### PSA Comparison of the Geometries of Two Pleistocene Shelf-Margin Delta Sequences, Vermilion South Addition and Northeast Garden Banks, Gulf of Mexico\*

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### **Abstract**

Shelf margin delta systems are the result of the progradation of sediment to the shelf edge during a period of low relative sea level, a depositional system that has few modern proxies. The present-day Gulf of Mexico contains numerous Plio-Pleistocene shelf margin deltas, many of which have been deformed extensively by the underlying Louann Salt. Two of these vertically stacked delta sequences, located in the South Vermilion Addition and northeastern Garden Banks, have been described using 3D seismic data and well logs. They are found in a salt mini-basin about 160 km off the Louisiana coast in the Gulf of Mexico.

The lower deltaic sequence contains a wave-influenced delta with burgeoning muddy-silty clinoforms, scoured by a mass transport complex. This delta contains a sprawling network of tributive shelf and slope channels that feed past the edge of the dataset into deeper waters. The shelf-slope break of this facies was eroded by a sandier slump-type mass transport complex containing normal faulting at its head and thrust faults at the toe. Over this, a thin sandy, late-lowstand river-dominated delta prograded, lobate in shape and connected to a clearly-imaged single trunk channel that siphoned sediment over the shelf-slope break. This delta system is onlapped by a transgressive belt of heterolithics in the distal margin of the delta (Trangressive Systems Tract). This system is capped by a maximum flooding surface.

The smooth-fronted upper deltaic sequence comprises a second lowstand and contains clearly imaged muddy-silty clinoforms that show some reworking of sediment in the more proximal areas of the delta. Both of these delta sequences contain complex systems of

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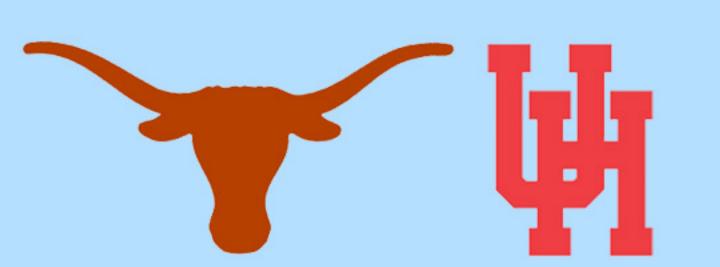
tributive shelf and slope channel systems that extend from the delta front and into the deeper upper slope and basin. Within the clinoforms extending the length and breadth of the mini-basin is an intricate network of shelf and slope channels that flush sediment directly from the most proximal end of the basin straight to the continental slope, and presumably, to the abyssal plain as a deepwater fan. Understanding the sequence stratigraphy and 3D seismic architecture of shelf margin deltas and their corresponding channel systems will further our understanding of the means by which reservoir-quality sediments are deposited on the continental shelf and transported to deepwater systems.

### **Selected Reference**

Perov, G., 2009, Pleistocene shelf-margin delta: Intradeltaic deformation and sediment bypass, northern Gulf of Mexico: Thesis (M.S.), University of Houston, Houston, Texas, vii, 49 leaves, illustrations, map.

# A COMPARISON OF THE GEOMETRIES OF TWO PLEISTOCENE SHELF-MARGIN DELTA SEQUENCES, VERMILION SOUTH ADDITION AND NORTHEAST GARDEN BANKS, GULF OF MEXICO

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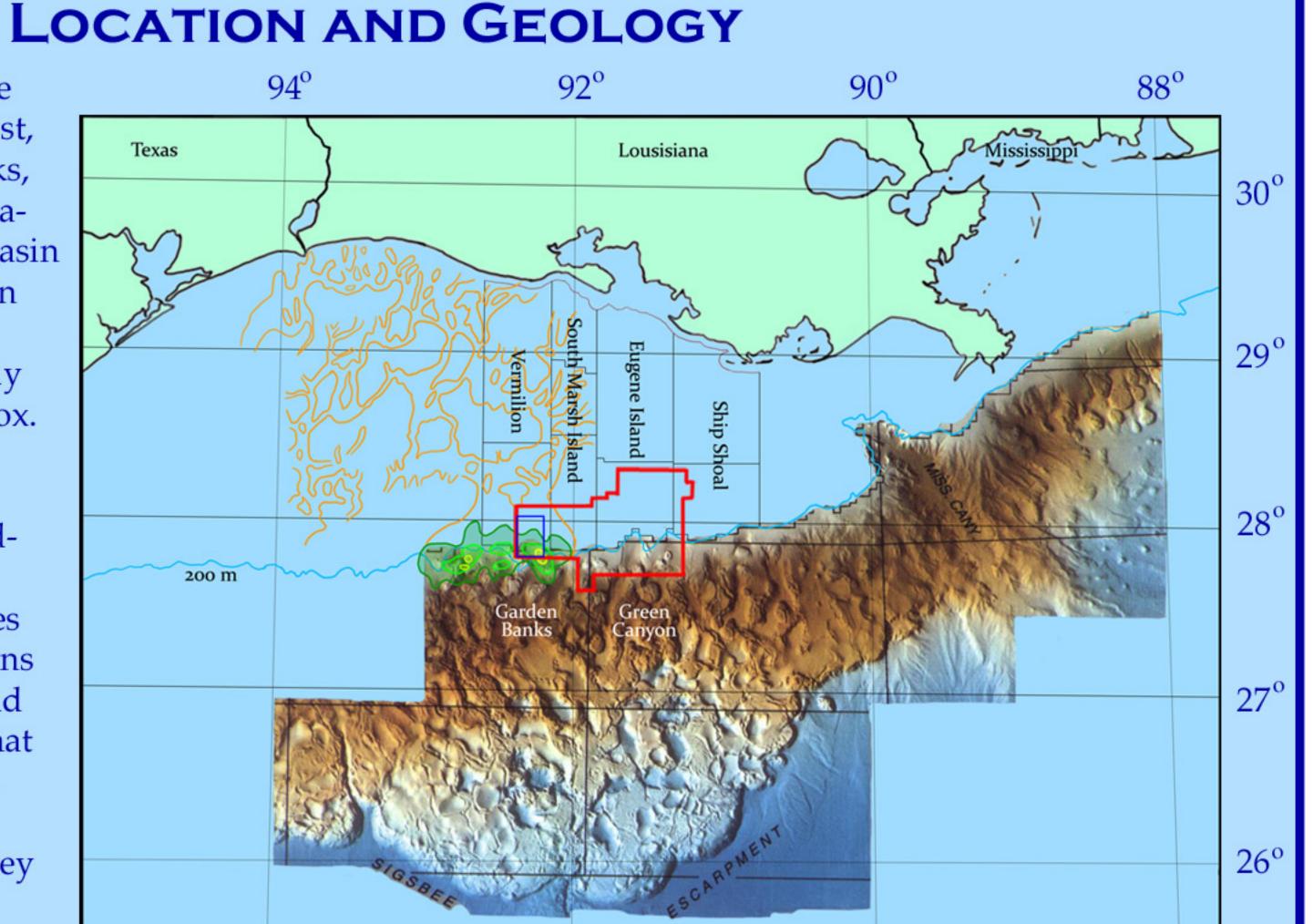
### ABSTRACT

Shelf margin delta systems are the result of the progradation of sediment to the shelf edge during a period of low relative sea level, a depositional system that has few modern proxies. The present-day Gulf of Mexico contains numerous Plio-Pleistocene shelf margin deltas, many of which have been deformed extensively by the underlying Louann Salt. Two of these vertically stacked delta sequences, located in the South Vermilion Addition and northeastern Garden Banks, have been described using 3D seismic data and well logs. They are found in a salt mini-basin about 160 km off the Louisiana coast in the Gulf of Mexico.

The lower deltaic sequence contains a wave-influenced delta with burgeoning muddy-silty clinoforms, scoured by a mass transport complex. This delta contains a sprawling network of tributive shelf and slope channels that feed past the edge of the dataset into deeper waters. The shelf-slope break of this facies was eroded by a sandier slump-type mass transport complex containing normal faulting at its head and thrust faults at the toe. Over this, a thin sandy, latelowstand river-dominated delta prograded, lobate in shape and connected to a clearly-imaged single trunk channel that siphoned sediment over the shelf-slope break. This delta system is onlapped by a transgressive belt of heterolithics in the distal margin of the delta (Trangressive Systems Tract). This system is capped by a maximum flooding surface.

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Redrawn and combined map of the Gulf of Mexico. It displays the coast, relevant Gulf of Mexico lease blocks, 200-meter water depth line, and seafloor bathymetry of the salt mini-basin province. The dataset is outlined in red, and covers a portion of the continental shelf margin. The study area is outlined by the dark blue box. Ancient channels are outlined in orange, and the paleo-Mississippi Delta in green to yellow, with sandstone thicknesses increasing from green to yellow. The study area lies within a salt mini-basin and contains a series of alternating deformed and non-deformed deltaic sequences that contain clinoforms in the proximal areas of the basin. Some of these clinoforms become deformed as they prograde into the basin.

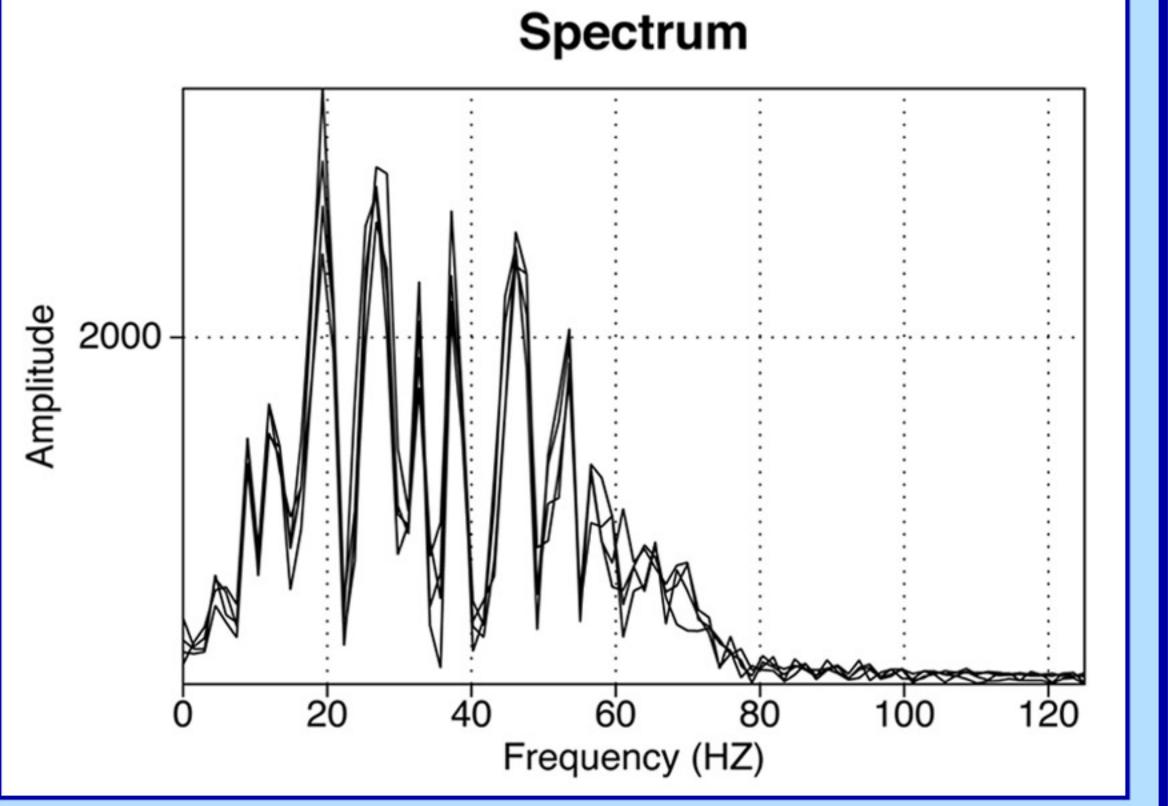


### DATASET AND METHODOLOGY

This study used a 3D seismic dataset named FlexR Phase III; it covers an area of roughly 8,000 km<sup>2</sup> and was donated to the University of Houston by Petroleum Geo-Services (PGS). The dataset encompasses 288 offshore continental shelf blocks and lies on the continental shelf margin in the Gulf of Mexico. It is located approximately 160 km south of the Lousisiana coast in water depths varying from 80 - 270 m. The focus of this study encompasses the westernmost portion of the dataset. The study area is ensconced predominantly within the southern Vermilion South Addition and northeastern Garden Banks areas. It covers 600 km<sup>2</sup>: 30 km in length north to south, and 20 km in width east to west, and is located between 27°50′ N - 28°06′ N

latitude and 92° 10′ W - 92° 23′ W longitude. The seismic volume was analyzed using several different steps. The delta sequences were first stratigraphically divided by picking strong, continuous amplitude reflections that separated the deformed sequences from the non-deformed sequences. Faults were also mapped to ensure that the inital picked horizons were the same throughout the mini-basin, using both amplitude and coherence, by observing the lapout relationships and horizon offset. Various seismic attributes were derived from the original amplitude data to allow for improved imaging and interpretation. Shelf and slope channels were mapped using proportional slicing. Internal features were mapped out, including distributive and tributive channel systems, delta lobes, strandplains, masstransport complexes (MTCs) and their associated

deformational features.



equency versus amplitude spectrum within theinterval of interest. The main frequencies range from 7 to 60 Hz, yielding a mean dominant frequency of 33.6 Hz (generated by Scott Rubio, 2010). The mean dominant frequency is calculated by taking the average of the highest and lowest higher-amplitude

### SEISMIC STRATIGRAPHY

reflections that are continuous

These diapirs have induced

The mini-basin is bounded to the

oldest to youngest, respectively.

Locations of various cross sections

The upper section of the dataset has been divided into four separate sequences bounded by maximus flooding surfaces (MFSs) (Figure 1). The MFSs used to define these sequences are high-amplitude

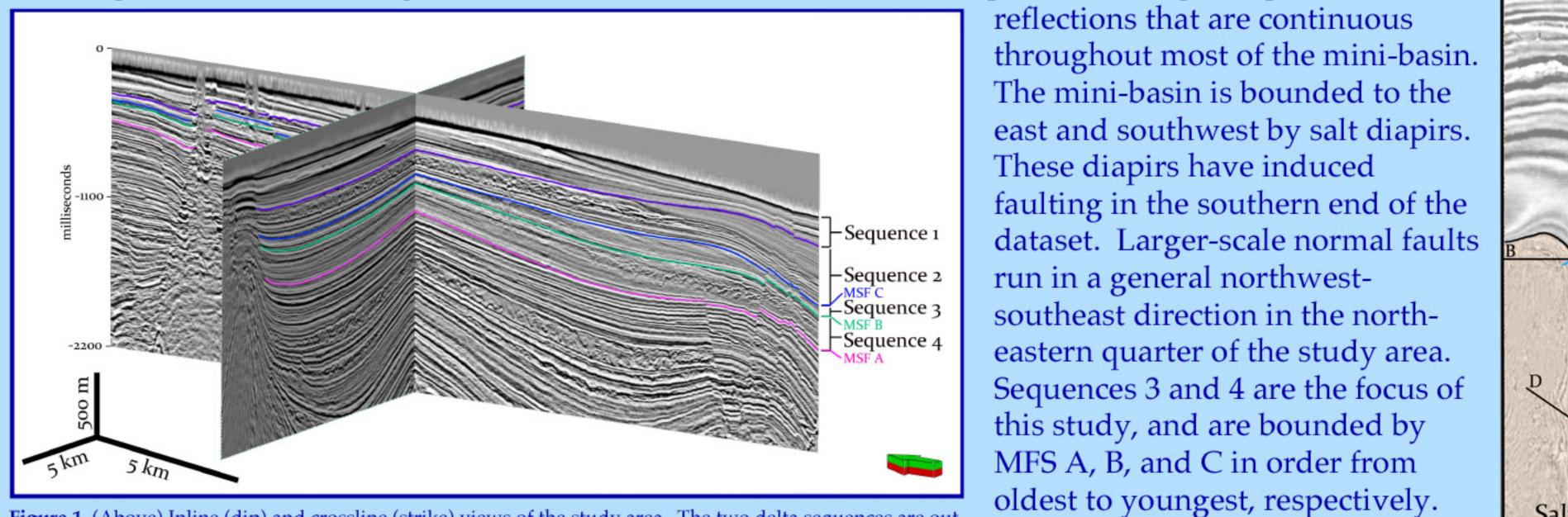


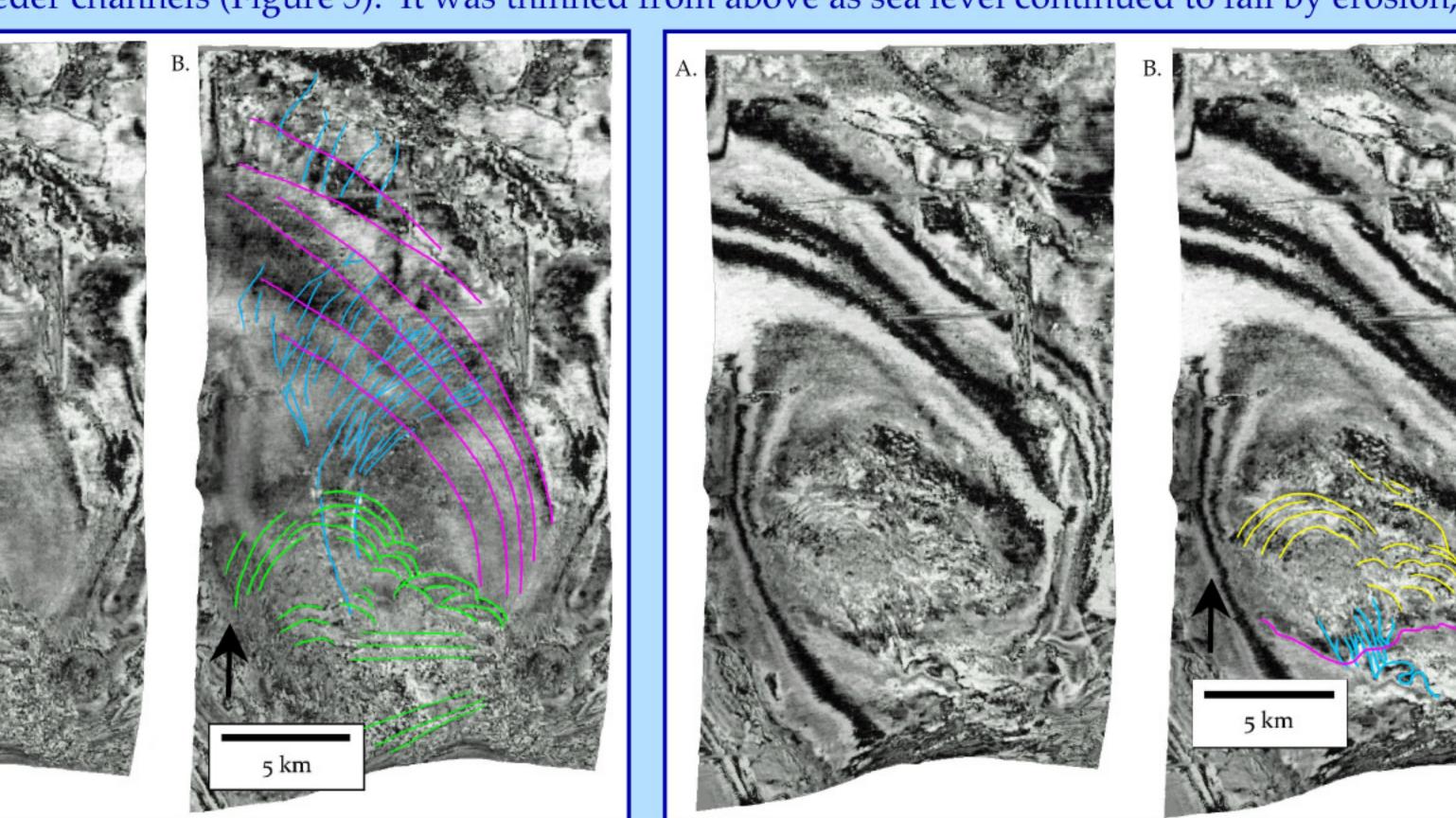
Figure 1. (Above) Inline (dip) and crossline (strike) views of the study area. The two delta sequences are ou lined by maximum flooding surfaces (MFSs) in blue, green, and pink, labeled as C, B, and A, respectively Green and red arrow points north. Note the alternation of non-deformed and deformed deltaic sequences.

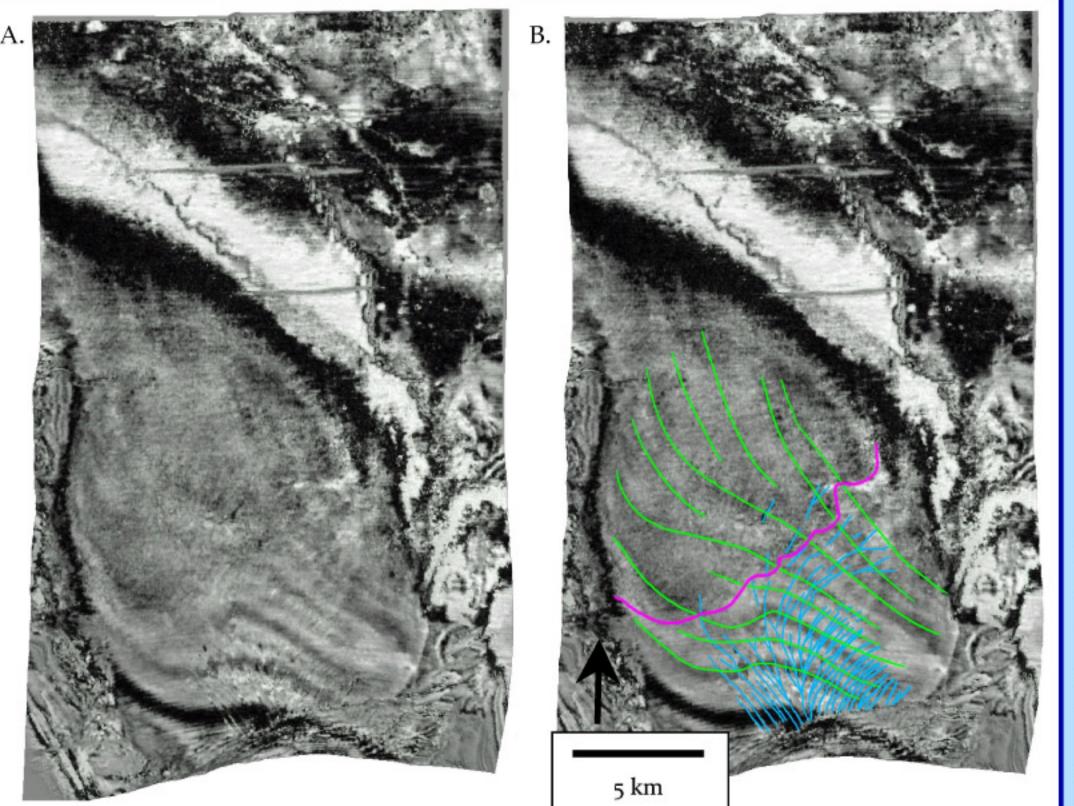
The uppermost sequence is studied by Lozano (in prep); the second sequence has been studied by Perov (2009). are found Figure 2. The third and fourth sequences are the focus of this study.

Figure 2. (Upper right) Plan view of the study area. The lines indiccate locations of various cross sections. A - A' and B - B' indicate the dataset dip and strike cross sections found in Figure 1. C - C' and D - D' indicate the depositional dip and strike of the delta sequences, and D - D' also indicates where Figure 8 is found. E - E' shows where Figure 9 is found. Blue lines indicate faults, and salt diapirs are outlined and shaded a light beige. The black arrow indicates north.

Figure 3. (Lower right) Depositional dip and strike views of the mini-basin. A and C are non-interpreted, while B and D are interpreted and labeled; the upper labels are surfaces while the bottom labels are systems tracts. Green lines indicate fault planes. Depth is measured in ms. The black arrows indicate where

The deposition of the MFS A surface occurred first in terms of the interval of interest. Highstand systems tract (HST) 1 is deposited over this basal surface. During the deposition of HST 1A, a tributive network of channels formed, stretching most of the length and two-thirds the width of the basin. This channel system terminates along a single clinoform (Figure 4), and is separated from a set of shoestring channels in the proximal end of the basin. Between these two systems are a set of linear, strikeoriented features that are interpreted as strandplains. A sandier body was deposited above the HST 1 and caused instability in the muddier delta below. This slump-type MTC contains assorted faults and blocks within it, and is labeled HST 1B. After the formation of the MTC, the same sandier sediment prograded over the slump, producing growth strata within the normal faults. The overlying delta, known as lowstand systems tract (LST) 1, contained a single well-imaged slope channel feeding from a lobe that had smaller feeder channels (Figure 5). It was thinned from above as sea level continued to fall by erosion, producing sequence boundary





The deposition of MFS B marked the division between the lower and upper sequences. Over MFS B lies a high-amplitude condensed section that belongs to HST 2. The deltaic body of HST 2 is interpreted to be proximal to the minibasin, with the sediment labeled as HST 2 slope sediment. LST 2 prograded over HST 2 and is a distinctly clinoform unit. LST 2 also contains a system of (Figure 6). Above LST 2 is an erosive surface labled TSE 2, which is then overlain by MFS C. Based on the laterally varying vertical thickness of the upper delta sequence, the trajectory of the shelf-slope break of the individual clinoforms indicates possible progradation, as well as a slight down-stepping in the most distal clinoforms. This overall oceanward shift with a minor downward component is indicative of either an increase in sedimentation rate or a drop in relative sea level, or both.

MES C TSE 2 TSE 1 MES A -200 MES C TSE 2 SB 2 MFS A

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Figure 4. (Upper left) Horizon slice through the HST 1A 70 ms above MFS A. A is a non-interpreted view; B contains interretation. Blue indicates channels, pink the strandplains, and green indicates faulting from the MTC in HST 1B above. There are two types of channels: the ones proximal to the strandplains are distributary shoestring channels feeding the

Figure 5. (Above) Horizon slice through LST 1 190 ms above MFS A. A is a non-interpreted view; B contains interpretation Blue indicates channels, yellow indicates faulting from the MTC in HST 1B below, and pink outlines the lobate shape of the

Figure 6. (Left) Horizon slice through LST 2 20 ms above MFS B. A is a non-interpreted view; B contains interpretation. Blue indicates channels, green the strandplains, and pink the boundary where features have been reworked slightly due to creep from uplift of the western diapir.

### DEPOSITIONAL SYSTEMS

There are two different types of deltas found within the study area: wave-dominated and river-dominated deltas. These were identified based on plan view geometry and the lateral location of the shelf-slope break. They were then further associated with certain types of channel systems. There are two wave-dominated systems found within the two sequences found in HST 1A and LST 2. These two deltas possessed shingled to parallel clinoforming geometries, and in the case of the younger delta, a smooth, even shelf-slope break. The river-dominated delta was identified as such due to its lobate external geometry and internal clinoform geometry. Although these deltas have been coarsely clasified based on their external geometries, almost certainly there may be secondary or tertiary fluvial or tidal influences that keep these deltas from being end member deltas. The presence of certain types and styles of slope channels may also depend on the delta type.

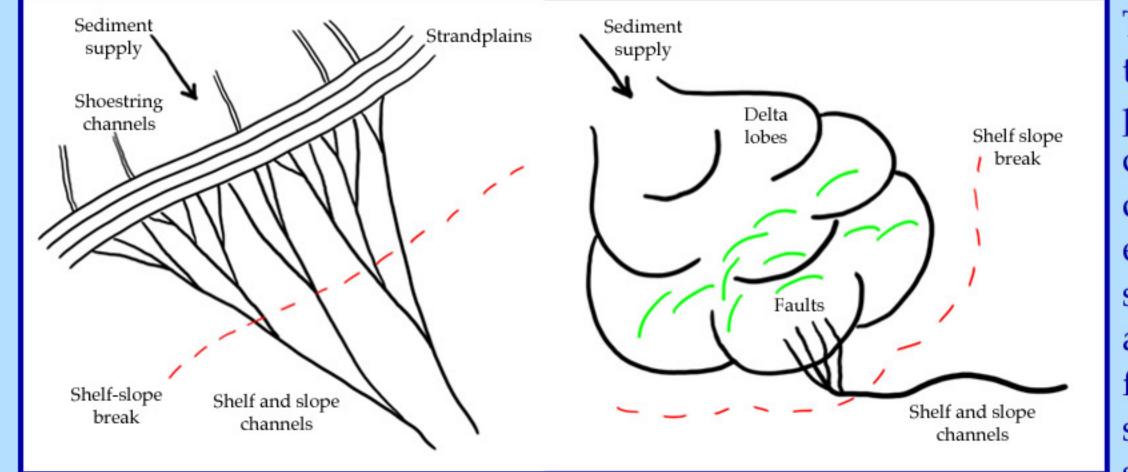


Figure 7. Schematic diagrams of the geometries of a wave-dominated delta (left) and a river dominated delta (right). The arrows indicate the direction of sediment supply and the location of the shelf-slope break is denoted as the dashed red line. The shoestring channels presumably feed into strandplains in the wave-dominated delta. In the river-dominated delta, a single main trunk channel feeds from a delta lobe with smaller channels feeding it. Channels stemming from other delta lobe were not imaged. Green lines indicate faults.

The two wave-dominated deltas contain clinoforms that are continuous and linear, and resemble strandplains that are found in modern wave-influenced deltas. The two delta systems both possess a clinoforming internal geometry combined with extensive lateral coverage of the mini-basin and a smooth delta front geometry. Both deltas are associated with a tributive network of channels that eed from the proximal areas toward and past the shelf-slope brea. The more numerous channels of the shelf and slope system found in the landward end are thinner and shallower, becoming wider and deeper as they course through the basin. These deltas tend to be muddier based on seismic amplitude and well log data (not shown), and the presence of strand lines

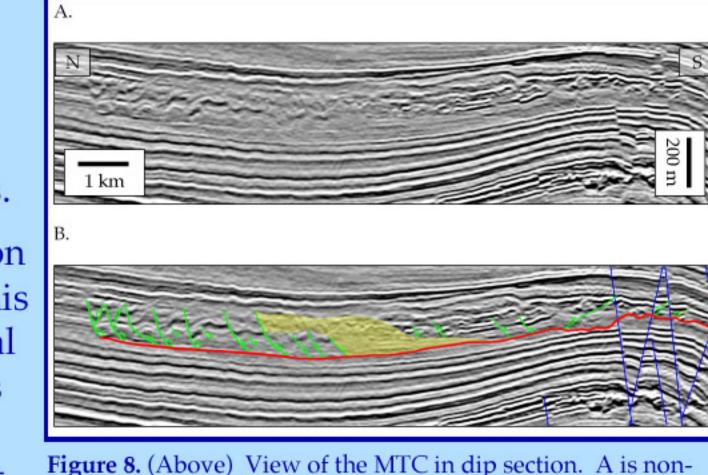
within a muddier environment suggests that within the mini-basin a possible trapping mechanism for mud particles existed, allowing for the formation of a regressive mudbelt not unlike the modern chenier planes of Louisiana. This combination of features could also be interpreted as a distal prodelta mudbelt, but further research would be required.

The single river-dominated delta found in the interval of interest is a thin, sandier layer found at the top of the lower delta sequence that prograded over the wave-dominated delta below. The progradation of this river-dominated delta caused instability in the lower delta and produced the MTC. The presence of the MTC ensured that most features within

this unit are disturbed, and traces of the faults found in the MTC can be seen. This unit is identified as river-dominated because of the stronger amplitudes found here, which are interpreted to be predominantly sand, and the lobate morphology. It is also linked to a singular large trunk upper slope channel with few poorly imaged tributive channels that feed off one of the delta lobes.

The deformation within th lower sequence is entirely internal; the deformation does not extend beyond the upper and lower boundaries of the sequence. Th deformational unit is a slump-type MTC, and contains a head of listric normal faults (in this instance, growth faults), a body of reworked, chaotic reflections that indicate soft-sediment deformation, and a toe containing thrust faults. The proximal end of the facies contains tensional listric growth faults that flatten in to the decollement and show an arcuate geometry in plan-view. Strong coherent reflections in the footwal thicken as they dip towards the fault plane. There are several smaller antithetic normal faults found amongst the listric growth faults. The distal end of the facies is marked by imbricate toe thrusts.

lines the extent of creep in green. The deformation found in the upper deltaic sequence is significantly less than that found in the lower deltaic sequence. This style of deformation is identified as creep. Creep occurs over relatively long periods of time and over wide areas due to their slow rate of deformation. The creep that occurs in the upper delta sequence is entirely constrained to LST 2. The extent of deformation can be detected in both vertical sections and plan-view via the distortions in the clinoform geometry of the delta. Because clinoforms are still visible within the deformed section, this unit is determined to be a syndepositional feature.



blue are larger-scale normal faults, red the decollement, and Figure 9. (Below) View of the region of creep in dip sectin. The image is flattened along MFS B. A is mon-interpreted; B out-

### CONCLUSIONS

The two delta sequences were divided by flooding surfaces and further separated by classification of features found within the sequences. They were deposited over the course of two sea-level cycles and contain highstand, lowstand, and transgressive systems tracts. The HSTs are non-deformed, consisting of either a delta with reworking from the subsequent LST, or a condensed section with the deltaic body further landward than the dataset. The HST delta found within the mini-basin is composed of muddly to silty subparallel reflections. HST 1 was broken down into HST 1A and HST 1B. Both of the LSTs are responsible for some form of sediment deformation and reworking. The TSTs were defined as a transgressive wedge and a relatively thin layer of shales that indicated a major transgression.

There are two distinct types of deformation within the interval of interest: the lower delta sequence contains a slumptype MTC and the upper delta sequence contains a creep section. The MTC contains listric growth faults, toe thrusts, and a body composed of deformed, soft-sediment deformation with some rotated brittle slide blocks internally. This unit formed due to overloading of heavier sediment above, causing the system ot fail and slump, and therefore is syndepositional. The creep in the upper delta sequence slightly reworks the proximal portion of the mini-basin; the clinoforms found within the upper delta can still be traced in the reworked areas.

The deltas have been interpreted as wave- and river-dominated deltas using the available data. The two wavedominated deltas appear to be smooth-fronted, with clinoforms or parallel internal geometries and are associated with a large, tributive network of channels that flush sediment through the mini-basin. They are muddier in lithology, and when combined with the strandplains, might be an analogous depositional environment to the present-day Louisiana chenier plains. The single river-dominated delta shows a lobate appearance with few poorly imaged tributive channels within the lobes that feed into a single well-defined upper-slope trunk channel. This delta contains clinoforms that converge tangentially with the base of the unit.