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# Controls on the Transgressive facies of coastal plain incised valley systems - Sabine and Calcasieu Lakes, East Texas and West Louisiana

***Research objective**:* To investigate the relative affects of eustasy, climate, subsidence, and antecedent topography on the depositional architecture of transgressed fluvial valleys.

***Introduction**:* Many studies attribute depositional facies changes in Gulf Coast incised valleys during transgression to eustatic sea level rise (Curray, 1960; Coleman and Smith, 1964; McFarlan, 1961; Nelson and Bray, 1970; Thomas, 1991, Penland et. al., 1991). Sea level curves (sea level depth versus time) produced from these studies show a stair step pattern with apparently slow to no sea level rise punctuated by very rapid rises and even minor regressions (Figure 1). This history of episodic sea level rise is based, in part, on backstepping facies patterns within incised valleys.

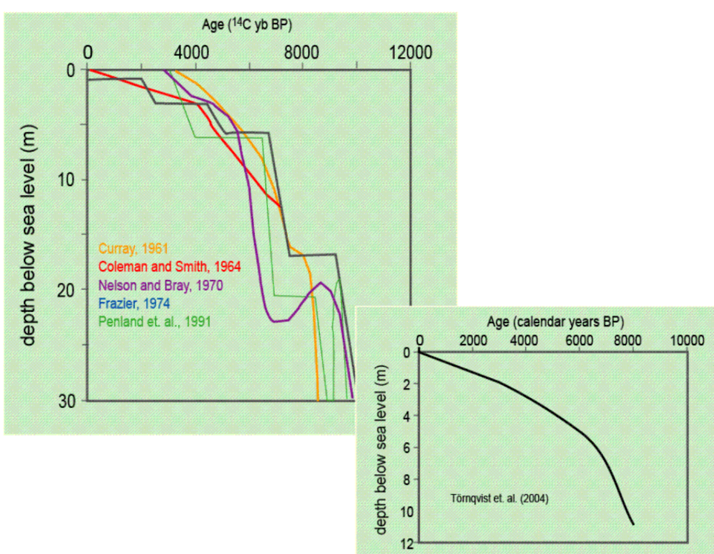



Figure 1: A. Northern Gulf of Mexico sea level curves. B. Tornqvist et. al., 2004, smooth, continuous sea level rise.

An alternate hypothesis is that sediment supply variations, antecedent topographic effects, and subsidence changes could result in backstepping facies patterns. Each fluvial-marine system will have a unique fluvial sediment input controlled by drainage basin extent, topography, substrate, and climate. Variations in climate potentially control fluvial-deltaic progradation or retrogradation within a system. Antecedent topography, produced during the former highstand and lowstand, is manifested as fluvial terraces that are flooded as sea level rises. Flooding of terraces changes the shape and extent of the bay and can significantly influence the evolution of the fluvio-deltaic/bay depositional systems. Long term basinal subsidence is minimal on the inner shelf and in coastal areas but increases linearly offshore. Subsidence is also greater on the shelf near large sediment loads.

A study of the Holocene transgression provides several advantages to older transgressions, including excellent chronostratigraphic control through radiocarbon dating, extensive core sampling and recovery of shallow sections, excellent seismic imaging using high resolution methods, and knowledge about drainage basin characteristics. Constraining the relative effects of eustasy, sediment supply, antecedent topography, and subsidence on a modern transgressive system is important when trying to model and understand ancient systems. For instance, during times of slow sea level rise, how did climatic fluctuations affect incised valley fill?

Sabine Lake and Calcasieu Lake, along the east Texas and west Louisiana coast, are the flooded fluvial valleys of the Sabine/Neches and Calcasieu rivers, respectively (Figure 2). The Sabine system drains approximately 50,000 $km^2$ of Tertiary and Quaternary fluvio-deltaic sand and mud whereas the Calcasieu system drains approximately 10,000 $km^2$ of Plio-Pleistocene sediments. Present day climatic conditions are subtropical and humid with temperatures averaging 10 C (50 F) and 1350 mm (53 in; www.cdc.noaa.gov). Inner-shelf subsidence rates average 0.15 mm/yr (Wellner, 2001) and is assumed to be relatively constant over the time frame considered in this study. During transgression, the lowstand sequence boundary surface is flooded and can be used to approximate antecedent topography. The study area was inundated within the past 10,000 years and encompasses the modern bays and extends approximately 20 km updip and downdip as well as laterally along the chenier plain (Figure 2).

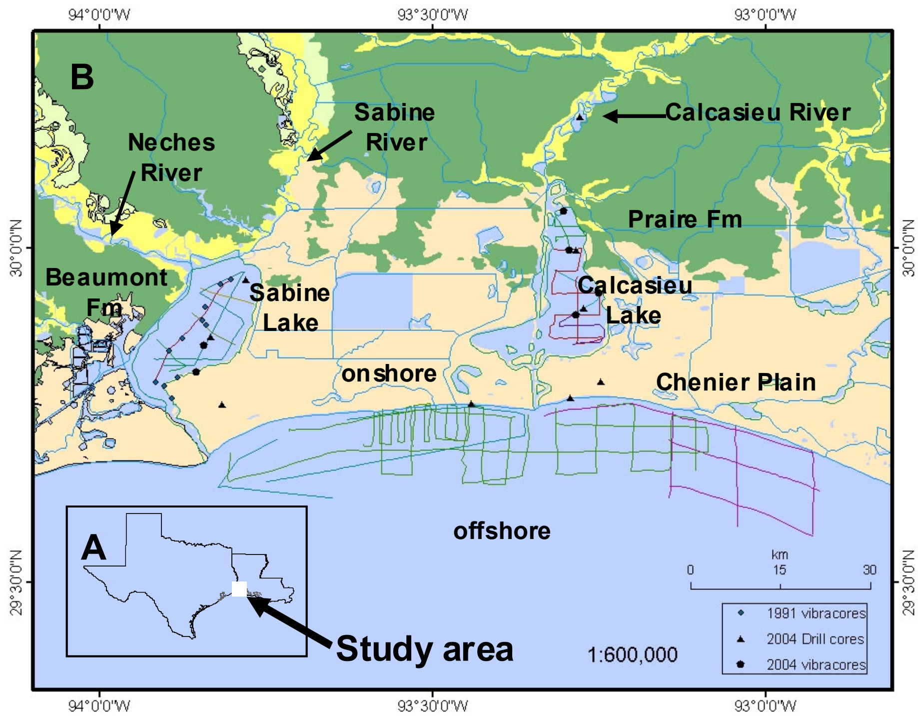



Figure 2: A. The study area borders Texas and Louisiana. B. Seismic and core data located in and around Sabine and Calcasieu lakes. Seismic data is shown as lines and core locations are displayed as dots.

A total of 197 km (86 Calcasieu, 111 Sabine) of high-resolution seismic data and 7 continuous cores, up to 20 m in length, along the valley axes were collected to examine the response of the bays to eustatic sea level rise and other forcing mechanisms, such as changes in antecedent topography and climate. Additional datasets (Thomas, 1991; USGS, 1995; Lacoss, 1983) and previous studies (Fisk, 1948; LeBlanc, 1949; Gould and McFarlan, 1959; McFarlan *et al.*, 1959; Kane, 1959; McFarlan, 1961; Nelson and Bray, 1970; Nichols *et al.*, 1994; Fearn, 1995) have also provided valuable litho-, bio-, and chronostratigraphy.

***Methods:*** For this study, I assume a smooth, continuous eustatic sea level rise based upon the data of Tornqvist *et al.*, 2004 (Figure 1). Apparent sea level still stands, regressions, and rapid flooding are then attributed to sediment supply variations, flooding of antecedent terraces, or subsidence variations. Antecedent topography is constrained by the sequence boundary (SB2) surface map (Figure 3).

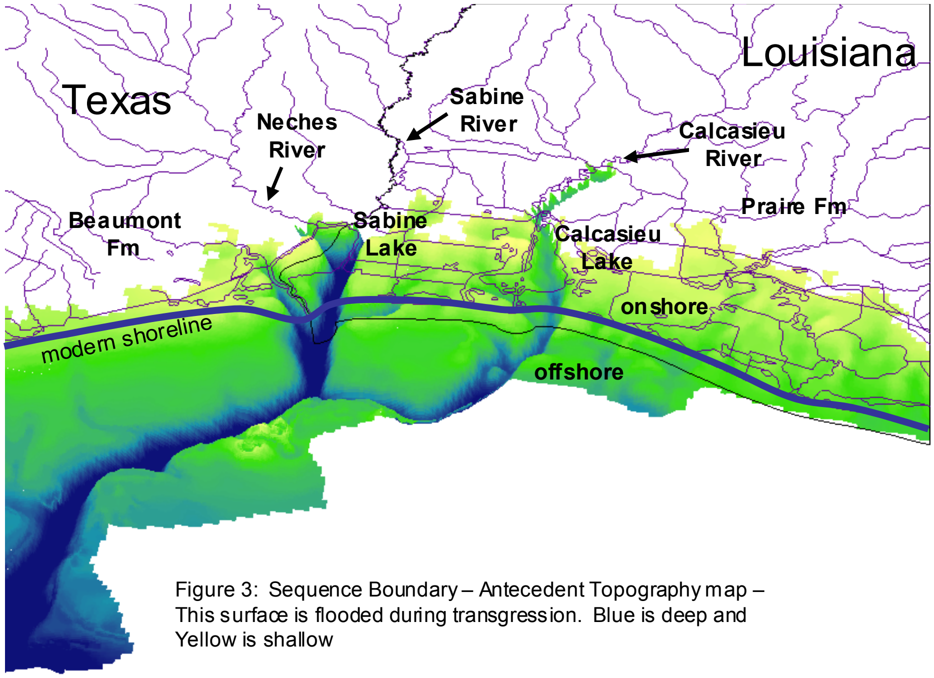
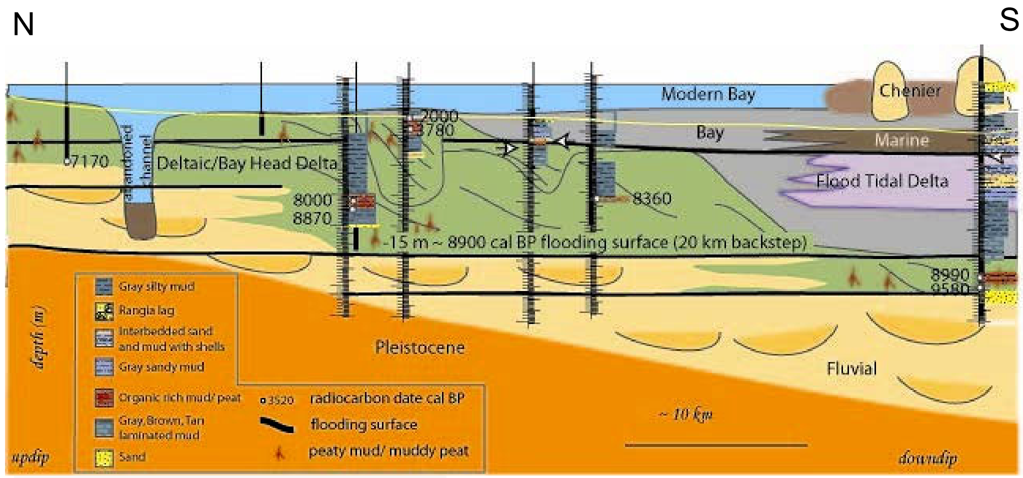



Figure 3: Sequence Boundary – Antecedent Topography map – This surface is flooded during transgression. Blue is deep and Yellow is shallow

Flooding surfaces identified in the seismic data as sharp truncational planar surfaces and documented in cores as facies changes can be attributed to decreases in sediment supply and/or increase of accommodation space. Flooding surfaces that correlate to the flooding of a valley margin highstand fluvial terrace and associated with rapid change in bay shape/accommodation space can be attributed to antecedent topography rather than rapid eustatic sea level rise. In contrast, flooding surfaces which do not correlate with antecedent terraces need to be explained by an alternative mechanism such as fluvial sediment supply or eustatic changes.

***Results****:* Seismic and lithofacies changes are remarkably similar to Galveston Bay (Smyth, 1991; Thomas, 1991; Rodriguez *et al.*, 2004) for the early Holocene. Typical valley fill successions consists of, from bottom to top, fluvial sand overlain by organic-rich bay head delta and delta plain deposits, These upper bay deposits are overlain sharply by laminated fine-grained middle bay mud and the succession is capped by chenier, tidal inlet, barrier deposits of the lower bay. In both bays, major flooding surfaces associated with back-stepping facies record dramatic changes in bay environments (Figure 4). Preliminary radiocarbon dates of the flooding events are consistent with well dated flooding surfaces in Galveston Bay. The flooding events in Galveston Bay occurred over a few centuries. In contrast to the early Holocene, middle to late Holocene depositional facies in the middle and upper areas of Calcasieu and Sabine Lake are different from Galveston Bay. Seismic stratigraphy linked to core facies illustrates bay head delta facies at a time when middle bay muds dominate Galveston Bay. This suggests differing controlling factors on deposition between the three bays.



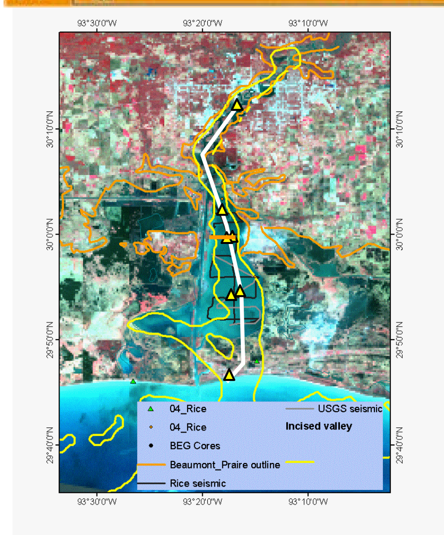




Figure 4:

A. Interpreted cross section based on seismic data and cores from Calcasieu Lake. White arrows locate examples of proposed radiocarbon dates. Cores in Sabine Lake also contain material suitable for radiocarbon dating at the-3 and -5 m flooding surfaces.

B. Landsat image showing core cross section location in white and Figure 5 seismic section in orange

Preliminary results (2 dates) shows a late Holocene flooding surface at 3m below present sea level which dates at approximately 2000 BP. All previous sea level studies (references above) agree that eustatic sea level reached present levels before this time. A large (greater than one meter) eustatic sea level rise, therefore, can not explain this flooding surface. The sequence boundary map (antecedent topography) does not show any significant corresponding terraces. Either climate induced sediment supply variations or centimeter to decimeter scale sea level variations cause dramatic 20 to 40 km backstepping of bay head deltas. Additionally, both Sabine and Calcasieu lakes show a -5 m flooding surface that does not occur in Galveston Bay.

***Conclusions***: A more detailed chronostratigraphy is needed to better constrain the 3m and 5m flooding events across both bays (Figure 5). For instance, is the 3m flooding surface isochronous or time transgressive (i.e., did the bay head delta step back 20 km within a few centuries or a few thousand years)? Flooding surfaces also occur at -9, -10m, -15, -16m, -18, and -20m. A accurate and precise chronology will also aid in comparisons with the findings of other workers/studies in bays such as Galveston, Mobile, Corpus Christi, and Matagorda, as well as deltaic systems like the Brazos. Ultimately, similarities and differences across the Gulf of Mexico will shed light upon the forcing mechanisms as well as potentially provide Holocene paleoclimate information.

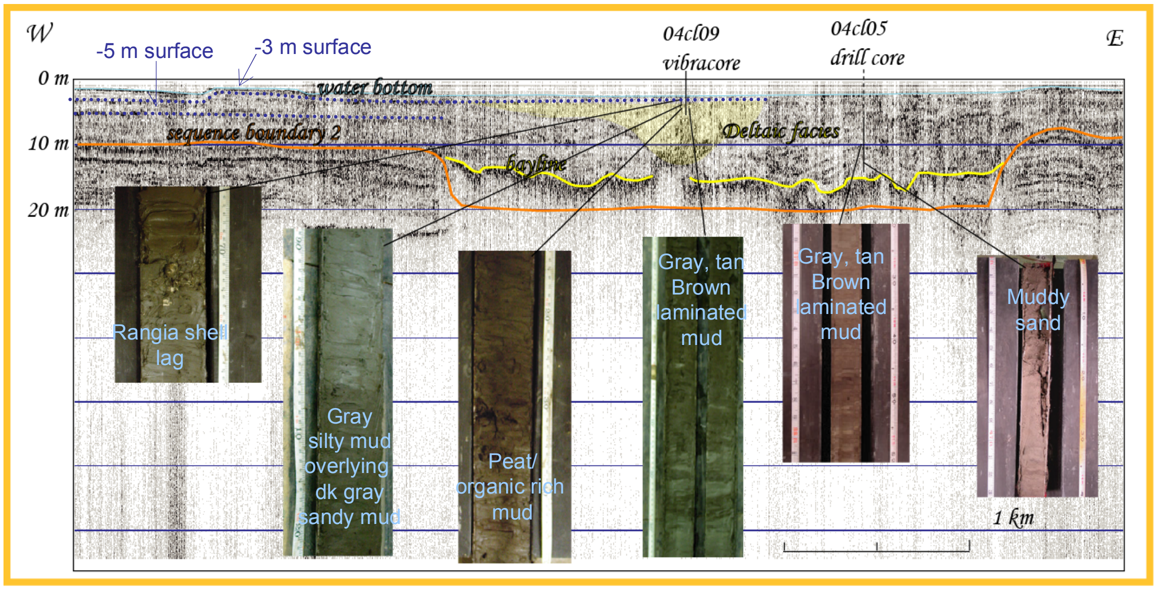



Figure 5: High resolution seismic section across the upper part of Calcasieu bay. Location shown on Figure 4B. Orange line marks the lowstand incised valley (sequence boundary 2) correlative with oxygen isotope stage 2. The yellow line deliniates the high amplitude surface marked by high contents of organic matter and coincident with the bayline. The light yellow shading highlights a bay head delta channel fill.

***References***:

Berryhill H.L, and J.R. Suter, 1986, Late Quaternary Facies and Structure on the northern Gulf of Mexico: interpretation from seismic data: AAPG Studies in Geology 23, 289p.

Byrne, J.V., D.O. LeRoy, and C.M. Riley, 1959, The Chenier Plain and its stratigraphy, southwestern Louisiana GCAGS Transactions, v. 9 p. 237-260.

Coleman, J.M., and W.G. Smith, 1964, Lake Recent rise of sea level: GSA Bulletin, v. 75, p. 833-840.

Curray, J.P., 1960, Sediments and history of the Holocene transgression, continental shelf, Northwest Gulf of Mexico, *in* F.P. Shepard, F.B., Phleger, and T.H. Van Andel (eds.), Recent Sediments, Northwest Gulf of Mexico: AAPG., p. 221-266.

Fairbanks, R.G., 1989, A 17,000-year glacio-eustatic sea level record: influence of glacial melting rates on the Younger Dryas event and deep-ocean circulation: Nature, v. 342. p. 637-642.

Fisk, H.N., 1948, Geological investigation of the lower Mermentau River basin and adjacent areas in coastal Louisiana: Unpublished report, in Definite project report, Mermentau River, Louisiana, Appendix II, U.S., Army Corps Engineers, Mississippi River Commission, 145p.

Frazier, D.E., 1974, Depositional episodes: their relationship to the Quaternary stratigraphic framework in the Northwest portion of the Gulf Basin, Austin Texas Bureau of Economic Geology, Geologic Circular, 74-1, 28 p.

Gould, H.R., and McFarlan, E., 1959, Geological History of the chenier plain, Southwestern Louisiana, GCAGS Transactions, v. 9. p. 261-272.

Kane, H., 1959, Late Quaternary Geology of Sabine Lake and Vicinity, Texas and Louisiana. GCAGS Transactions, v. 9 p. 225-235.

Le Blanc, R.J., 1949, Unpublished Shell Oil Company Report 128, 27p.

McFarlan, E., 1961, Radiocarbon dating of lake Quaternary deposits, south Louisiana: Geological Society of America Bulletin, v. 72, p. 129-158.

NCDC, 1994, Time Bias Corrected Divisional Temperature-Precipitation-Drought Index. Documentation for dataset TD-9640. Available from DBMB, NCDC, NOAA, Federal Building, 37 Battery Park Ave. Asheville, NC 28801-2733. 12pp. – www.cdc.noaa.gov

Nelson, H.F., and E.E. Bray, 1970, Stratigraphy and history of the Holocene sediments in the Sabine-High Island area, Gulf of Mexico, *in* J.P. Morgan (ed), Deltaic Sedimentation Modern and Ancient: SEPM Special Publication 15., p. 48-77.

Penland, S., R.A. McBride, S.J. Williams, R. Boyd, and J.R. Suter, 1991, Coastal Sediments '91, p. 1248-1264.

Nichol, S. L., R. Boyd, and S. Penland, 1996, Sequence stratigraphy of a coastal-plain incised valley estuary: Lake Calcasieu, Louisiana: Journal of Sedimentary Research, v. 66, p. 847-857.

Rodriguez A.B., J.B. Anderson, F.P. Siringan, and M. Taviani, 2004, Holocene evolution of the east Texas coast and inner continental shelf: along-strike variability in coastal retreat rates: Journal of Sedimentary Research, v. 74, p. 406-422.

Rodriguez A.B., J.B. Anderson, and A.R. Simms (in review), Incised-Valley fill Parasequence formation and implications for estuarine evolution: Galveston Estuary, Texas.

Siringan, 1993, Unpublished thesis, Rice University, 247 p.

Tornqvist, T.E., J.L. Gonzalez, L.A. Newsom, K. van der Borg., A. F.M. de Jong, and C.W. Kurnik, 2004, Deciphering Holocene sea-level history on the US Gulf Coast: A high-resolution record from the Mississippi Delta: GSA Bulletin, v. 116. p. 1026-1039.

Thomas, M.A., 1990, The Impact of long-term and short-term sea level changes of the evolution of the Wisconsinan – Holocene Trinity/Sabine Incised Valley system, Texas Continental shelf: Unpublished thesis, Rice University, 247p.

Wellner, J. S., 2001, Late Quaternary glacial history of the Pennell Coast region, Antarctica, with implications for sea-level change and ice sheet behavior; and Late Quaternary Stratigraphic Evolution of the West Louisiana continental shelf: Unpublished thesis, Rice University. 217p.