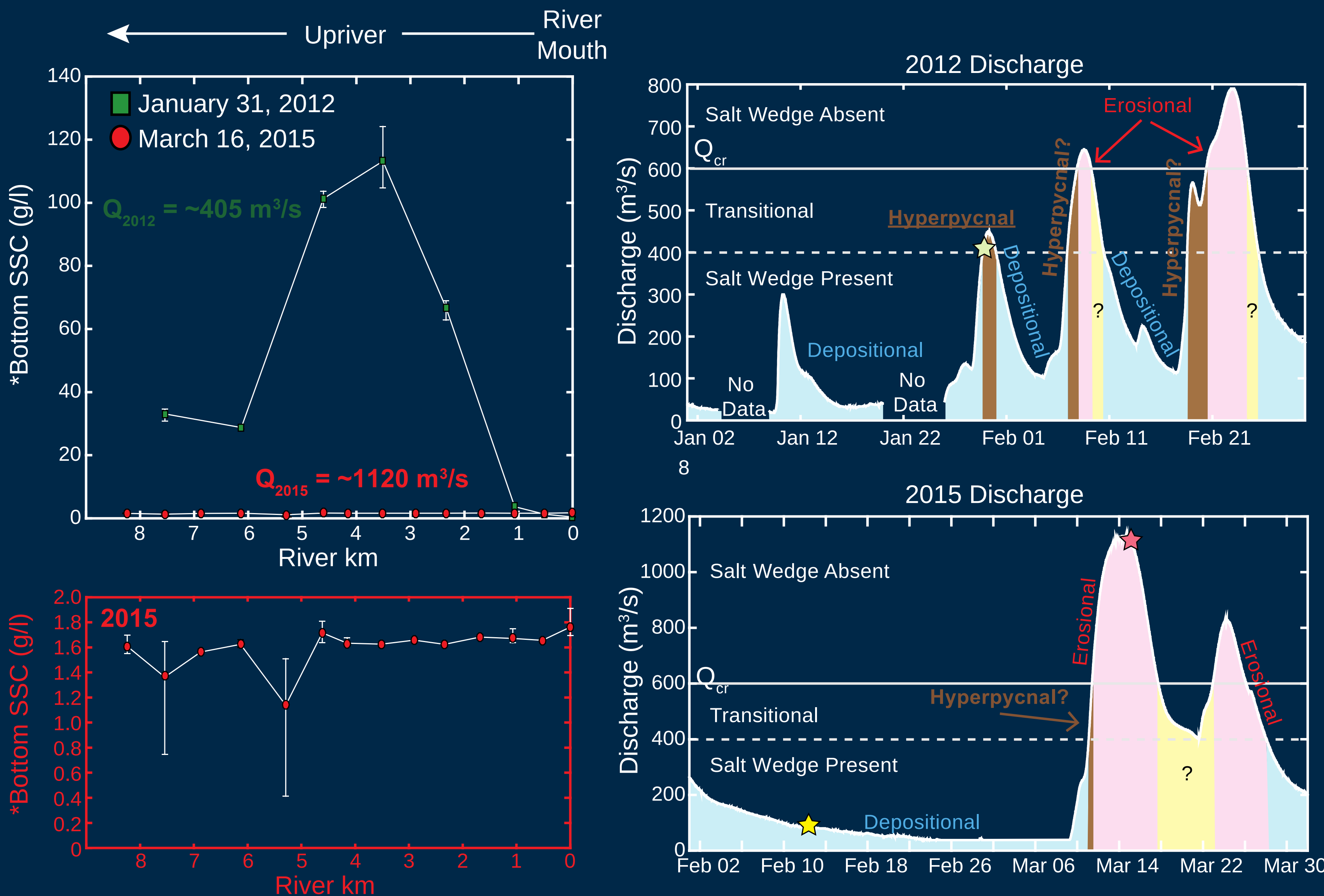




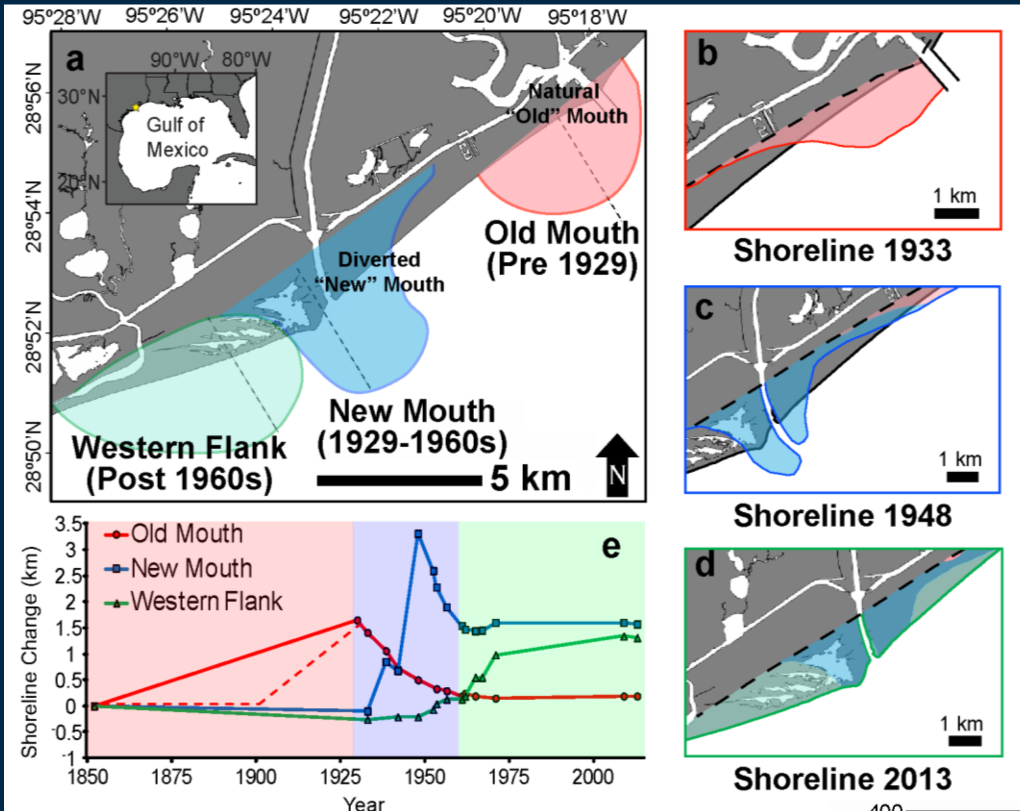
Hyperpycnal?

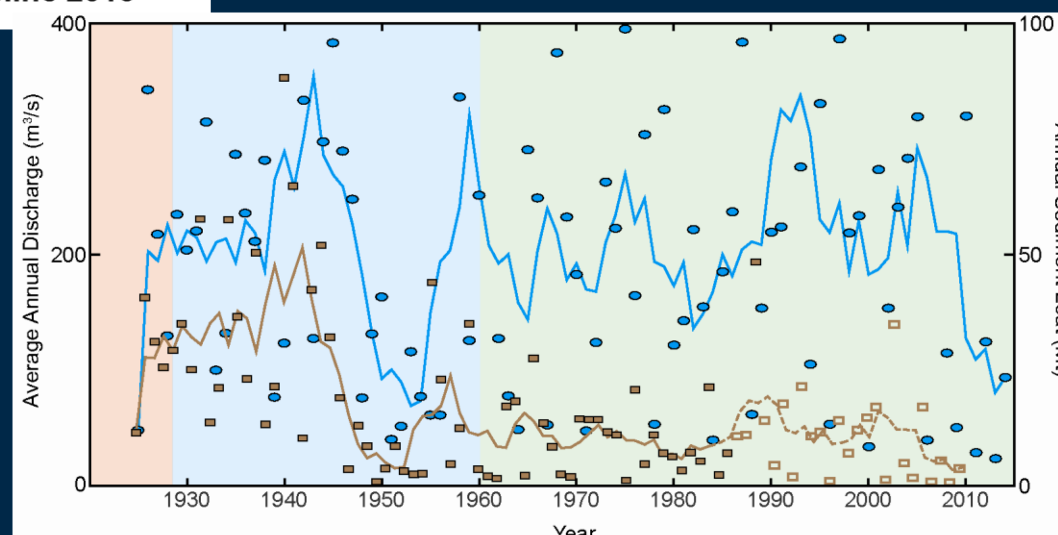


Mechanism to Generate Hyperpycnal Flow



Sediment Alterations on the Subaqueous Delta





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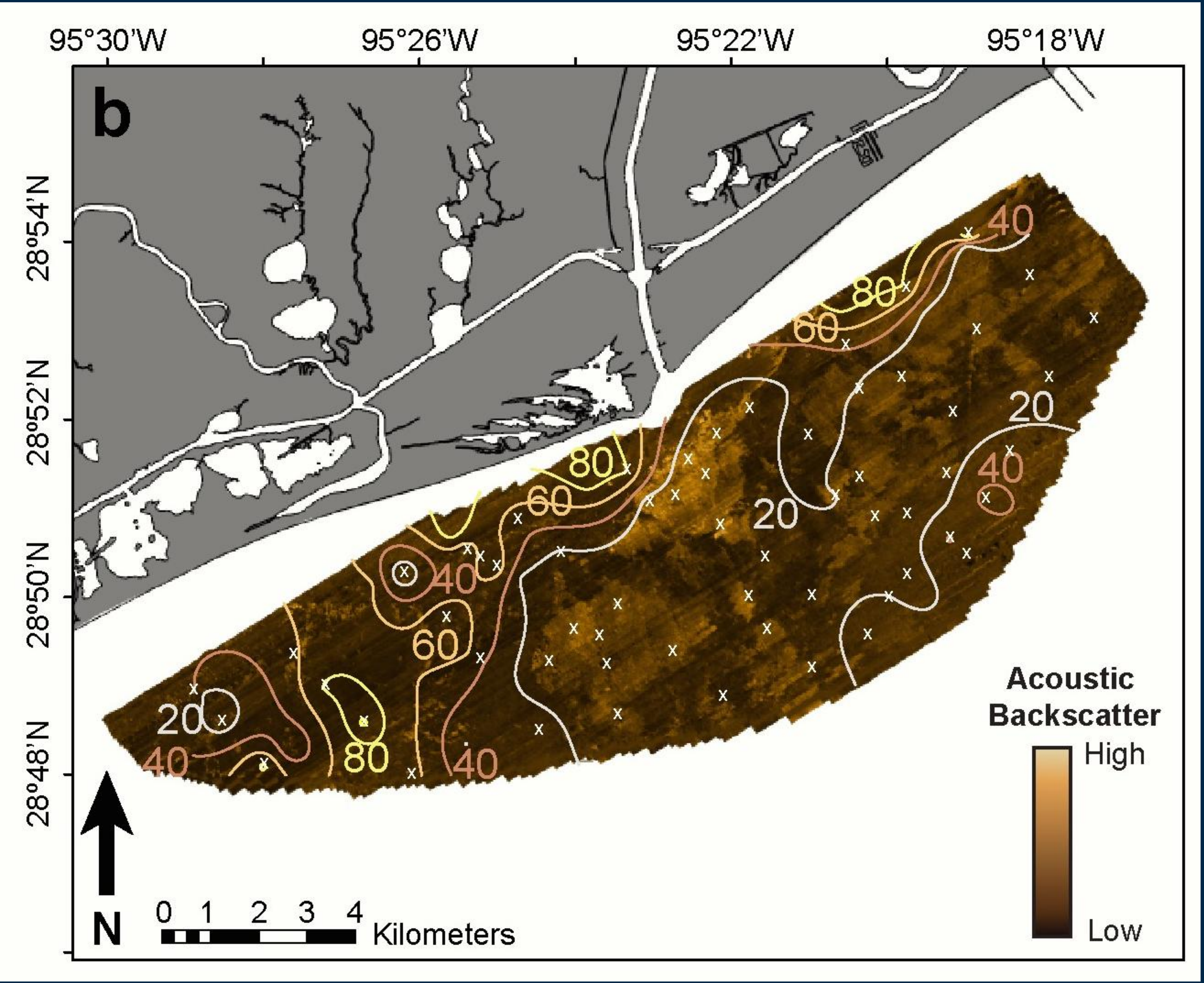

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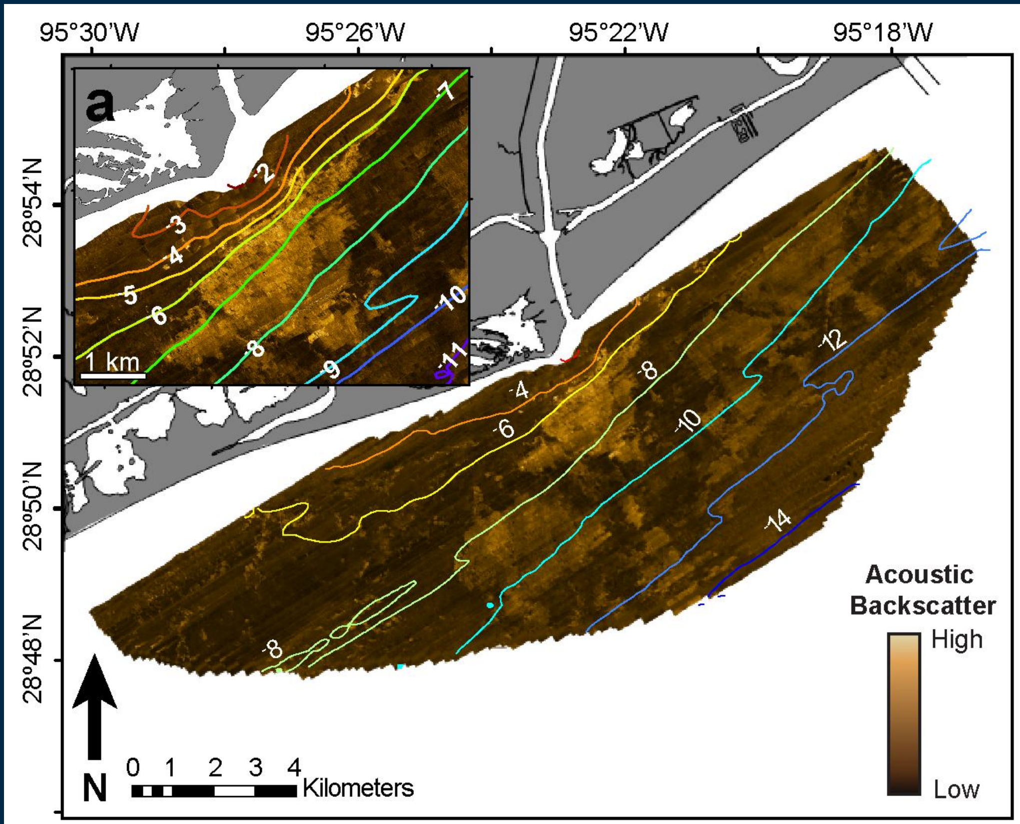
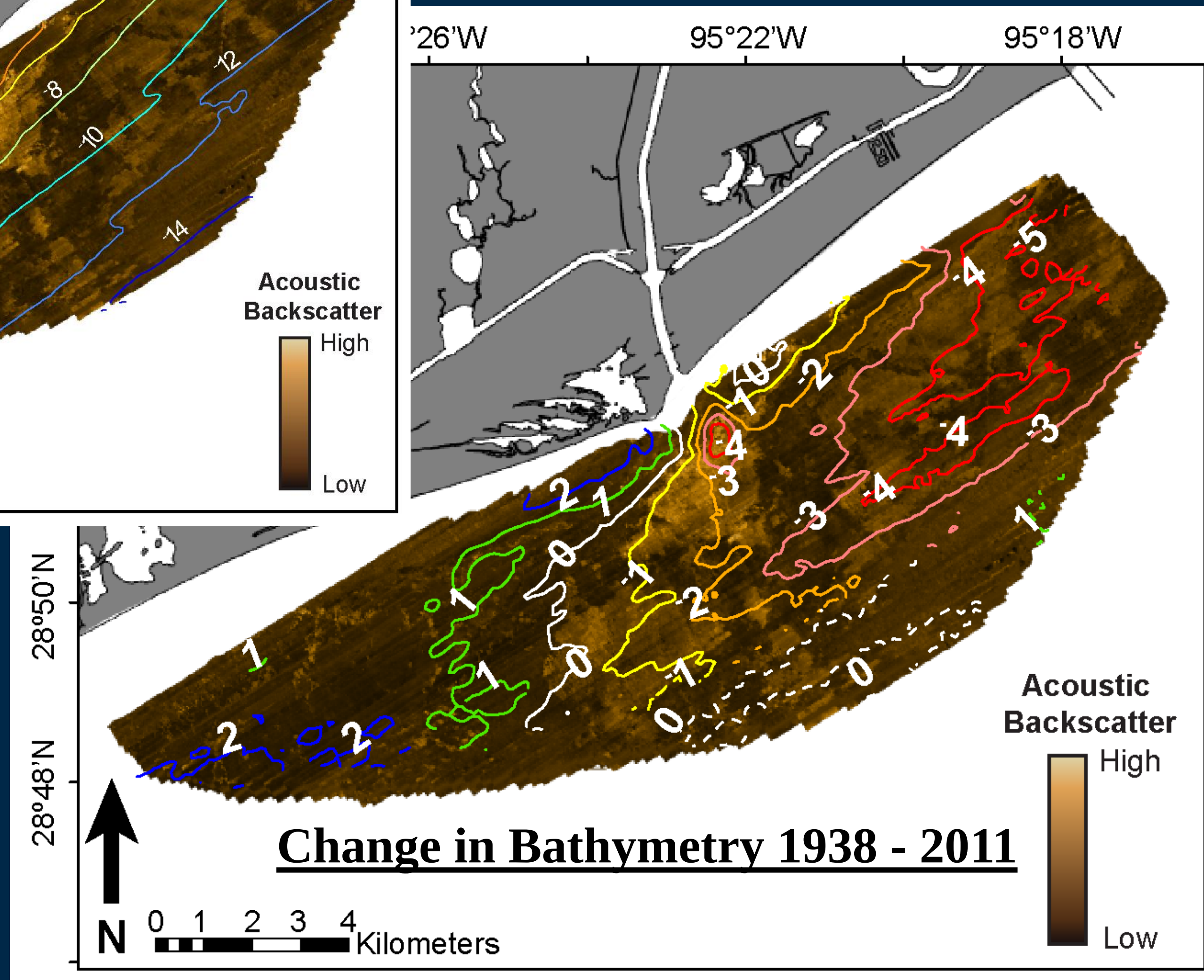
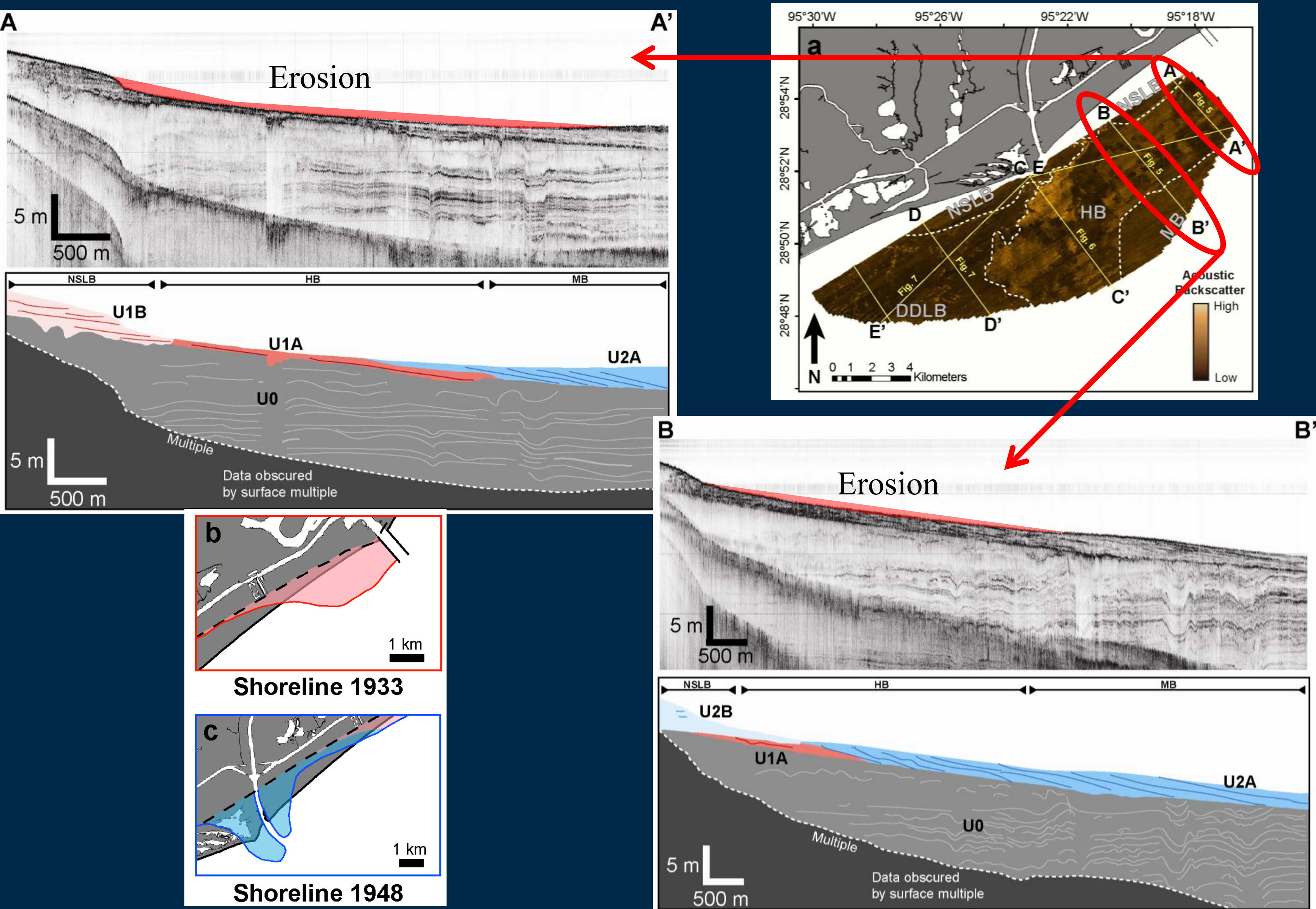




Change in Bathymetry 1938 - 2011

Sediment Alterations on the Subaqueous Delta



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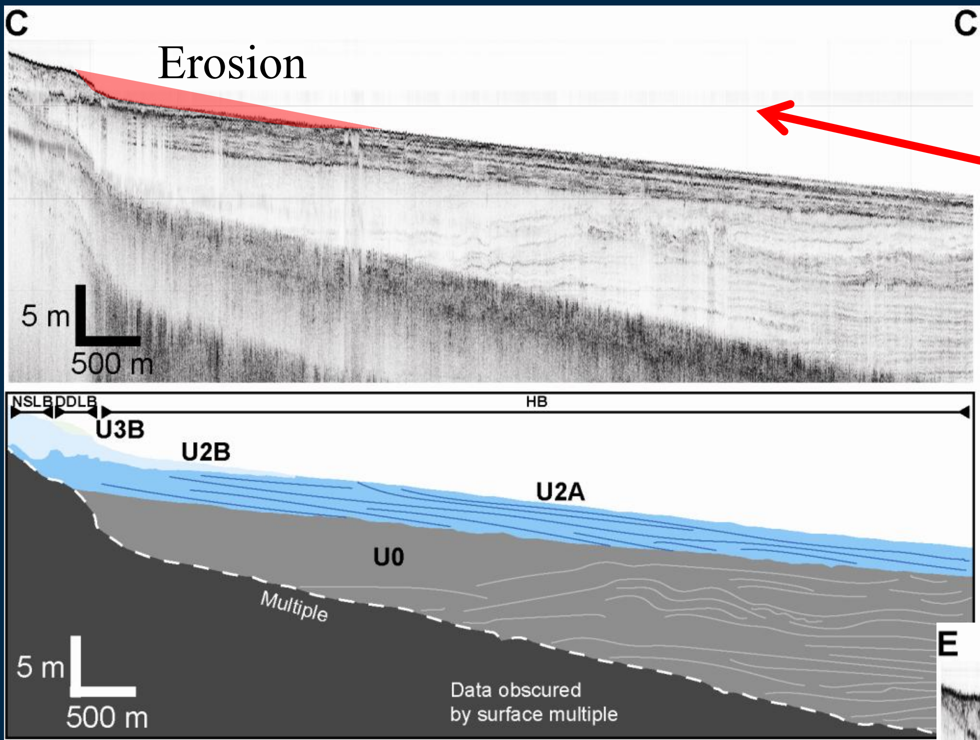

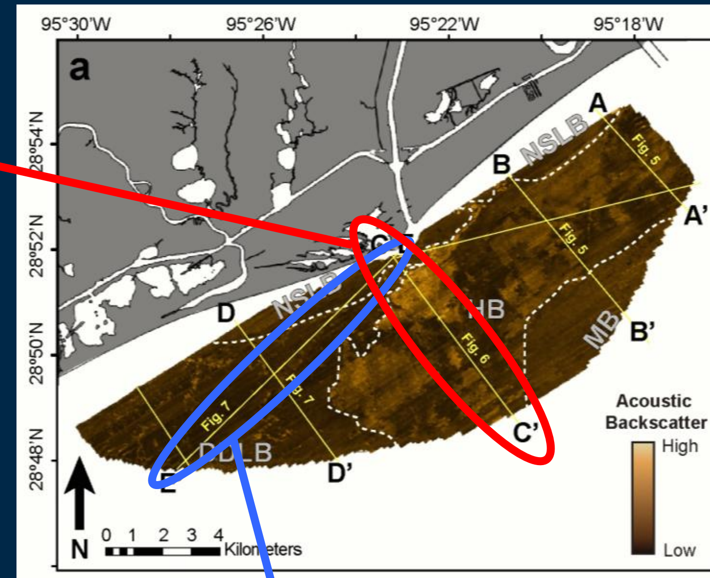

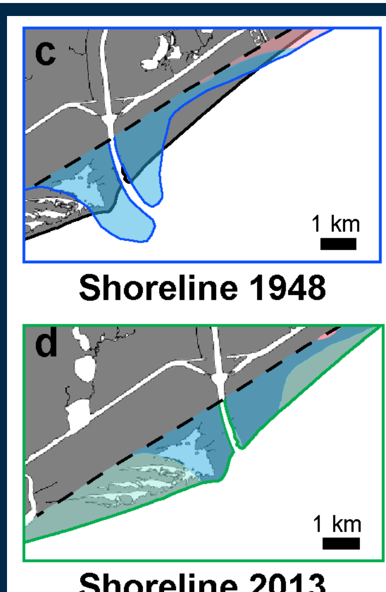

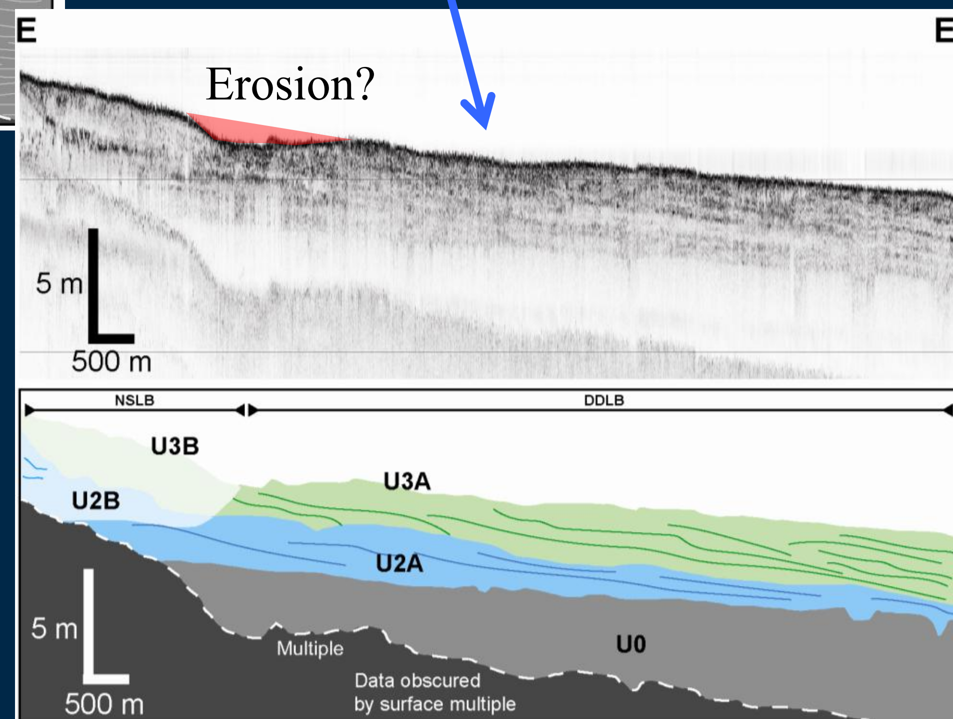

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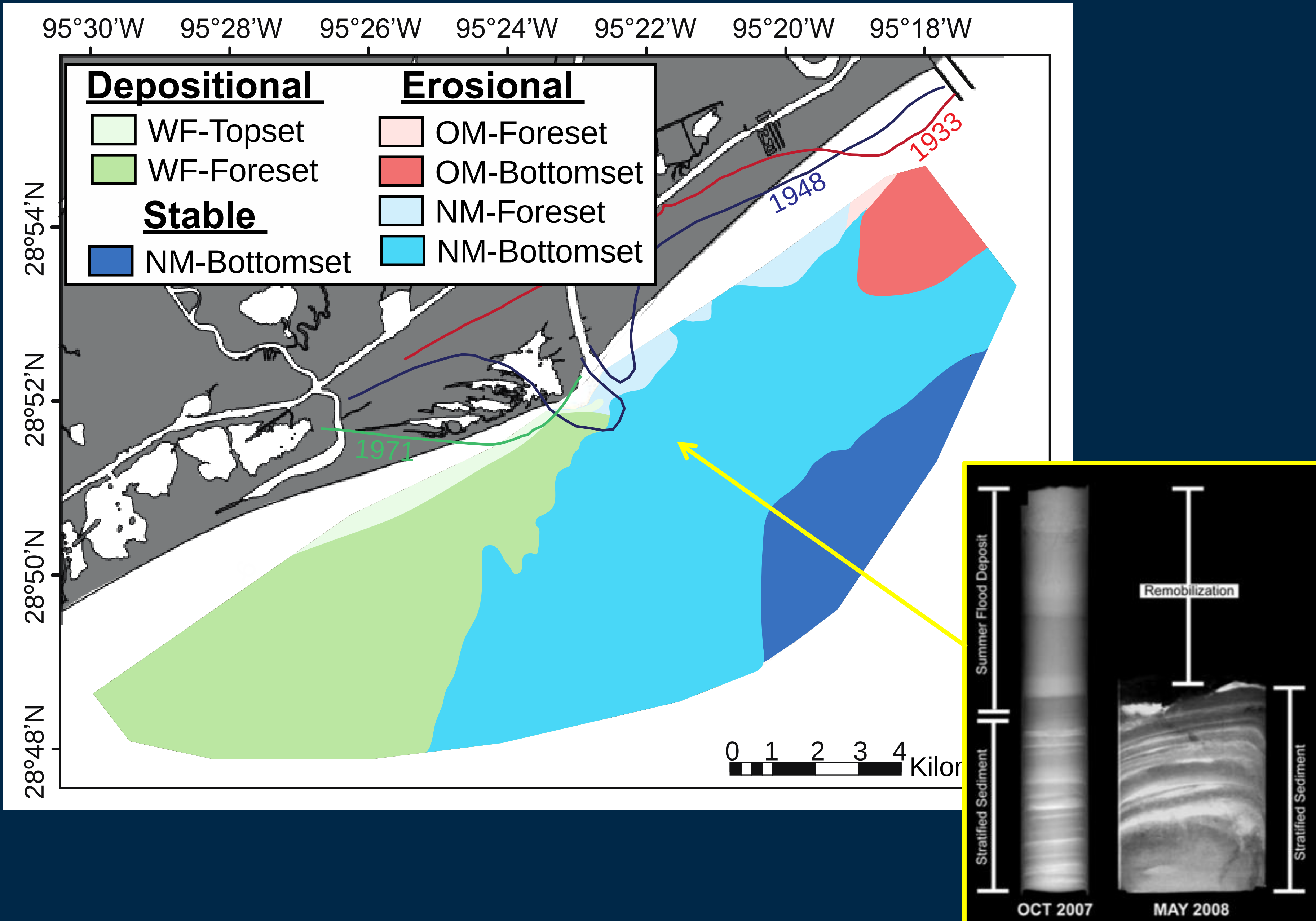

Conclusions, Implications, and Future Questions

- Sediment trapping in the lower river can create create hyperpycnal suspended sediment concentrations during as the trapped sediment is remobilized during the rising limb of a flood event

- Periods of rapid growth on the delta can be followed by wide-spread sediment mass movements and deltaic reorganization when the balance between fluvial sediment supply and sediment remobilization from marine processes shift

- The Brazos River is a moderate-sized system, on a low-gradient passive margin that at time may be more similar to small mountainous rivers on active margins
    - Possibility to generate hyperpycnal flows at the mouth more often than predicted from rating curves
    - Subaqueous delta sedimentation can be easily altered, and undergo subsequent transport following initial deposition

- Future Questions include:
    - Are hyperpycnal conditions in the lower river a consistent feature of the rising limb of the hydrograph, or were the observations in 2012 the result of the first big flush event following the drought?
    - What is the final depocenter for remobilized delta sediment?