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Deltaic Deposits and Linked Downslope Petroleum Systems

Deltas in siliciclastic and mixed carbonate – siliciclastic deposystems are key to understanding processes that transfer terrigenous detritus from continental uplands to deep-ocean environments. The Lagniappe Delta deposystem located on the shelf and slope in the northeastern Gulf of Mexico has characteristics that make it a useful laboratory for developing petroleum system insights. During the last 100 ka glacioeustatic cycle, delta lobes fed by southern Appalachian rivers with relatively high sand-to-mud ratios, prograded rapidly across a broad shelf, reaching the shelf-edge only about 1000 years before the maximum lowstand. Offset stacking of delta lobes at the shelf edge is responsible for facies heterogeneity and is of importance in predicting sediment by-pass to deep water reservoir systems.

Thick sandy Lagniappe clinoforms constructed at the shelf-edge are excellent analogs for the growth-fault related hydrocarbon reservoirs in the Gulf of Mexico and other petroleum basins. A strongly laminated prodelta apron, constructed on the upper slope, grades down-slope into hemipelagic drape, but is characteristically punctuated by occasionally striking, but often subtle, bypass features related to channelized flow and basinal submarine fan development. It is generally assumed that sediment transport to deep water peaks during maximum lowstands. However, true maximum lowstand deltas are rare and have not been studied in detail in the Gulf of Mexico.

Delta front clinoforms often exhibit strong acoustic impedance contrasts suggesting the presence of bubble phase gas. Because growth faults and salt structures commonly co-exist with shelf edge deltas, they may offer the migration linkage between deep hydrocarbon systems and the lateral migration pathways provided by distal clinoforms that are directly linked to deltaic reservoirs. Thin fine-sand, silt, and clay laminae in the prodelta apron create effective capillary seals that inhibit vertical hydrocarbon migration while allowing hydrocarbons to move laterally up-dip within coarser laminae. Gas presently seeping from truncated clinoform sets and anomalous $\delta\,^{13}O$ and $\delta\,^{13}C$ values of authigenic carbonates within sediments of the clinoform packages strongly suggest that hydrocarbon migration is an on-going process.

The hydrate stability zone plays a critical role in the delta-slope system, in regulating the up-dip migration of hydrocarbons through the delta front turbidites, and in triggering slope failure that may lead to long-term sediment by-pass routes to deep water depositional sites. Slope failures can mobilize large volumes of shelf-edge clinoform and prodelta apron sediments, creating turbidity currents and debris flows that nourish deep-sea fan systems. These processes are modulated by sea level change. Gas hydrates in continental margin sediments decompose as hydrostatic pressure decreases during a sea level fall and the upper slope becomes bathed in warm surface waters. Depending on the rate of this decomposition, gas may be slowly released for up-dip migration into reservoir facies or more rapid gas production from destabilized hydrates may induce sediment instability and slope failures.

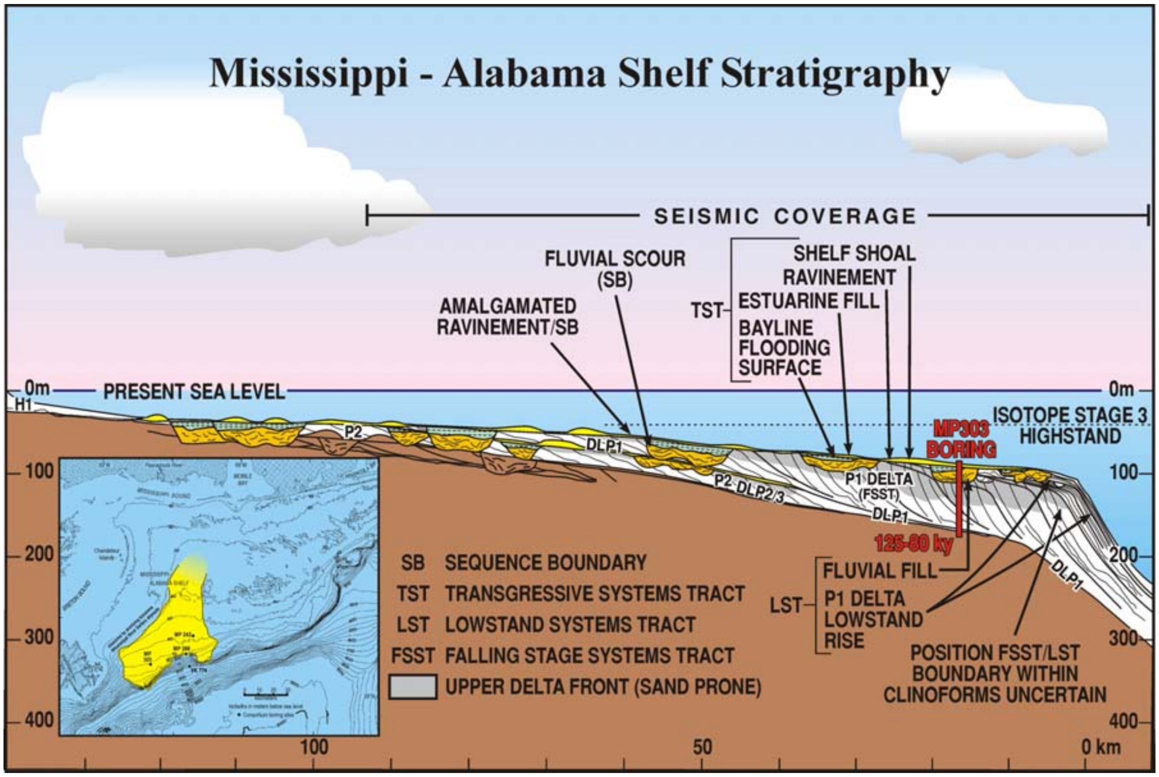

Figure 1. During periods of falling-to-low sea level, rivers build seaward-thickening multilobed delta complexes at the shelf edge. These complexes contain thick clinoform sets that drape onto the upper continental slope. This schematic diagram shows the complex internal geometries of the Lagniappe shelf edge depocenter. The inset map locates the Lagniappe delta along the Mississippi-Alabama shelf-edge just east of the active Mississippi River delta.

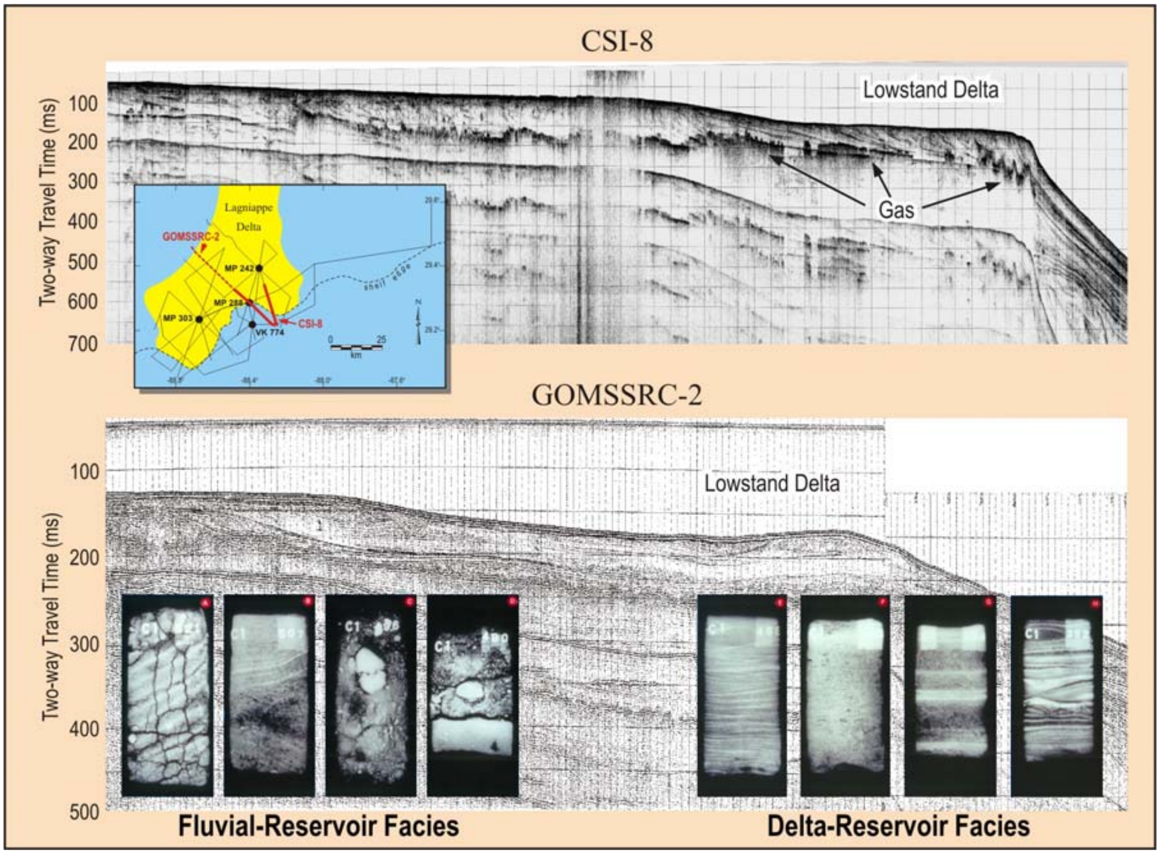

Figure 2. The high resolution seismic profiles illustrated here (see inset map for location within Lagniappe delta complex) show clinoform architectures typical of shelf edge deltas. The high amplitudes in the lower parts of the clinoform packages reflect the presence of bubble phase gas. These deltas contain reservoir facies ranging from massive distributary mouth bar and channel sands to delta front turbidites. The fluvial facies illustrated by X-ray radiographs is composed of gravel-rich sands while clean sand comprises the delta facies. These X-ray radiographed core samples were selected from the MP303 corehole (see inset map).

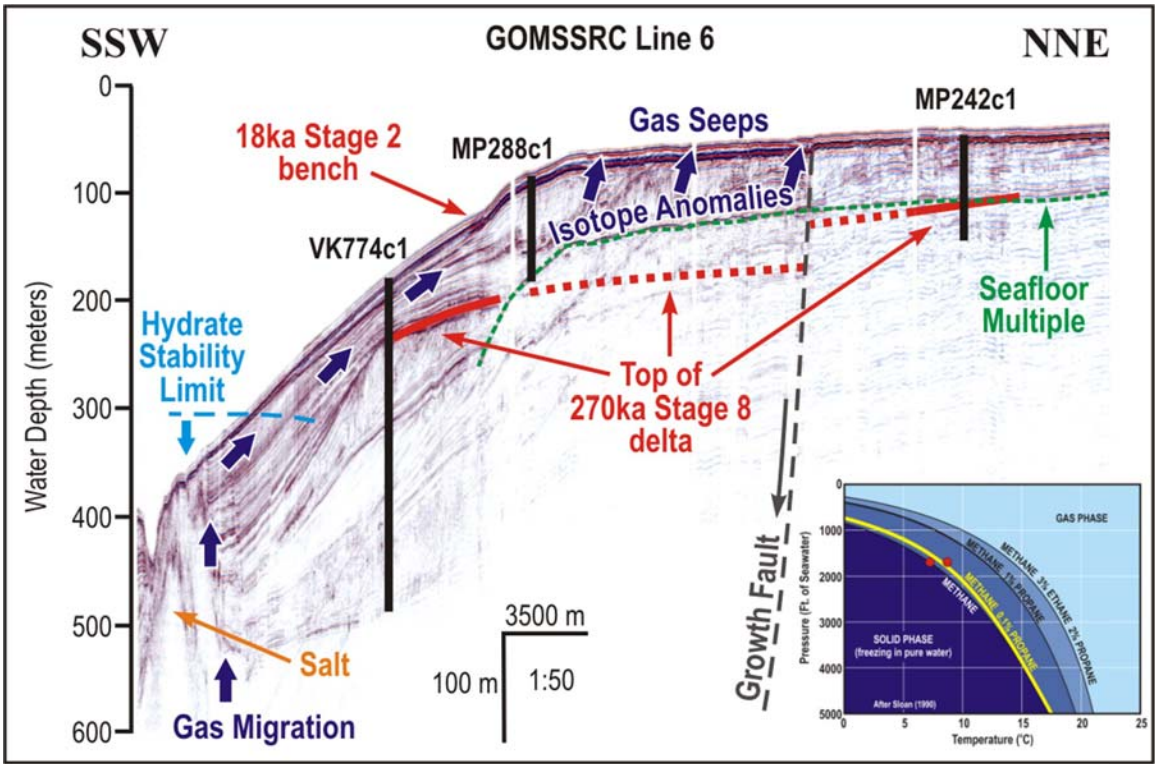

Figure 3. In this figure the shelf edge delta illustrated in Figure 2 is seen in the broader context of a shelf margin system bounded by a major growth fault (at right) and a deeply rooted near surface salt body (at left). Here, the shallow delta lobe is seen as back-stepping from the more seaward position of an older delta which has been displaced downward along the growth fault. This cross section provides a hydrocarbon migration model in which vertical migration along the salt body is blocked by the development of gas hydrates. Gas liberated from the hydrate stability zone in response to temperature and pressure fluctuations may laterally migrate through delta front turbidite beds into more massive up-dip reservoir facies.