Establishing Geochronologic Order of the Early and/or Middle Holocene Mississippi River Delta: Trinity and Tiger Shoals

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EXTENDED ABSTRACT

The evolutionary history of the Holocene Mississippi River Delta is written in its preserved stratigraphic record (Fig. 1). However, our realization of its complete history is hindered by formidable logistics in accessing that record, particularly for the early delta (i.e., offshore deposits). Because the Mississippi delta region experienced up to 10+ m (33+ ft) of relative sea-level rise during the early-to-middle Holocene (Törnqvist et al., 2006; Blum et al., 2009), abandoned delta complexes of this time period, specifically the Maringouin and Teche delta complexes, long ago entered the transgressive phase of the delta cycle, and consequently, a succession of associated, reworked depositional features now lie on the Louisiana inner-continental shelf (Penland and Boyd, 1981; Penland et al., 1988; Penland et al., 1989; Roberts, 1997). These depositional features are remnants of once prograding delta lobes: it is during the final transgressive stage of the delta cycle that a previously subaerial barrier island succumbs to relative sea-level rise and marine-reworking processes, ultimately transforming into a submarine sand shoal (Fig. 2).

Two such shoals are Trinity and Tiger shoals, neighboring submarine sand bodies positioned approximately 30-40 km (18-25 mi) offshore of west-central Louisiana (Fig. 1). These shoals have previously been suggested as remnants of the Teche delta complex, an assertion based primarily on bathymetric and geomorphic relationships (Penland et al., 1990; Pope et al., 1991). This study engages an alternative hypothesis that Trinity Shoal, which lies seaward of Tiger Shoal, is genetically linked to the Maringouin delta complex, whereas Tiger Shoal evolved afterwards in association with the Teche delta complex.

To test this hypothesis, we are developing a high-resolution depositional model of the Trinity and Tiger shoals study area by integrating 2D subbottom profiles (i.e., seismic), vibracores, and, subsequently, the lithostratigraphic, chronostratigraphic, and sedimentological data gleaned from their analysis (Fig. 3). An initial marine geophysical survey collected approximately 1,150 km (715 mi) of high-resolution, 2D chirp subbottom profiles across the study area (Fig. 3A) using an Edgetech 512i "chirp" subbottom profiler, a frequency-modulated marine sonar system that delivers vertical resolution on the decimeter scale in the upper ~30 m (100 ft) sediment column (Quinn et al., 1998). For this study, we used a chirp frequency range of 2-12 kHz, with a potential vertical resolution of ~10 cm (4 in). Seismic data were imported into Petrel, and major seismic reflectors were subsequently mapped (Figs. 3B and 3C). Mapped seismic surfaces were then used as a guide in selecting vibracore locations: a strong motivation was to pene-

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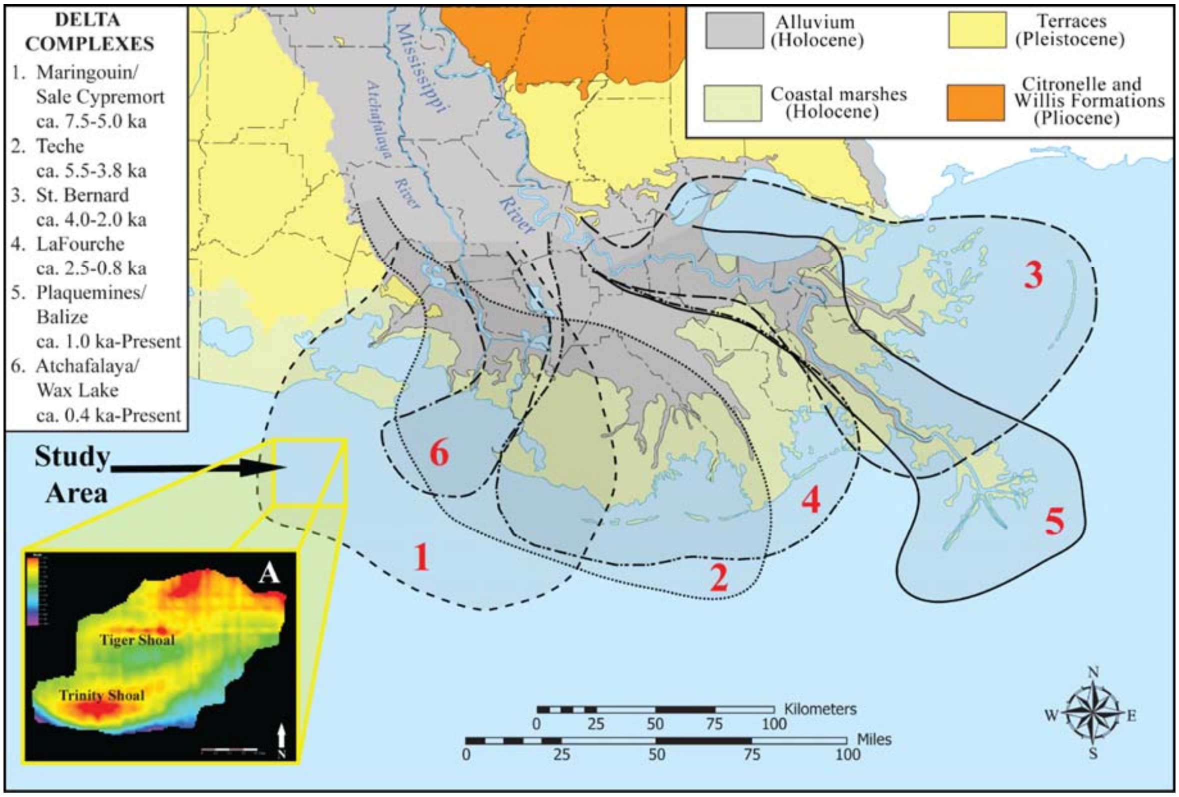

Figure 1. The Holocene Mississippi river delta plain, with individual delta complexes and their approximate ages depicted. Inset A is a bathymetric map of the Trinity and Tiger shoals complex. The underlying Louisiana geological base map is modified from www.lgs.lsu.edu, whereas delta complex interpretations are after Roberts (1997).

trate these surfaces in as many locations as possible, so as to integrate core data with geophysical data, and, subsequently, extrapolate stratigraphic, and geological interpretations across the study area. In total, 46 vibracores, with a maximum length of 4.5 m (15 ft), were extracted (Fig. 3D). Cores were then processed using a GEOTEK core logger (which measures gamma density and p-wave velocity), imaged, described lithologically, sampled at 50 cm (20 in) intervals for grain-size analysis, and sampled for radiocarbon dating and palynology studies.

The subbottom profiles and vibracores of Figures 4 and 5 were selected to illustrate the stratigraphic and sedimentological character of the Trinity and Tiger shoals complex. As vibracore TT-09-08, subbottom profiles A-A' and D-D', and bathymetric maps reveal, Trinity Shoal is a thick, predominantly sandy, bathymetrically pronounced depositional feature in the study area's western section. Towards the east, however, Trinity Shoal thins (see subbottom profiles C-C' and D-D' and vibracore TT-25-09). Vibracore TT-25-08 reveals sandy sediments near the sea-bottom surface (upper 1.1 m [3.6 ft]), but sediments become progressively muddier with depth. A sharp lithologic change exists at approximately 2.85 m (9.35 ft) subbottom depth, indicating the absolute subbottom extent of any Trinity Shoal related lithofacies.

Unlike Trinity Shoal, Tiger Shoal exhibits a more symmetrical shape. From its thin western section (see subbottom profile A-A', Fig. 4), Tiger Shoal thickens into its central section, which is indicated by vibracore TT-40-08 and subbottom profile B-B'. Similar to vibracore TT-25-08, vibracore TT-40-08 reveals sandy sediments near the sea-bottom

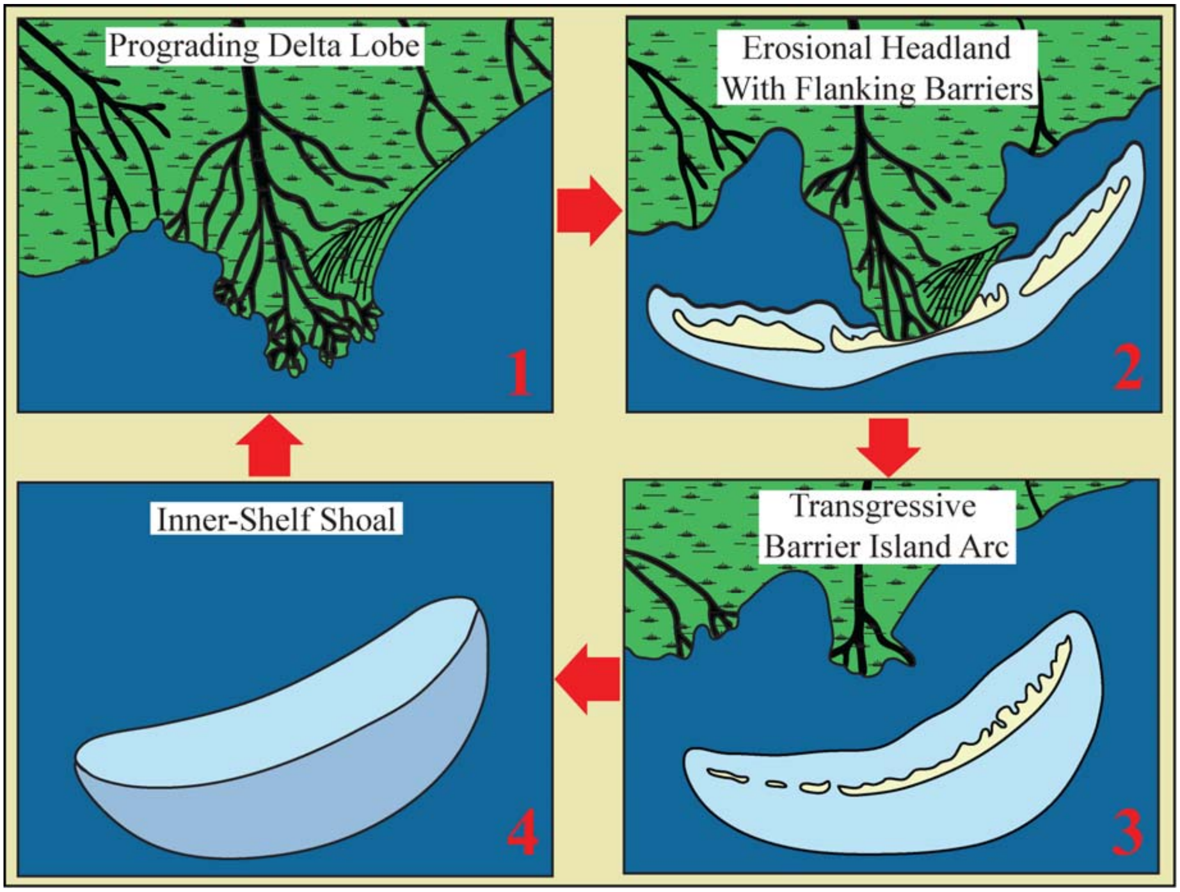

Figure 2. The Delta cycle (modified after Penland et al., 1988). (1) The regressive phase of the delta cycle, i.e. the progradation of an active delta lobe. (2-4) The transgressive phase of the delta cycle. (2) The progressive abandonment of a delta lobe is first perceived by erosional headland development, with flanking spits and barriers. (3) Back-barrier headland and marshes eventually submerge under relative sea-level rise, and barriers subsequently detach from the mainland. (4) Relative sea-level rise and marine reworking processes continue unabated, ultimately transforming this barrier island arc into a submarine sand shoal. Assuming conditions are met, a later, prograding delta lobe will reoccupy this area, relegating the shoal to the stratigraphic record.

surface (upper 1.2 m [3.9 ft]), but sediments become progressively muddier with depth. A sharp lithologic change exists at approximately 2.9 m (9.5 ft) subbottom depth, indicating the absolute subbottom extent of any Tiger Shoal related lithofacies. Towards the east, Tiger Shoal thins once more, as indicated by subbottom profile C-C'. Selected seismic lines of Figure 4 together expose the spatial extent of both shoals, and confirm that in fact these shoals are separate, discrete sedimentary deposits.

Examination of lithological and geophysical data reveals distinct differences between Trinity and Tiger shoals. First, the base of Tiger Shoal is at a much shallower subbottom depth than that of Trinity Shoal. For instance, the base of Tiger Shoal, in its central section, lies at an approximately 1.20 m (4 ft) subbottom depth (see subbottom profile B-B', Fig. 4; core TT-40-08, Fig. 5). However, the base of Trinity Shoal, in its central section, is yet defined: high-frequency chirp seismic attenuates completely in thick sands, and TT-09-08, an approximately 4.3 m (14 ft) vibracore consisting entirely of massive sand (i.e., shoal facies), does not penetrate the base of the shoal (see subbot-

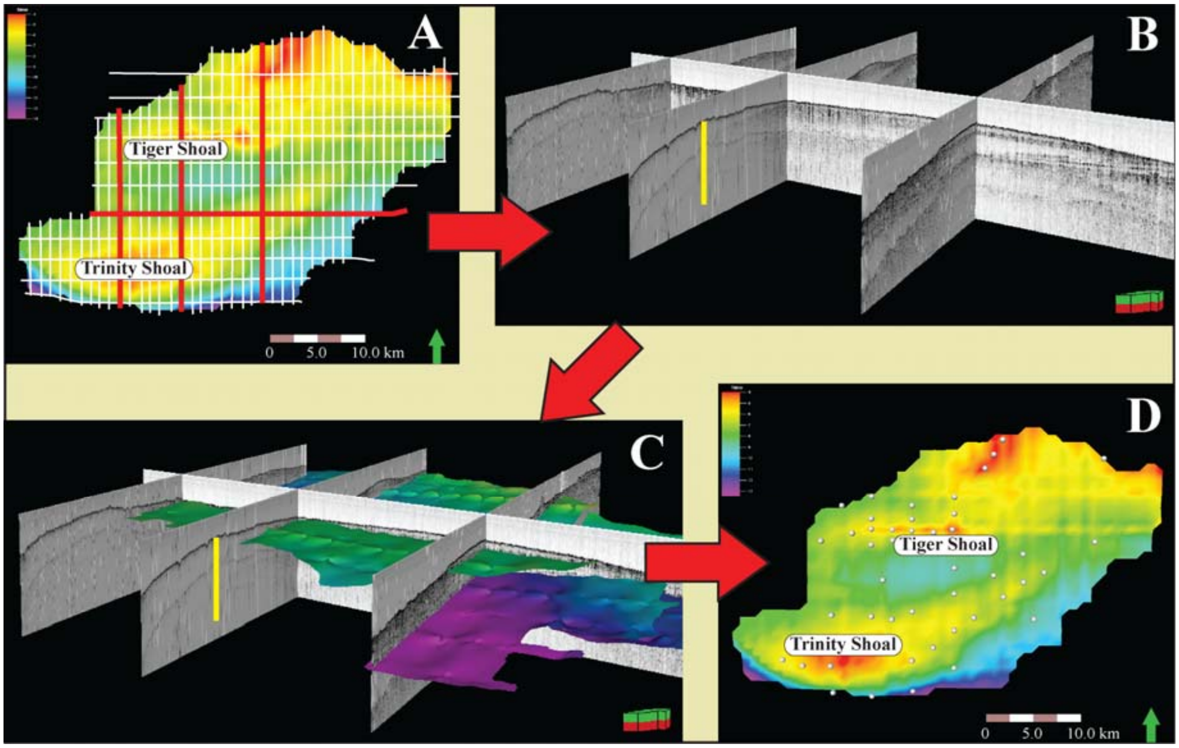

Figure 3. (A) Bathymetric map of the Trinity and Tiger shoals complex with geophysical track lines (white lines) superimposed. Highlighted red lines indicate the positions of seismic lines shown in B-C. (B) For an illustrational example, a 3D image of selected 2D seismic lines. Vertical exaggeration is 5X. For reference, a vertical scale for the central seismic line is shown here in yellow; this yellow line indicates 10 msec of one-way travel time. Considering the range of sediment type (clay to medium sand), a conservative acoustic velocity estimate of 1,550 m/s (5,100 ft/s) is applied to the entire study area for time-depth conversion. See bathymetric maps for a horizontal scale. (C) Illustrational example of mapped surfaces that were interpreted from key seismic reflectors. (D) Bathymetric map of the Trinity and Tiger shoals complex, with vibracore locations depicted. The green arrow in A-D points north. 100 km = ~62.1 mi.

tom profiles A-A', B-B', and D-D', Fig. 4; core TT-09-08, Fig. 5). Nevertheless, based on the basinward trajectory of Trinity Shoal (see subbottom profiles A-A' and B-B'), it is clear that the base of Trinity Shoal is much deeper than that of Tiger Shoal. Second, Tiger Shoal is both thinner and smaller in area than is Trinity Shoal; hence, it is volumetrically smaller. Though research is ongoing and conclusions are undefined, these preliminary observations suggest that Tiger Shoal may have been deposited post-Trinity Shoal, under higher sea-level conditions, and that its sand source was much smaller.

In addition, three radiocarbon dates were recently obtained from discrete shell layers sampled near the base of both shoals, from vibracores TT-25-08, TT-40-08, and TT-43-08 (TT-43-08 is not shown, but is located on the northern flank of Tiger Shoal); note that TT-25-08 does technically reach the base of Trinity Shoal, but does so in the shoal's most eastern section (see C-C', Fig. 4). This is not considered the core of the Trinity Shoal, and therefore does not contradict the above discussion. Ages are 1,070 to 920, 510 to 410, and 210 to 200 calendar years before present, respectively. Considering that the source(s) of Trinity and Tiger shoals was/were likely the Teche and/or Maringouin delta complexes (ca. 3.5 ka and older), dates are considered relatively young. However, these

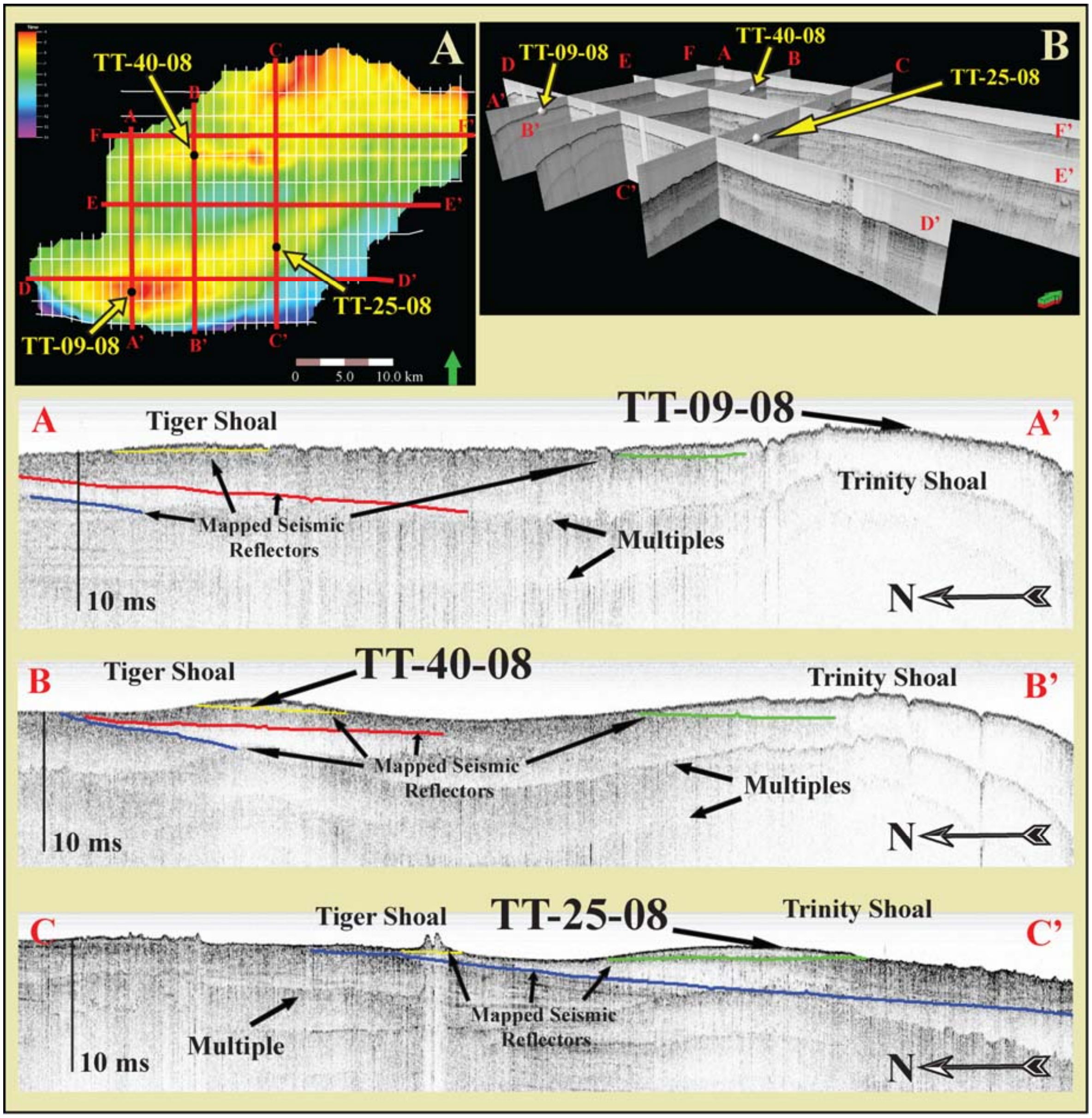

Figure 4. Seismic lines A-A', B-B', C-C', D-D', E-E', and F-F'. Selected seismic reflectors (i.e., various colored mapped horizons) are indicated, as are shoal locations, selected vibracore locations, multiples, and certain depositional features. Vertical exaggeration is 5X. Vertical time scale is in milliseconds (ms), and is one-way travel time. Considering the range of sediment type (clay to medium sand), a conservative acoustic velocity estimate of 1,550 m/s (5,100 ft/s) is applied to the entire study area for time-depth conversion. See bathymetric map for a horizontal scale. For seismic lines A-A', B-B', and C-C', arrow points north, whereas E indicates east and W indicates west for seismic lines D-D', E-E', and F-F'. Inset A is a bathymetric map of the Trinity and Tiger shoals complex; highlighted red lines indicate the positions of seismic lines in this figure; and selected vibracore locations are also indicated. Inset B is a 3D image of these selected seismic lines and vibracore locations. 100 km = ~62.1 mi.

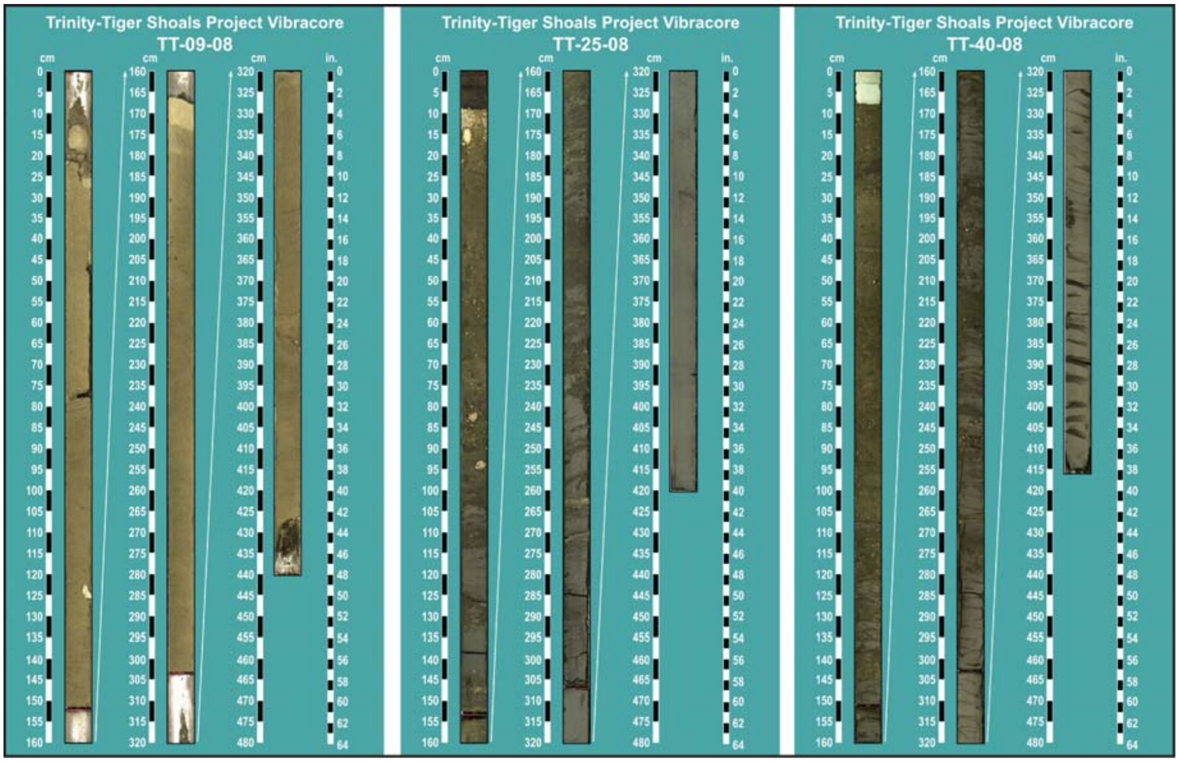

Figure 5. Vibracore images of TT-09-08, TT-25-08, and TT-40-08. See Figure 4 for locations. TT-09-08 is a massive, entirely very-fine sand unit. The upper 1.10 m (3.6 ft) of TT-25-08 is predominantly a massive, very-fine sand unit, capped by ~5 cm (2 in) of shell and hash. Beneath this, a muddy-to-sandy mud lithofacies, with interlayering sands, extends to 2.85 m (9.35 ft) depth. Below 2.85 m (9.35 ft) to the bottom of core is a clay unit. Though from a different shoal, TT-40-08 is similarly described as is TT-25-08. The upper 1.20 m (3.9 ft) is predominantly a massive, very-fine sand unit. Beneath this, a predominantly sandy-mud lithofacies, with interlayering sands, extends to 2.90 m (9.5 ft). Below 2.90 m (9.5 ft) to the bottom of core is a clay unit.

dates are not considered to represent the timing of shoal evolution, but rather depict the rate of landward migration of Trinity and Tiger shoals. For comparison, Penland et al. (1988) calculated that Ship Shoal, located approximately 100 km (62 mi) east of the Trinity and Tiger shoals complex, migrates landward at rates of between 7-15 m/yr (23-49 ft/yr). Such rates indicate that this shoal is being continuously reworked, and likely incorporates marine shell and shell layers as it is transported landward.

Data gathered thus far are considered insufficient to effectively address this study's objective. Hence, additional geophysical surveying and coring will occur in the summer of 2010. This upcoming field season will gather approximately 500 km (310 mi) of additional geophysical data, while extending the previous survey farther south and west. Up to 35 additional cores will be extracted where ground-truth data are needed. Furthermore, recently awarded student-research grants will allow for additional radiocarbon dating.

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