Latest Pleistocene 'Blue Unit' of the Mississippi Fan System, Gulf of Mexico

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ABSTRACT

Shallow water flow events in the central Gulf of Mexico that have caused drilling complications define the approximate areal extent of an Upper Pleistocene fan-channel sequence termed the 'Blue unit' by shallow geohazard interpreters in the Mississippi Canyon protraction area. Mapping on 3D time volumes has established that the Blue unit can be traced throughout the Mississippi Canyon, Atwater Valley, DeSoto Canyon, and Lloyd Ridge protraction areas. The Blue unit is a low-stand system deposited during the Wisconsin glaciation (marine isotope stage [MIS] 4) approximately 71 kya. It is interpreted with a lower canyon-cutting facies, and an upper sheet sand facies deposited in the channel and in ponded overbank areas formed between salt diapirs.

A deep canyon was cut in the shelf edge during the MIS 4 low stand with the knickpoint centered on the South Pass Southeast Area. The canyon trends south-southeast and was apparently diverted east-southeast by rising salt diapirs. Where the Blue unit is present near the modern Mississippi Canyon it is less organized and dominated by mass transport deposits. Here it is also highly deformed by salt diapirism and erosional beheading by younger channel systems.

Erosion and canyon incision in northwestern Mississippi Canyon grades eastward into a fan system deposited on the basin plain. Farther southeast in the Elbow area of the eastern Gulf of Mexico to the current limit of 3D data coverage the Blue unit can be genetically linked to a well-organized meandering channel-levee system along the toe of the Florida Escarpment. Abandonment of the meandering system resulted from sea level rise at MIS 2 (29 kya) and updip channel avulsion that diverted sediment to create younger channel-fan complexes to the southwest, most notable of which is the modern Mississippi Fan.

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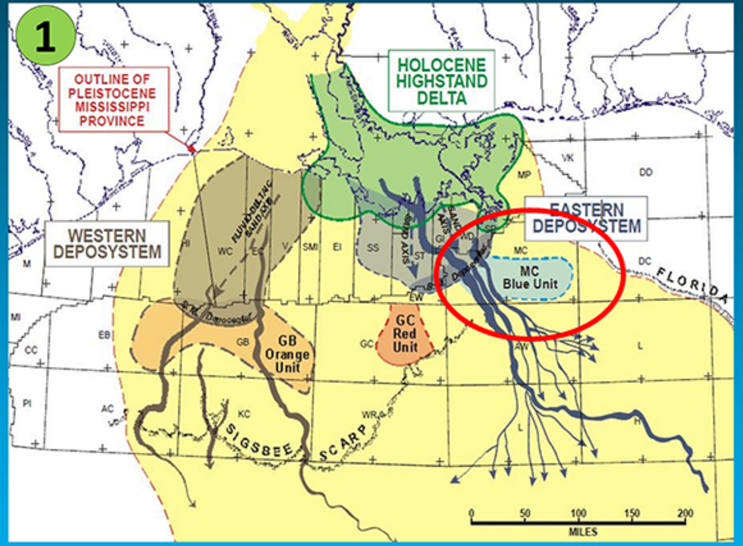


FIGURE 1. Pleistocene Mississippi River depositional provinces (Winker and Booth, 2000).

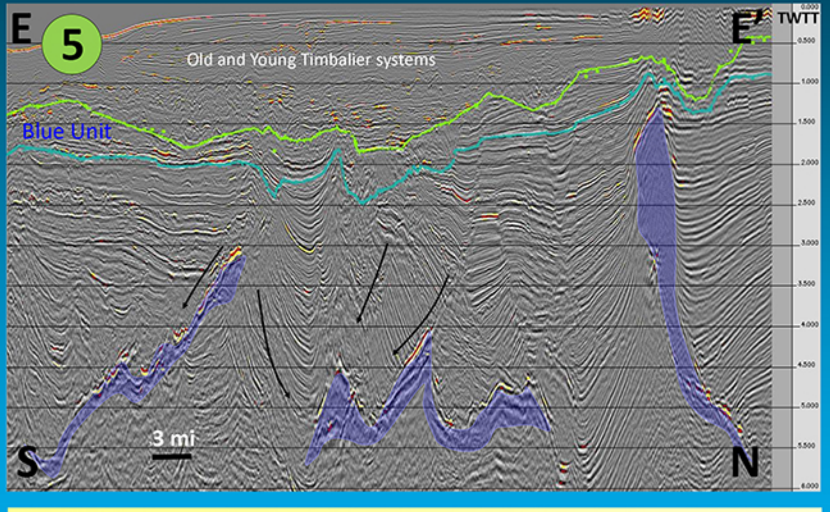


FIGURE 5. Seismic cross section along E-E' showing hypothesized shelf-margin collapse. Evacuation and weld-out of salt appears to have formed a pathway for sediment to pour into the basin and onto salt canopy. Sea level fall of ~400 ft (~120 m) (Donahgue, 2012) during MIS 4 may also have contributed to destabilization of ~20 mi of shelf margin. The collapsed margin furnished a preferential pathway for Blue Unit and the younger Timbalier Canyon systems. Because the collapse influenced Blue Unit deposition we tend to think this slope failure is older than 25 kya, having taken place during the MIS 3 lowstand (~60-25 kya) (Proprietary data courtesy of TGS).

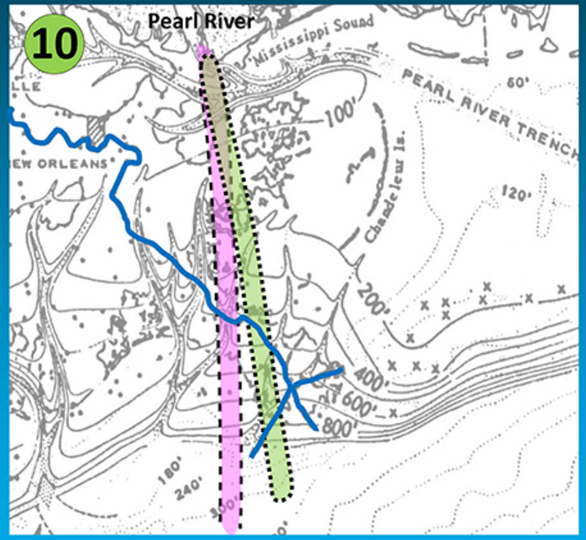


FIGURE 10. The Pearl River Canyon as interpreted by Mobley (2005; Figure 51) (fucia; dashed) overlying the paleodrainage of Fisk and McFarlan (1955; Figure 4). Mobley inferred a north-south trend for the canyon that is corroborated by Frazier's (1974) identification of "Pearl River Trench" on trend (see Figures 8 and 9). We interpret the Pearl River Canyon trend line to be south-southeast based on the seismic connection to the mapped canyon system (green; dotted) (see also Figure 12).

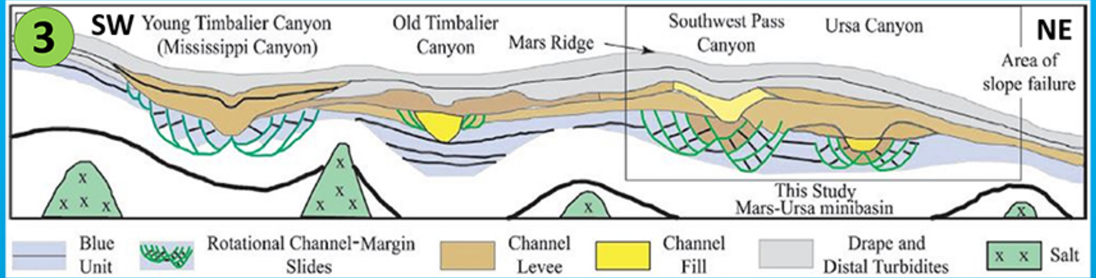


FIGURE 3. NE-SW strikeline cartoon across the southwestern part of Mississippi Canyon Area. Inspection of seismic data through the area shows that this cross section is approximately 30 mi long (from Sawyer et al., 2007; Figure 2).

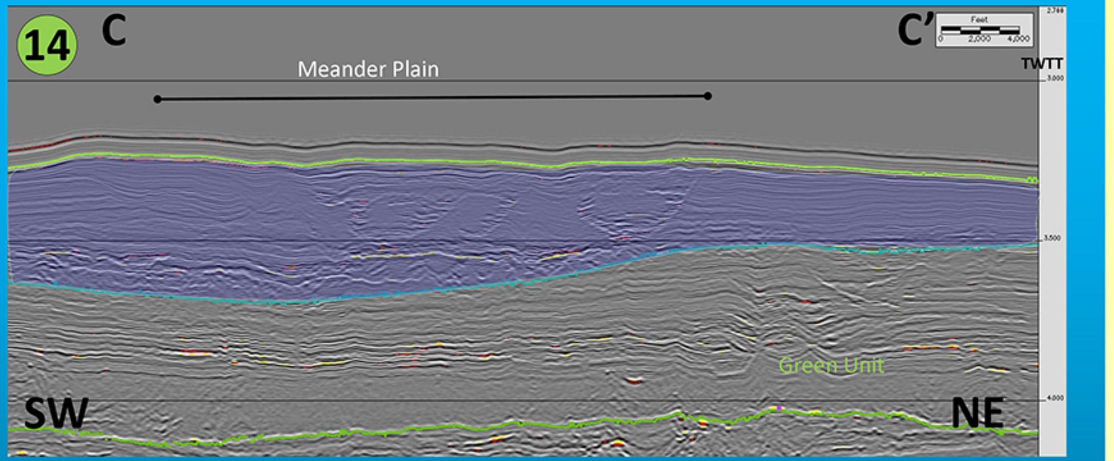


FIGURE 14. NE-SW cross section C-C' through of the Pearl River Canyon middle fan showing deep-cut channels on the meander plain ~6 mi wide (Proprietary data courtesy of TGS).

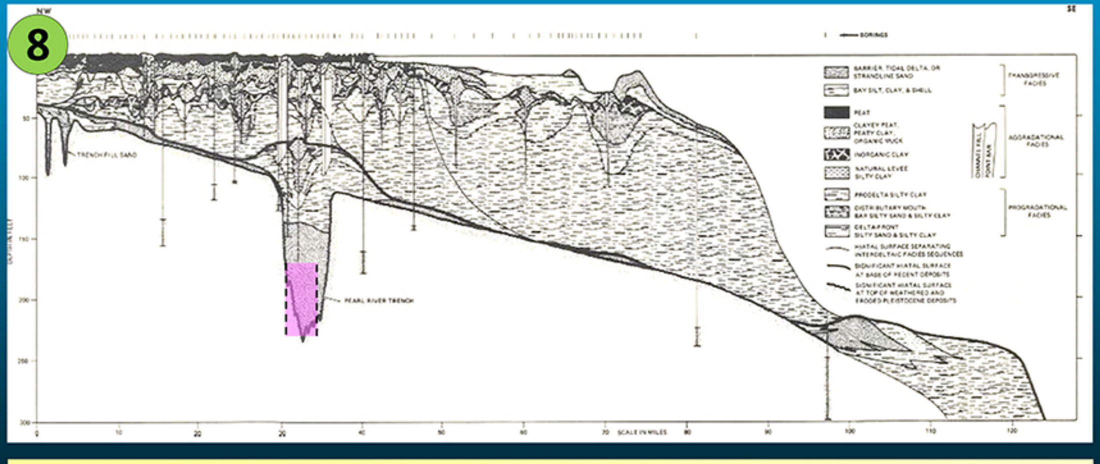


FIGURE 8. Frazier's (1974; Figure 5) cross section across the St. Bernard delta lobe showing the position of the "Pearl River Trench." The depth of incision into the Pleistocene shelf is shown to be ~150 ft deep and ~5 mi wide at this point updip.

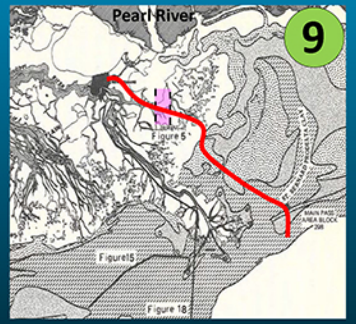


FIGURE 9. The location of "Pearl River Trench" (fucia) along cross section in Frazier (1974; Figure 12) (red).

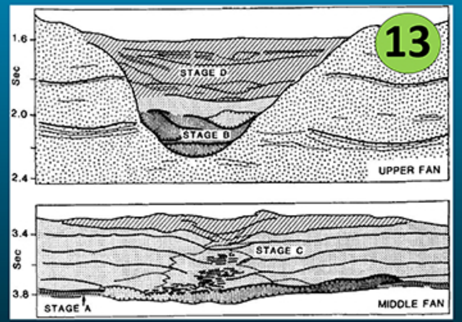


FIGURE 13. Cross sections defining the upper and middle fan as defined by Bouma et al. (1989) for younger Mississippi Canyon. It is also applicable to the Pearl River Canyon system. Compare with Figures 11 and 14.

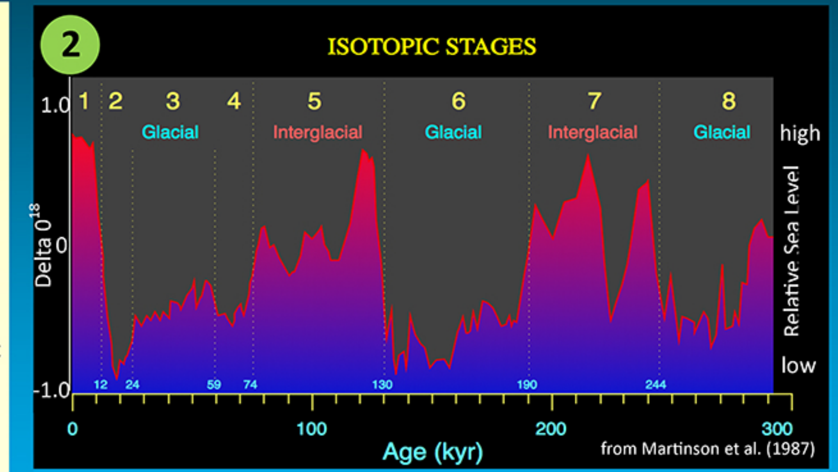
Introduction and Results

The Pearl River Canyon, its down slope fan, and the shallow hazard mapper's "Blue Unit" (Winker and Booth, 2000) (Figure 1) were all deposited during the same genetic event; the sea level fall of ~120 m (~400 ft) (Donoghue, 2011) during the Wisconsin Glaciation (Marine Isotope Stage 4; ~74 kya) (Figure 2). The Blue Unit (likely originating from a mapper's workstation horizon color) can be mapped below younger canyon systems (Ursa Canyon, Southwest Pass Canyon, Old and Young Timbalier Canyons, and the modern Mississippi Canyon) (Sawyer et al., 2007) (Figure 3). The Blue Unit interval, primarily the upper backfill facies, has been the source of many shallow water flows reported by operators in Mississippi Canyon (MC) (BOEM, 2016). The Blue Unit is a challenge to map in any regional context because it was deposited on a terrane of moving salt and it was subject to truncation by one or more younger channel systems. Instability of the substrate, high sedimentation rate, and repetitive slope failure deposits created an ideal situation to preserve buried compartments of anomalously high pressure that could lead to well control issues.

Workers have reported the Blue Unit as "deformed" (Sawyer et al., 2007) and for most of its lateral extent its depositional style is relatively unorganized or chaotic (Figure 4). Winker and Stancliffe (2007) call the Blue Unit a basin floor fan of the younger channel systems (Figure 3). At a large enough scale that is true, but in tracing the Blue Unit/Pearl River Canyon system laterally it is its own genetic unit with shelf margin collapse/canyon-cutting, fanlobe build out, and backfill facies. Collapse of the shelf margin (collapse facies) may have been caused by weld-out and evacuation of salt and destabilization of the margin after sea level drop (Figure 5). Throughout the MIS 3 lowstand (~59-24 kya) sediment poured through the breach onto the salt canopy depositing the Blue Unit (Figure 4) while to the east the Pearl River Canyon was cut. Mass transport deposits and more continuous reflectors suggestive of sheet sands backfilled (backfill facies) (Figure 6) the canyon system and ponded in minibasins between salt structures. Coleman et al. (1983) dated the large-scale slope failure that formed the modern Mississippi Fan at approximately 25 kya after which backfilling began as sea level rose during MIS 2 (~24-12 kya) (Figure 2). The trend of the modern Mississippi Canyon superposes the northwest-southeast fabric of the Blue Unit collapse facies (Figure 4) but occurred earlier.

The Pearl River Canyon and fanlobe (Figure 4) is a more organized system contemporaneous with the Blue Unit (Figure 7). About 30 mi east of New Orleans Frazier (1974) recognized a "Pearl River Trench" (Figures 8 and 9). Downdip Winker and Stancliffe (2007) recognized a depocenter south of Southwest Pass (Figure 4) that Mobley (2005) hypothesized was linked to the Pearl River (Figure 10). Our mapping shows this sedimentary pile to be ~2250 ft thick in this area, ~10 mi south-southeast of Southwest Pass. At A-A' (Figures 4 and 11) the Pearl River Canyon is ~1000-1500 ft deep (Figure 12). The upper fan is defined by an incised valley ~5 mi wide that trends north-south, then abruptly east-southeast (B-B') (Figures 4 and 13). The position of diapiric salt and northwest-southeast basement transfer fault-defined structural corridors (Stephens, 2009, 2013) influenced the northwest-southeast depositional pattern of the Blue Unit and Pearl River Canyon (Figure 4).

The middle fan begins where the geomorphic canyon ended and a graded profile was established. The meander plain on the middle fan (C-C') is ~7 mi wide (Figure 14) and emerges from burial by younger systems near the MC/DeSoto Canyon boundary to extend east to the toe of the Florida Escarpment; being deflected southeast by it. Distal fan facies (D-D') extend to the limit of seismic 3D coverage and is defined by a well developed channel/levee along its axis (Figure 15). Our mapping shows the clear genetic link of this system to the ancestral Pearl River. It is therefore appropriate it should bear the name.



ABSTRACT (1-16-2016)

Shallow water flow events in the central Gulf of Mexico (GOM) that have caused drilling complications define the approximate areal extent of a Late Pleistocene fan-channel sequence termed the "Blue Unit" by shallow geo-hazard interpreters in the Mississippi Canyon (MC) Area. Mapping on 3D time volumes has established that the Blue Unit can be traced throughout MC, Atwater Valley, DeSoto Canyon, and Lloyd Ridge. The Blue Unit is a low-stand system deposited during the Wisconsin glacial (marine isotope stage (MIS) 4) approximately 71 kya. It is interpreted with a lower canyon-cutting facies, and an upper sheet sand facies deposited in the channel and in ponded overbank areas formed between salt diapirs.

A deep canyon was cut in the shelf edge during the MIS 4 low stand with the knickpoint centered on the South Pass Southeast Area. The canyon trends south-southeast and was apparently diverted east-southeast by rising salt diapirs. Where the Blue Unit is present near the modern Mississippi Canyon it is less organized and dominated by mass transport deposits. Here it is also highly deformed by salt diapirism and erosional beheading by younger channel systems.

Erosion and canyon incision in northwestern MC grades eastward into a fan system deposited on the basin plain. Farther southeast in The Elbow Area of the Eastern GOM to the current limit of 3D data coverage the Blue Unit can be genetically linked to a well-organized meandering channel-levee system along the toe of the Florida Escarpment. Abandonment of the meandering system resulted from sea level rise at MIS 2 (29 kya) and updip channel avulsion that diverted sediment to create younger channel-fan complexes to the southwest, most notable of which is the modern Mississippi Fan.

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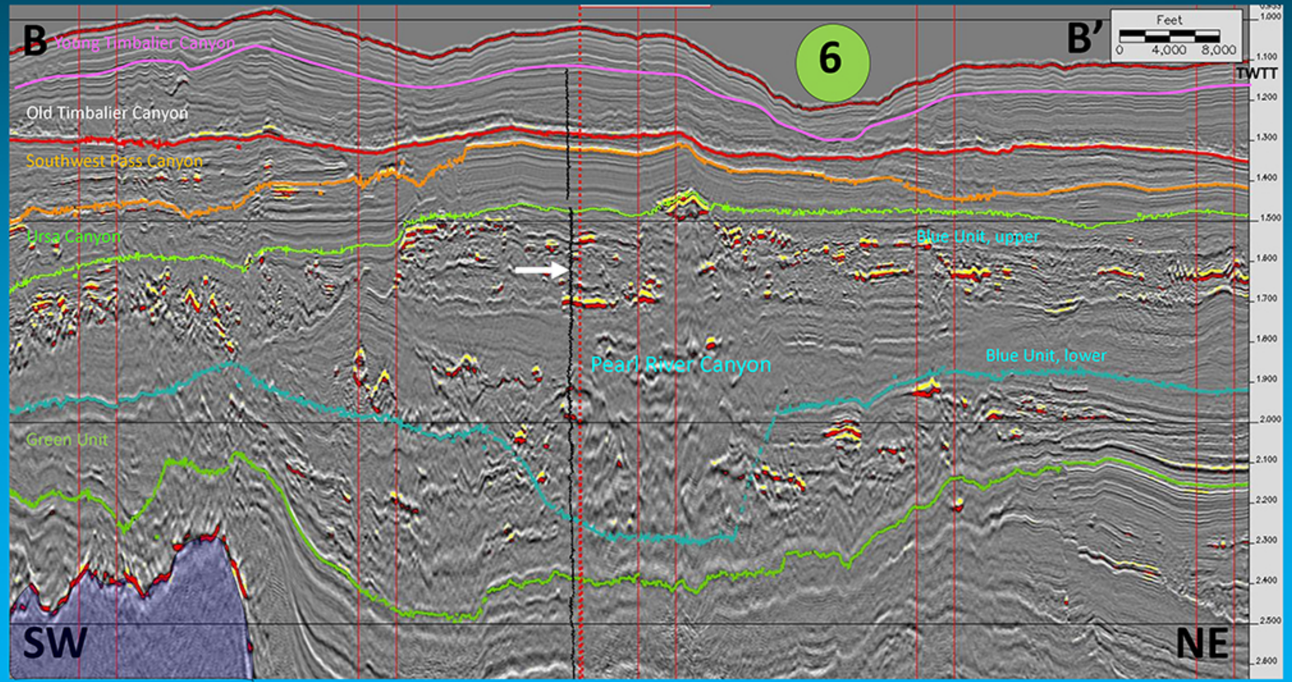


FIGURE 6. Cross section B-B' through the Pearl River Canyon. Younger channel systems include Ursa Canyon, Southwest Pass Canyon, Old and Young Timbalier (Sawyer et al., 2007; Figure 2) (see Figure 3). Well 002 in MC546 reported a flow incident at 1712 ft below mudline in the upper backfill facies of the Blue Unit (white arrow). Most shallow hazards reports for exploration programs show laterally small seismic windows for well top-hole prognoses. In many of these, if analysts identify the Blue Unit, it is typically the backfill facies that is usually distinct with seismic "chatter" and bright spots, or laterally continuous sheet-like reflectors. Red vertical lines = OCS blocks (Proprietary data courtesy of TGS).

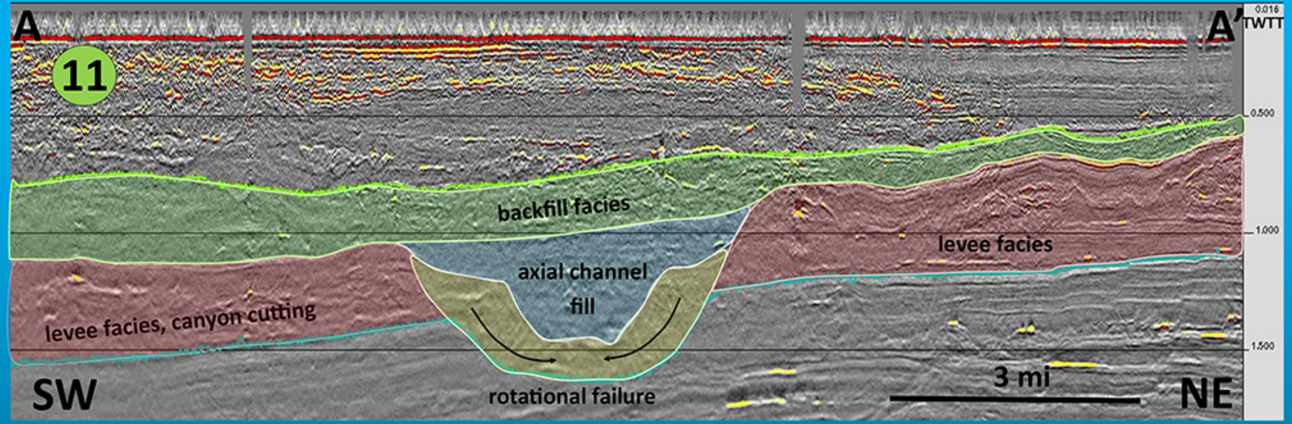
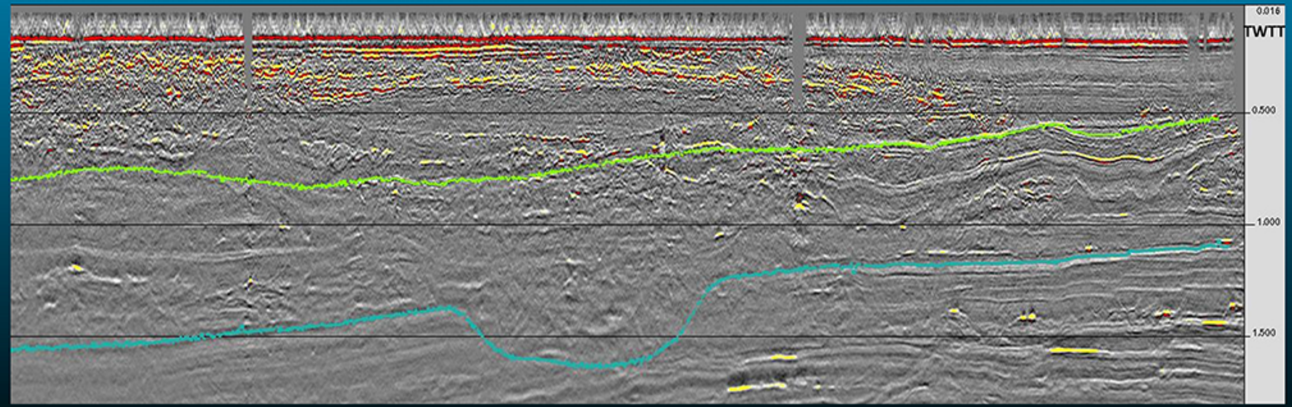


FIGURE 11. (Above) Updip cross section of Pearl River Canyon along B-B' with interpreted facies. (Below) Uninterpreted, except for seismic picks. The canyon mapped in time shows ~1000 ft of incision (based on the relationship 2.5 x thickness (ms) = ft thickness) between thalweg and the top of the levee complex or the base of the backfill facies (Proprietary data courtesy of WesternGeco/Schlumberger).



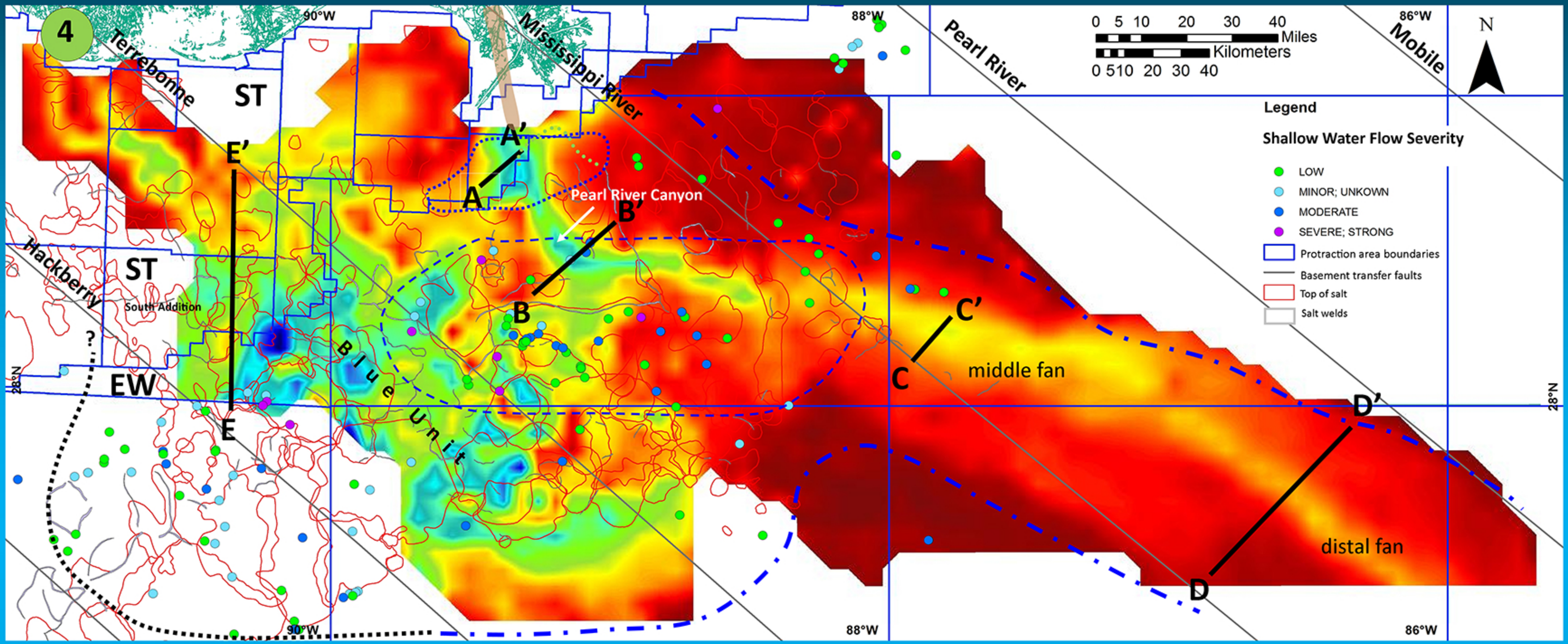


FIGURE 4. Isochron of the Blue Unit and Pearl River Canyon/fanlobe system (warm colors are thin and cool colors are thick). Blue dashed line is the depositional limit of the Blue unit as first defined by Winker and Booth (2000). Blue dot-dash-dot line is our revised approximate depositional limit of the Blue Unit/Pearl River Canyon. Blue dotted line is the depositional thick recognized by Winker and Stancliffe (2007). Green dotted line is the shelf edge separation scar mapped by Coleman et al. (1983). Dots are well locations with reported shallow water flow events identified according to their severity (BOEM, 2016). Black dotted line is the speculative lateral westward extent of the Blue Unit. A number of observations can be made. A deposystem south –southeast of modern Southwest Pass can be reliably linked updip to the ancestral Pearl River (A-A') (see Figures 10 and 12). The Pearl River Canyon (B-B') incised the shelf margin, avoiding salt structures down the path of least resistance, and built an organized fanlobe system far out onto the basin plain. Cross sections at C-C' and D-D' show facies of the middle and distal fan. West of the Pearl River Canyon in South Timbalier (ST) and Ewing Bank (EW) 3D seismic data shows collapse of the shelf margin (E-E') through which unorganized systems and mass transport movements disgorged sediment onto the very unstable salt canopy and into ponded minibasins (the Blue Unit). The southeast-northwest fabric of Blue Unit development and the Pearl River Canyon fanlobe shows a suggestive conformance to the basement transfer fault systems recognized by Stephens (2009; and others cited therein) that provided accommodation space (Proprietary data courtesy of TGS, WesternGeco/Schlumberger, Spectrum USA, PGS, and FairfieldNodal).

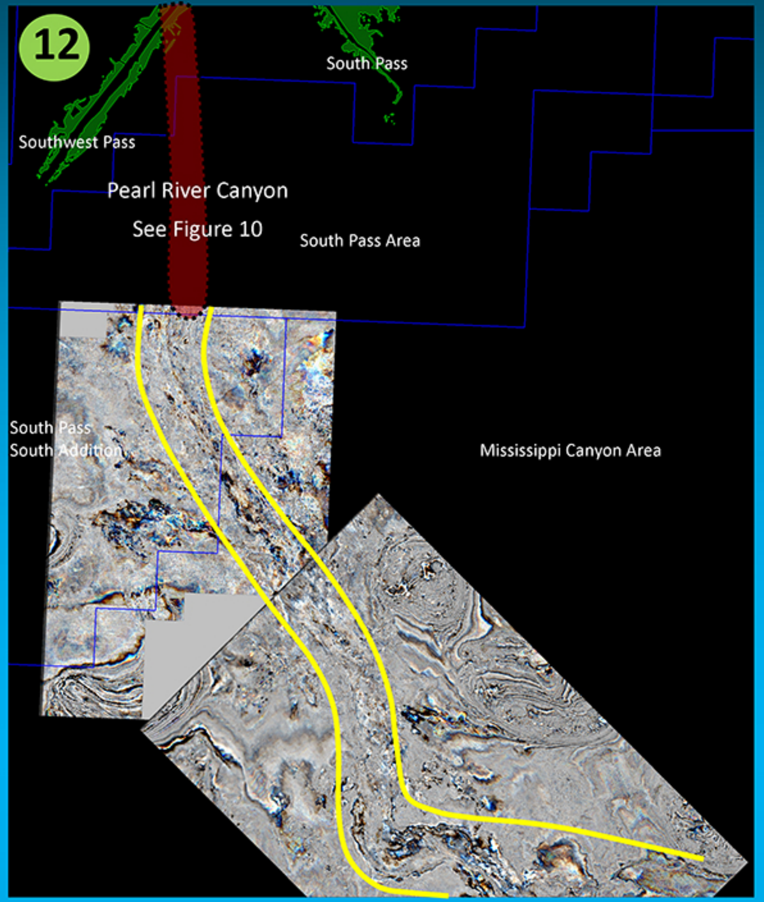


FIGURE 12. Two seismic time slices showing the thalweg of the Pearl River Canyon (Proprietary data courtesy of WesternGeco/Schlumberger and TGS).

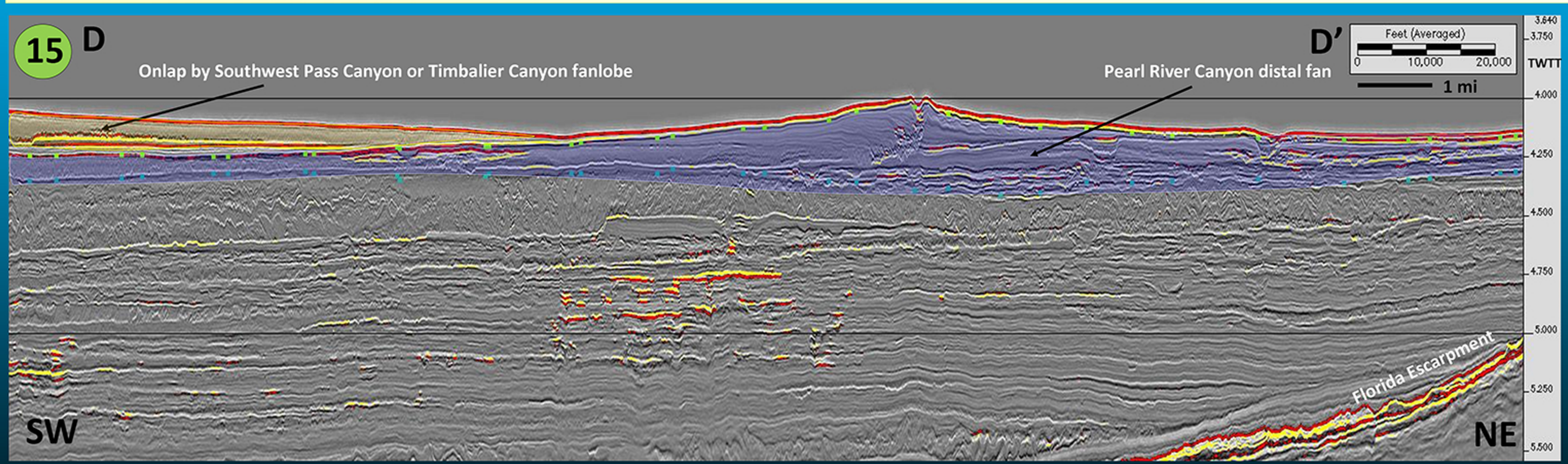


FIGURE 15. Seismic cross section along D-D' showing distal facies of the Pearl River Canyon fanlobe. The lobe geomorphology is well developed with an entrenched meandering channel. To the southwest is a fanlobe from the Southwest Pass Canyon or Timbalier Canyon system lapping onto the Pearl River Canyon fanlobe. This younger fanlobe eventually overrides and partially buries the Pearl River Canyon system farther southeast (Proprietary data courtesy of Spectrum USA).

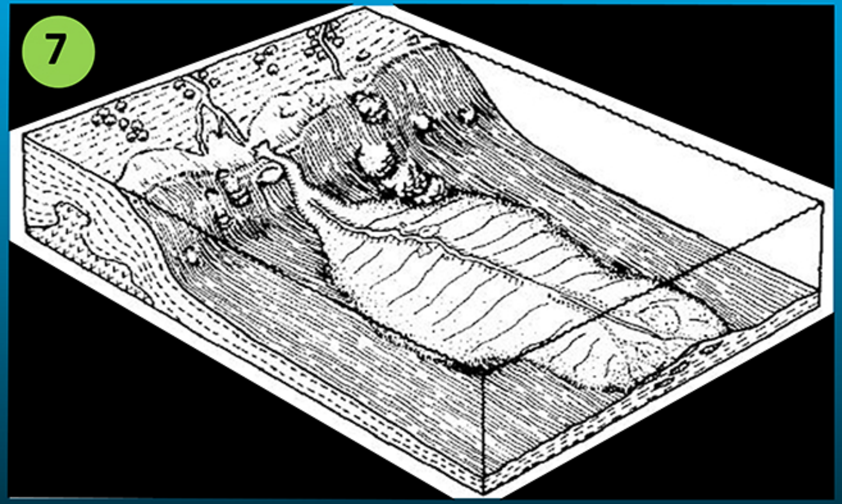


FIGURE 7. Block diagram showing updip canyon-cutting during lowstand and down dip deposition of an organized fanlobe system (Bouma et al., 1989). The use of "fanlobe" in reference to the Pearl River Canyon system is adopted from Bouma et al. because it was their description of the younger systems forming the modern Mississippi Fan beginning ≥25 kya (Coleman et al., 1983).