



# Geomorphic Evolution of Paleogene Yoakum Canyon in Northern Gulf of Mexico: Relationship with Coeval Wilcox Deltas and Implications for Basin Floor Fans

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## ABSTRACT

The Yoakum Canyon of the Gulf Coast Paleocene section is a shelf- and slope-incising canyon that was active during late Lower Wilcox and Middle Wilcox time. It is situated between two large sedimentary depocenters, the Colorado Delta to the east and the Guadalupe Delta to the west. The present-day subsurface expression of the canyon shows a V-shaped cross-sectional profile with a width of about 16 km, shelf indentation exceeding 100 km, and incision of the shelf to a depth of 1 km. High sediment supply during the late Paleocene promoted significant progradation of the earliest Lower Wilcox A deltas. Sustained progradation advanced the Lower Wilcox B deltas to the shelf edge. The delivery system remained docked near the shelf break, and wave-dominated deltas developed in growth faulted compartments during this time. Shelf edge loading resulted in slumping and sediment failure, followed by headward erosion and development of the canyon. During the late Lower Wilcox, the shelf was flooded, and C deltas in Colorado and Guadalupe depocenters built on the inner and middle shelf. Extensive shore-zone systems and a predominantly muddy shelf and upper slope were developed during Middle Wilcox time. The canyon excavation did not significantly contribute to the growth of submarine fans; however, the canyon acted as a conduit for sediment bypass during the late Lower Wilcox and Middle Wilcox times, when shelf depocenters were relatively small. The volume of sediments (330 km<sup>3</sup>) in the Yoakum Canyon represents about 1% of the volume of AlKeWa fan in the deepwater Gulf. It is inferred that the remaining 99% was transferred via longshore drift from adjacent Colorado deltas into the head of the canyon. The bulk of the canyon fill consists of muddy sediments with isolated sandstone bodies, as indicated by wireline-log patterns. Towards the end of the Middle Wilcox, the canyon was infilled by deltaic and shoreface sandstone bodies.

## INTRODUCTION

Submarine canyons along continental margins have received increased attention since the 1950s, a period marked by improvements in ocean survey methods (Kuehl et al., 1986). Recently, the use of global bathymetry mapping revealed thousands of continental slope canyons (Harris and Whiteway, 2011). Canyons form by submarine erosion caused by sediment density currents triggered on the outer shelf and upper slope (Pratson and Coakley, 1996; Puig et al., 2014). Erosive density currents can be caused by variations in temperature and salinity of suspended sediment (Canals et al., 2006, 2013). The morphology of canyons

is different compared to fluvial valleys (Dobbs et al., 2019), with canyons being, in general, deeper and wider (width to depth ratios of 10 to 100), especially the canyons that incise significant distances into the shelf (Sweet and Blum, 2011). The concept of incised valleys as sedimentary “conveyor belts” rather than significant sources of sediments was discussed by Blum and Tornqvist (2000). The model they proposed was based on estimating the sediment flux carried by the river during relative sea-level fall versus the sediment volume excavated from the valley incisions. Their calculations showed that incised valleys typically produced less than 10% of the total sediment volume delivered to the deepsea fans during lowstand. By analogy, the volume of a submarine canyon is just a fraction of the sediment volume that forms the basin floor fans, indicating the bypass nature of the canyon (Fisher et al., 2021).

The Yoakum Canyon of the Wilcox Group was first documented by Hoyt (1959). Subsequent drilling led to the discovery of hydrocarbons in the canyon, followed by focused exploration efforts, including the acquisition of more extensive well and seismic data (White et al., 2019). While the existence of the Yoakum

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Canyon has previously been documented by wireline-log correlations (Chuber and Begeman, 1982; Galloway and McGilveray, 1995) and low-resolution 2D seismic data (White et al., 2019), in this paper we explain how the Yoakum Canyon has been formed and its relationship with adjacent deltas using high-resolution 4th-order stratigraphic interpretations.

### GEOLOGIC SETTING

The Wilcox Group is a thick succession of about 3000 m of clastic sediments, deposited along the northern margin of the Gulf of Mexico Basin during the Early Paleogene (Galloway et al., 2000) over an interval of about 12 Myr (Fig. 1). Late Paleocene–early Eocene paleogeography of the Wilcox Group in Texas was characterized by widespread regressive-transgressive shoreline movements (Fig. 1) that repeated every few million years (Fisher and McGowen, 1967; Galloway et al., 2000; Crabaugh, 2001; Hargis, 2009). Reconstructions of Paleogene Gulf of Mexico drainage areas (Winker, 1982; Galloway et al., 2000; Galloway, 2008) and detrital zircon-based provenance

studies (Mackey et al., 2012) suggest that large fluvial systems, with headwaters in the Laramide Rocky Mountains, were responsible for the Wilcox depocenters of the Texas Coastal Plain and shelf. The shelf segment is primarily characterized by fluvial, deltaic, and shallow marine environments (Fisher and McGowen, 1967).

Onshore the Lower Wilcox Group was deposited along seven depocenters within the Rockdale Delta system (Fisher and McGowen, 1967) in the Houston Embayment (Fig. 2A). Each one of these depocenters incorporates three major units: Delta A (between Midway Shale and Top A), Delta B (from Dull Shale to Top A) and Delta C (from Big Shale to Dull Shale) (Fig. 1) each one lasting about 1 Myr (Chuber, 1987; Crabaugh, 2001; Hargis, 2009).

Xue and Galloway (1995) identified two sequences, A (older) and B (younger), separated by the Webb Shale in the Middle Wilcox (Fig. 2B). After a major transgression associated with Big Shale, the wave-dominated LaSalle Delta complex prograded into the northwest Gulf Basin along the Rio Grande axis and in the central Gulf, and the fluvial-dominated Calvert Delta

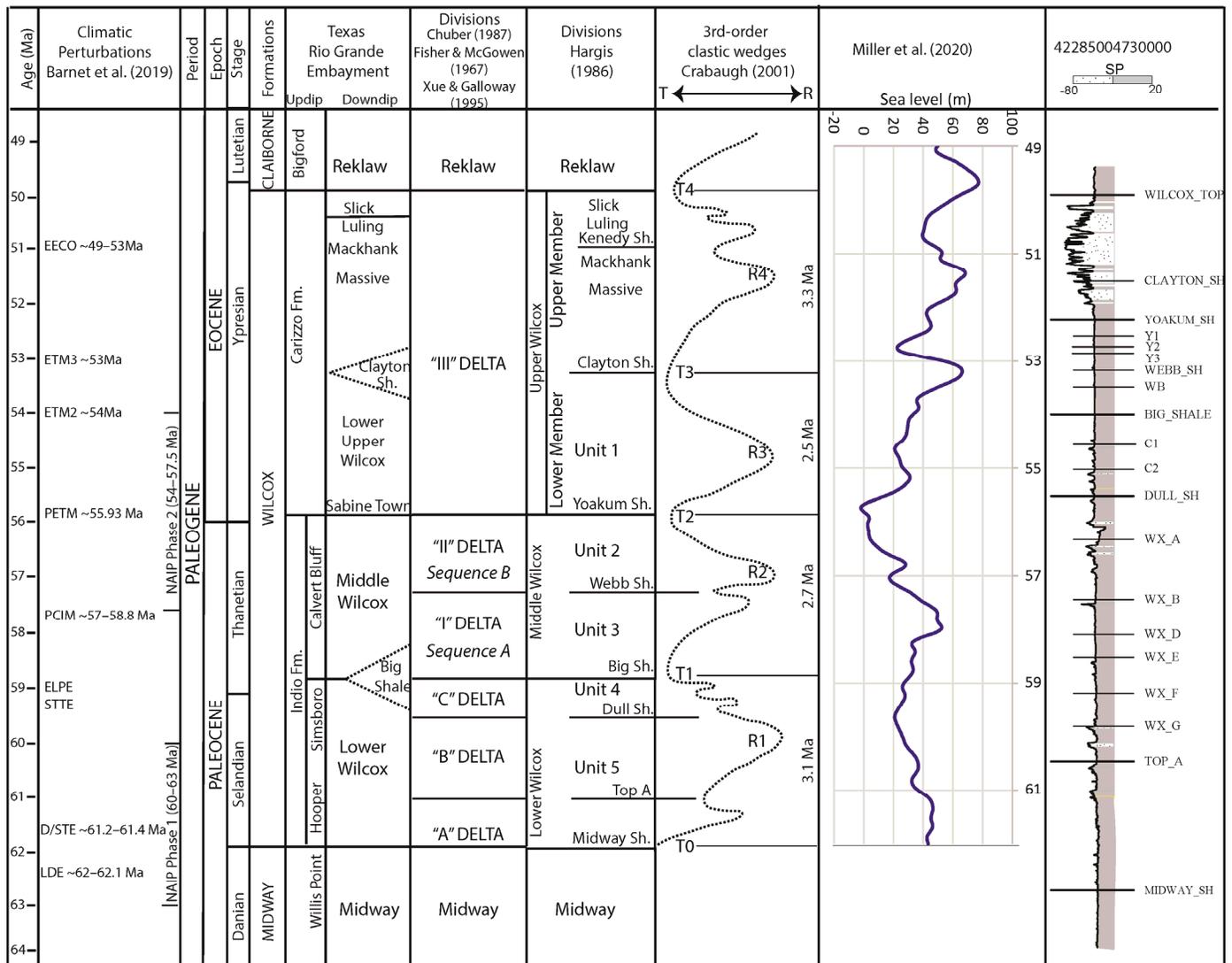
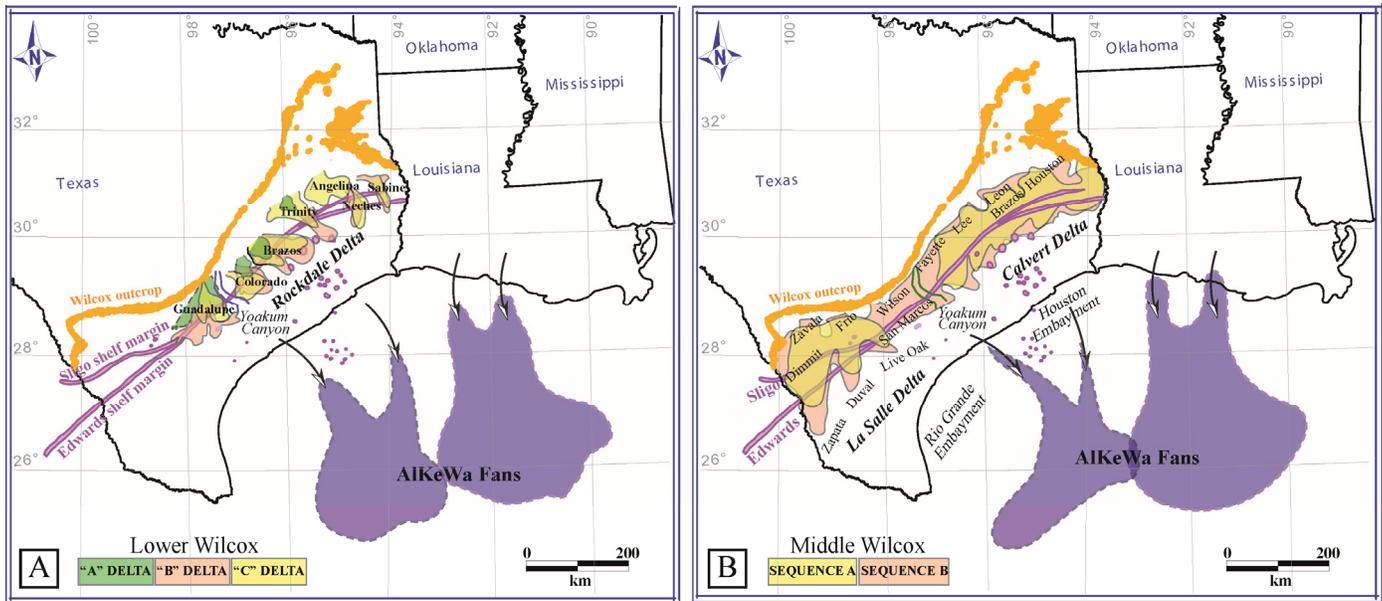


Figure 1. Correlation chart showing lithostratigraphic divisions of the Wilcox Group in Texas (LDE = Latest Danian Event; D/STE = Danian/Selandian Transition Event; STTE = Selandian-Thanelian Transition Event; ELPE = Early Late Paleocene Event; PCIM = Paleocene Carbon Isotope Maximum; ETM = Eocene Thermal Maximum; EEOCO = Early Eocene Climatic Optimum; and NAIP = North Atlantic Igneous Province).



**Figure 2.** Paleogeographic maps depicting paleoshoreline positions, distribution of principal deltas and deepwater fans (modified from [Snedden and Galloway \[2019\]](#)) (A) Lower Wilcox Rockdale Delta System (modified after [Fisher and McGowen \[1967\]](#)) and (B) Middle Wilcox Calvert and La Salle delta systems (modified after [Xue and Galloway \[1995\]](#)). Cretaceous carbonate shelf margins (Sligo and Edwards) and salt domes are shown in purple.

complex locally built to the shelf margin ([Fig. 2B](#)). Extensive shore-zone systems flank the deltas and downdip a predominantly muddy shelf and upper slope developed ([Xue and Galloway, 1995](#)).

Shelf-dissecting submarine canyons occur in various locations and were active for various periods throughout Wilcox time ([Clayton and Olariu, 2022](#)). These canyons, likely controlled by the tectonic fabric (incisions align with active uplifts) of the northern Gulf of Mexico, are key features within the source-to-sink sediment dispersal system and provide one of the main conduits for sediment bypass to the deepwater environment.

The Yoakum channel of the Gulf Coast Paleocene section is the largest and best-known Wilcox canyon. It is more than 16 km wide, 96 km long, and contains over 1000 m of fill, with a calculated volume exceeding 300 km<sup>3</sup> ([Vormelker, 1979](#); [Dingus and Galloway, 1990](#)). After retrogradational failure, the Yoakum matured into a canyon system that incised the shelf for tens of kilometers, tapped littoral and riverine sources, and developed major deep-basin-floor fans ([Fisher et al., 2021](#)). Wilcox deepwater deposits are extensive ([Meyer et al., 2007](#)), with an estimated areal extent of more than 104,000 km<sup>2</sup>. The deposits are up to 500 m thick, and very sandy, with sand-to-shale ratios of 40–70%, and a paucity of thick interbedded shales ([Sweet and Blum, 2011](#)). Deep-water facies observed in the core ([Lewis et al., 2007](#)) consist of turbidites and debrites deposited in basin-floor fans fed by slope canyons ([Galloway et al., 1991](#); [McDonnell et al., 2008](#)).

## METHODOLOGY

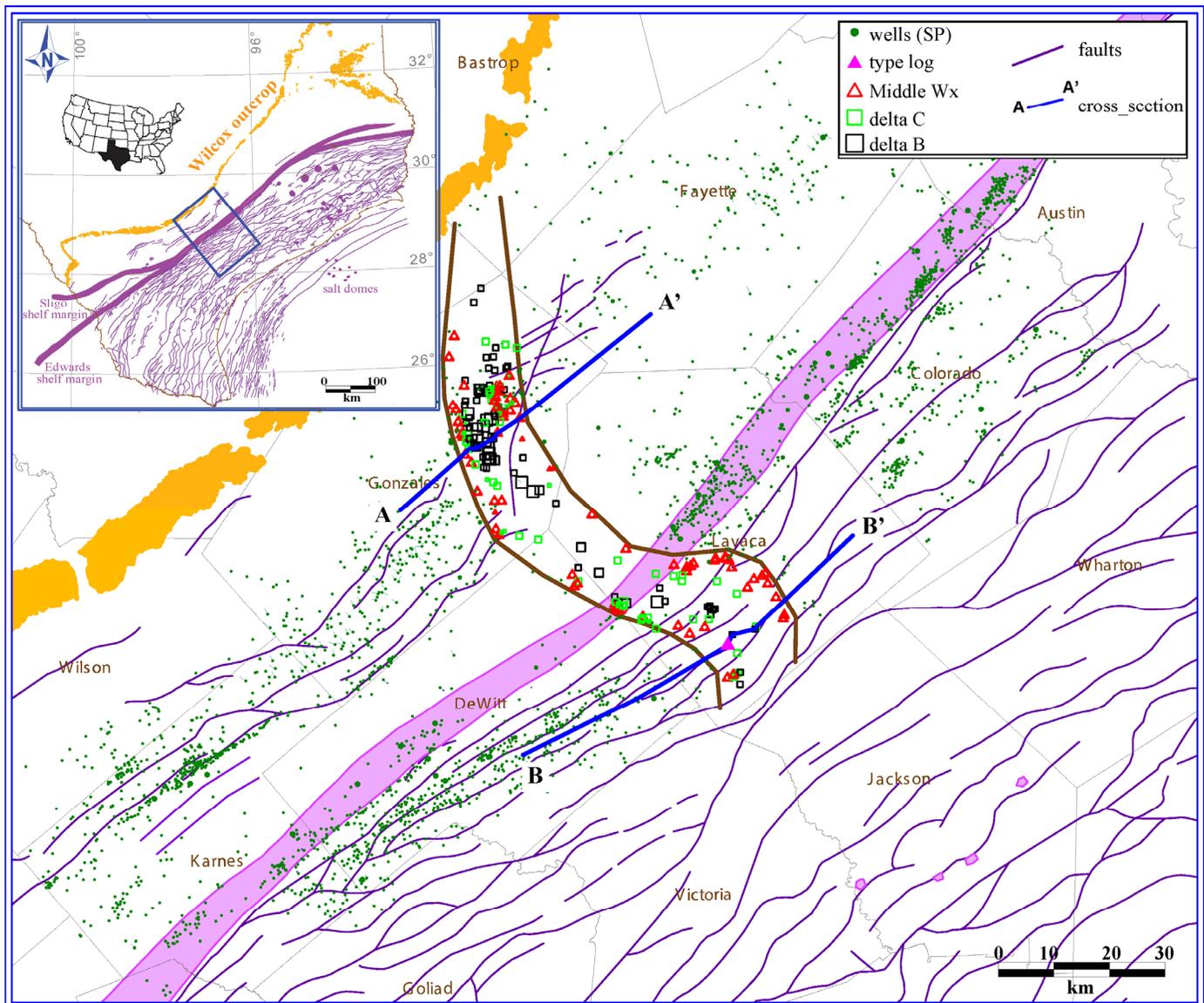
This study used about 700 wells ([Fig. 3](#)) with wireline-log curves that helped interpret subsurface lithologies such as sandstone and mudstone. Spontaneous potential (SP) wireline-log measurements were normalized by rescaling all curves, either by stretching or squeezing them to correspond to a type SP curve (-80 to +20 MV). A cutoff value of -20 MV was used to differentiate sandstone from mudstone. The normalized curves enabled the correlation of sandy intervals (SP values between -80 and -20 mV), allowing improved stratigraphic interpretation and mapping

of sandstone bodies to depict depositional environments. The computation of sandstone thickness between the surfaces of interest was achieved using Petra™ software and involved creating a grid for the study area using the least squares method. The genetic sequence approach of [Galloway \(1989\)](#) was considered for the subsurface regional correlation since mud-dominated intervals formed during high-frequency marine transgressions are easily detectable on SP logs (high values). Fourth-order regressive units (upward-coarsening log motifs) and intervals of shoreline transgression (upward-fining units) were recognized in each well log ([Fig. 4](#)) in the deltaic depocenters flanking the canyon. Inside the canyon, correlations were difficult because the infill is primarily composed of mudstone with discontinuous sandstone layers. Submarine canyons are dynamic environments shaped by complex processes, like erosion and sediment transport ([Chuber and Beggeman, 1982](#); [Galloway and McGilvery, 1995](#)). Therefore, various 4th-order cycles are inferred by extending correlation lines from adjacent deltas.

## RESULTS

### Subsurface Well Log Correlations

Wireline-log patterns indicate that the Yoakum Canyon is filled with shale and isolated sandstone bodies ([Fig. 4](#)). The sandstones are a few meters thick and are interpreted to be channel deposits. Two strike cross sections, one updip ([Fig. 4A](#)) and one downdip ([Fig. 4B](#)), show the present-day subsurface expression of the canyon cutting through late Paleocene Lower Wilcox and Middle Wilcox strata. Outside the canyon walls in the proximal setting, there are multiple 4th-order sandstone-rich, upward-coarsening, and upward-fining units. Downdip the sections become muddier, recording deposition of finer-grained sediments in the more distal parts of the deltas. The top of the canyon is marked by the Yoakum Shale, which marks a marine transgression at the end of Middle Wilcox time. The base of the canyon goes as deep as the top of Delta A. The upper part of the Middle Wilcox shows sand-rich, upward-coarsening successions.



**Figure 3.** Location map of the study area. Subsurface control consisted of about 700 wireline logs (SP). Oblique strike-oriented cross sections, (A) updip and (B) downdip, are indicated in blue. The inset shows closely spaced NE–SW normal faults (purple) oriented parallel to the depositional strike and to the present-day coastline. The canyon cut through Lower Wilcox B and C deltas and Middle Wilcox strata.

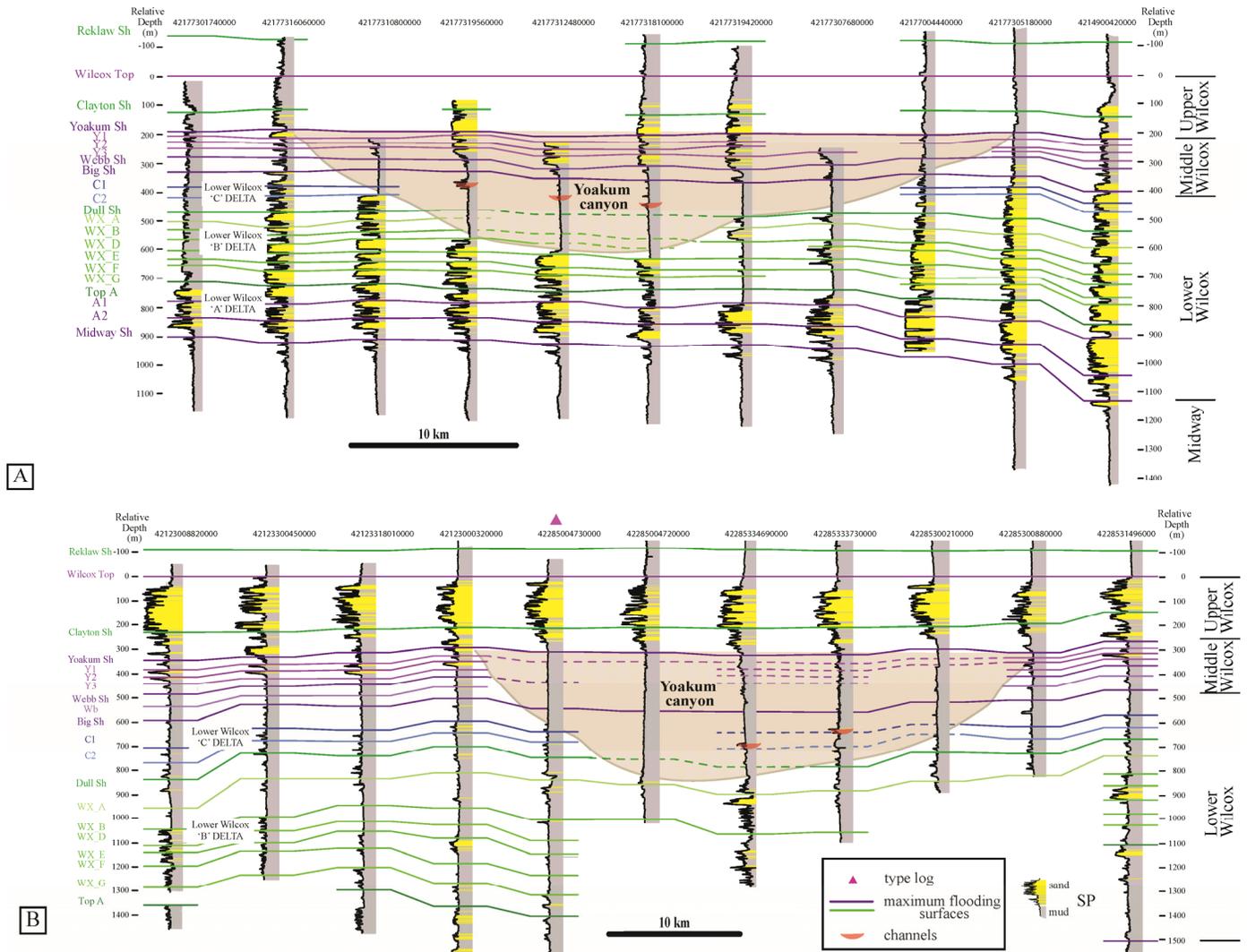
### Net Sandstone Maps—3rd–Order Cycles

The Yoakum Canyon trends northwest-southeast and is situated between two large delta systems, the Guadalupe to the west and the Colorado to the east (Fig. 5). During earliest Lower Wilcox deposition, the sediments reached about 300 m in thickness with a maximum of 160 m of sandstone (mean, 51 m) in Guadalupe A and Colorado A depocenters (Fig. 5A). During this time the deltas reach a great areal extent and the canyon is not yet formed (Fig. 4). This is also illustrated in Figure 5A by the presence of thick sandstone depocenters where the canyon would have been (see Olariu [2023] for maps of 4th-order cycles during Delta A). The sandstones in the B deltas reached a maximum thickness of 300 m (mean, 114 m) (Fig. 5B). There were multiple 4th-order cycles forming deltaic depocenters at the shelf edge during this time (Olariu, 2015). During the deposition of the C deltas (Fig. 5C), sandstone deposits reached a maximum thickness of 125 m (mean, 36 m); smaller

depocenters developed in the San Antonio and Guadalupe deltas, west of the canyon. During Middle Wilcox time (2.7 Ma), deposition mostly occurred east of the Yoakum Canyon in the Colorado depocenter (Fig. 5D). There is some deposition west of the canyon in strike-elongated sandstone belts with a maximum thickness of sandstone of 65 m (mean, 13 m). The shape and size of the canyon differed during each 3rd-order cycle (Fig. 5), recording the present-day morphology of the canyon in the subsurface.

### Net Sandstone Maps—4th–Order Cycles

Well-based sandstone thickness maps for 4th-order transgressive-regressive sedimentary cycles depict depositional environments of the San Antonio, Guadalupe, and Colorado C deltas (Fig. 6). The maps show different architectures for individual depocenters and the approximate position of the contemporaneous shoreline and the Yoakum Canyon.



**Figure 4. Stratigraphic cross-sections through the Wilcox Group. Spontaneous potential (SP) curves are used for correlations. Maximum flooding surfaces (green, purple) separate 4th-order cycles (for location see Figure 3). (A) Updip strike-oriented cross-section (flattened at the top of Wilcox). (B) Downdip strike-oriented cross-section (flattened at the top of the Wilcox).**

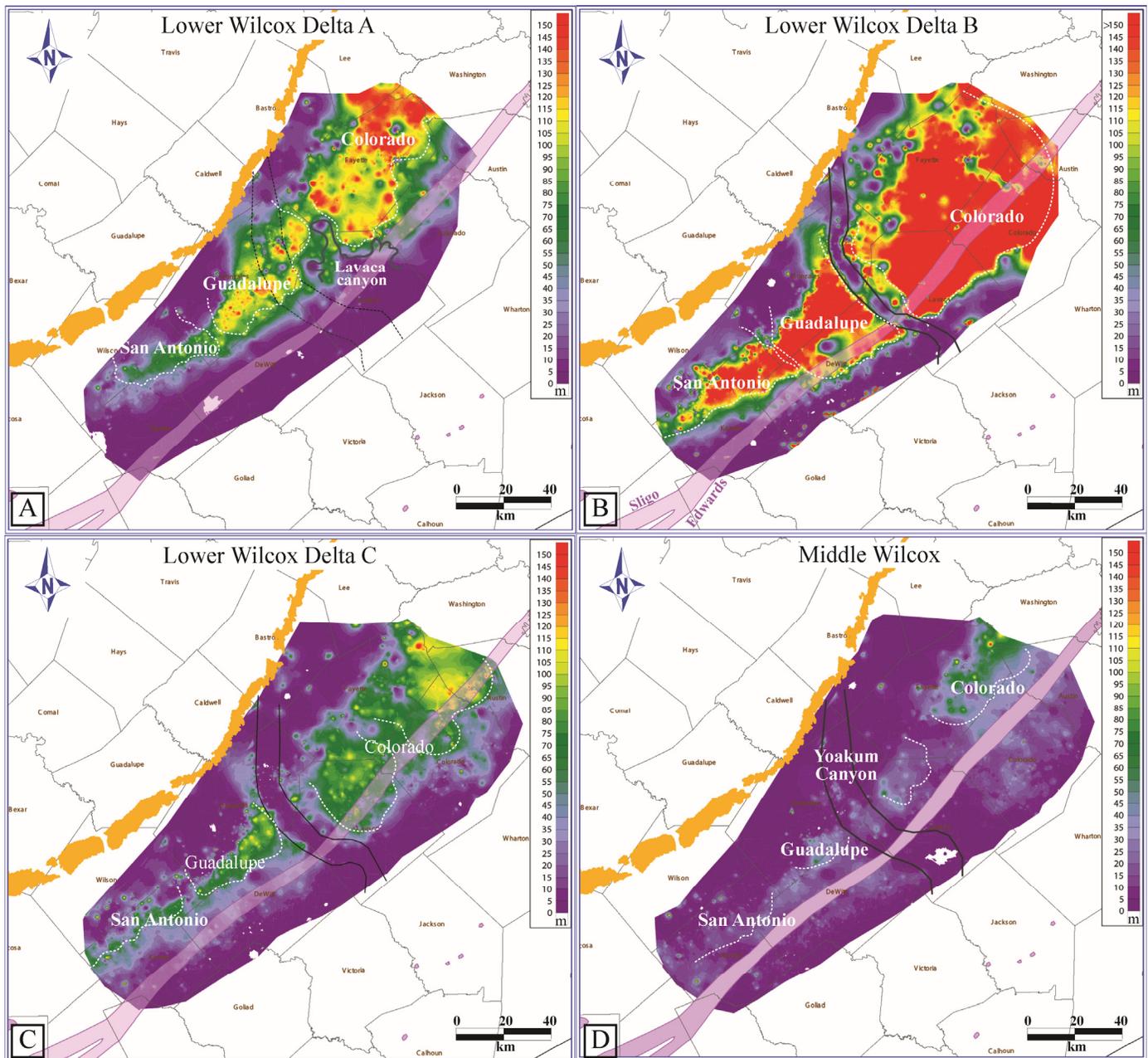
The Lower Wilcox C Delta (~1 Ma) has been divided into three 4th-order cycles (Fig. 6A–6C). The oldest C deltas, above the Dull Shale (Fig. 6A), have larger depocenters with mean sandstone thicknesses of about 10 m (maximum, 40 m). The next cycle (Fig. 6B) shows a mean sandstone thickness of 5 m (maximum, 25 m). The youngest C deltas, below the Big Shale (Fig. 6C), have a mean sandstone thickness of 4 m (maximum, 20 m).

The Middle Wilcox (2.7 Ma) is divided into two major units separated by the Webb Shale (Fig. 1). There are six 4th-order cycles between the Big and Yoakum shales (Fig. 6D–6I), and deposition mainly occurred east of the Yoakum Canyon in the Colorado depocenter. The oldest Middle Wilcox interval above the Big Shale (Fig. 6D) reaches a maximum sandstone thickness of 14 m (mean, 1 m). The interval below the Webb Shale (Fig. 6E) has a maximum sandstone thickness of 8 m (mean, 1 m). The sandstone isopach map of the interval above the Webb Shale (Fig. 6F) shows a maximum thickness of 10 m (mean, 1 m). The cycle between Y2 and Y3 (Fig. 6G) reaches a maximum sandstone thickness of 13 m (mean, 2 m). The interval between Y1 and Y2 (Fig. 6I) has a maximum sandstone thickness of 14 m

(mean, 3 m). The youngest cycle below the Yoakum Shale (Fig. 6I) has a maximum sandstone thickness of 21 m (mean, 4 m). The distance between the head of the canyon and the shoreline during deposition is shown for each cycle. During the early Middle Wilcox time, Colorado deltas are roughly 44 km from the head of the Yoakum Canyon. During Lower Wilcox and late Middle Wilcox time, the deltas were closer (less than 10 km) to the head of the canyon.

## DISCUSSION

Large, deeply incised submarine canyons are common features of many ancient (Fisher et al., 2021; Clayton and Olariu, 2022) and modern (Coleman et al., 1982; Harris and Whiteway, 2011; Sweet and Blum, 2016) continental margins. Modern slope canyons, with widths exceeding 10 km, depths ranging from 600 m to more than 1000 m, and lengths greater than 100 km, are not uncommon (Somme et al., 2009). Slope canyons are thought to be initiated on the upper slope, erode headward into the shelf edge, and extend shoreward for varying distances from the shelf margin. The longer the shelf incision, the more likely the connec-

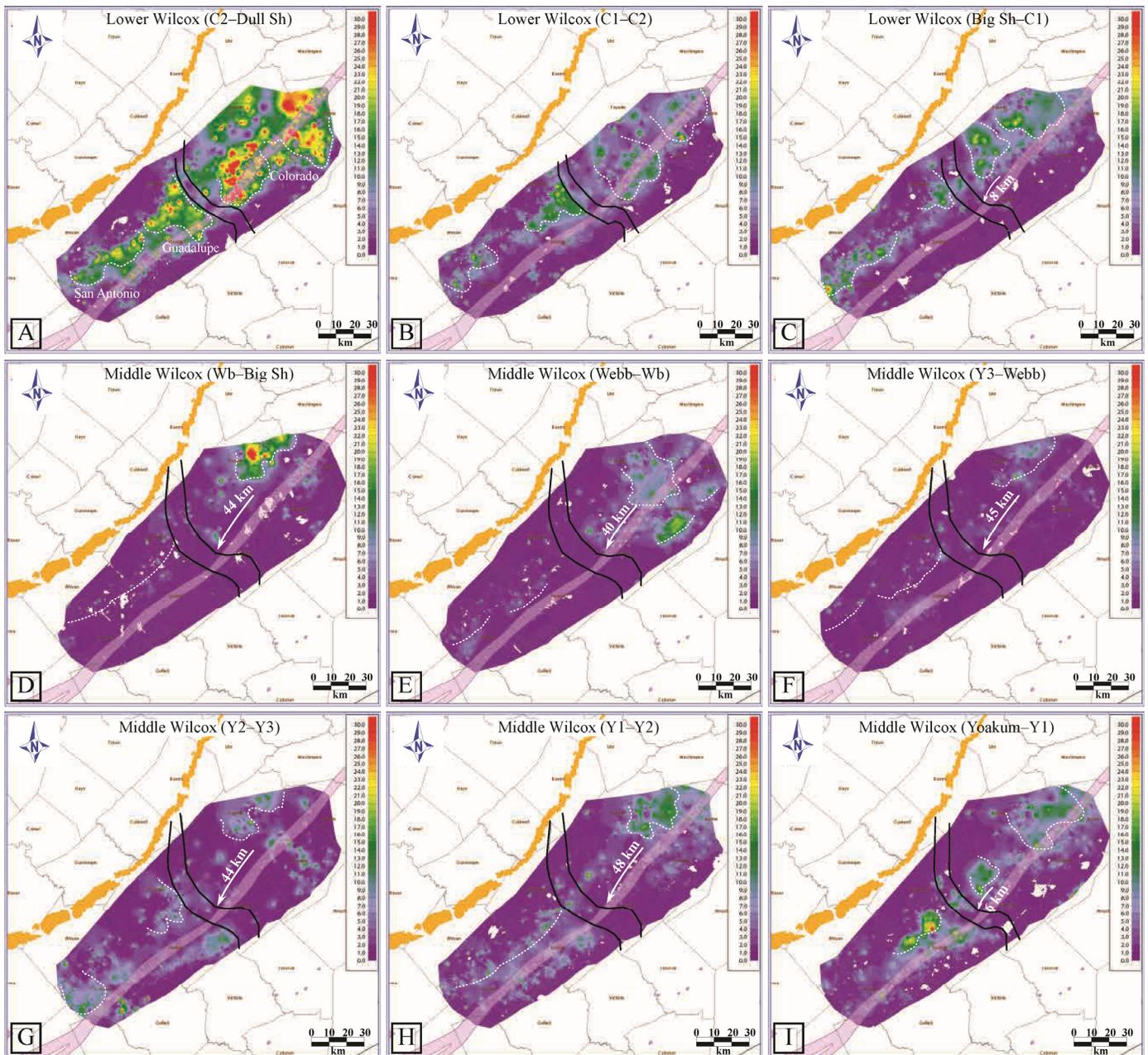


**Figure 5.** Well-based sandstone thickness maps for the Lower and Middle Wilcox. (A) Lower Wilcox Delta A (approx. 1 Myr). (B) Lower Wilcox Delta B (approx. 1 Myr). (C) Lower Wilcox Delta C (approx. 1 Myr). (D) Middle Wilcox (approx. 2.7 Myr). Main deltaic depocenters and the location of the Yoakum Canyon are indicated. During the deposition of A deltas, the canyon is not yet formed (see also Figure 4) as shown in Figure 5A by the presence of thick sandstone depocenters where the canyon would have been (dashed line). The shape and size of the canyon was different during each cycle, reflecting the present-day morphology of the canyon in the subsurface. Shoreline positions are indicated by white lines. Cretaceous carbonate shelf margins (Sligo and Edwards) are shown in purple. Wilcox outcrop belt is shown in orange.

tion with the shoreline (Sweet and Blum, 2016). Shelf-incising canyons connect shelf systems to the basin floor; the fans are large and the deltas are small during the time of canyon activity (Fisher et al., 2021). For shelf-incising canyons to form and supply sediment to the deep basin, the shelf has to be flooded and progradation, if it occurs, has to be restricted to the mid or inner shelf (Fig. 7). There is the presumption that if deltas reach the shelf edge, they will infill the canyons and shutdown the system.

### Development of the Yoakum Canyon

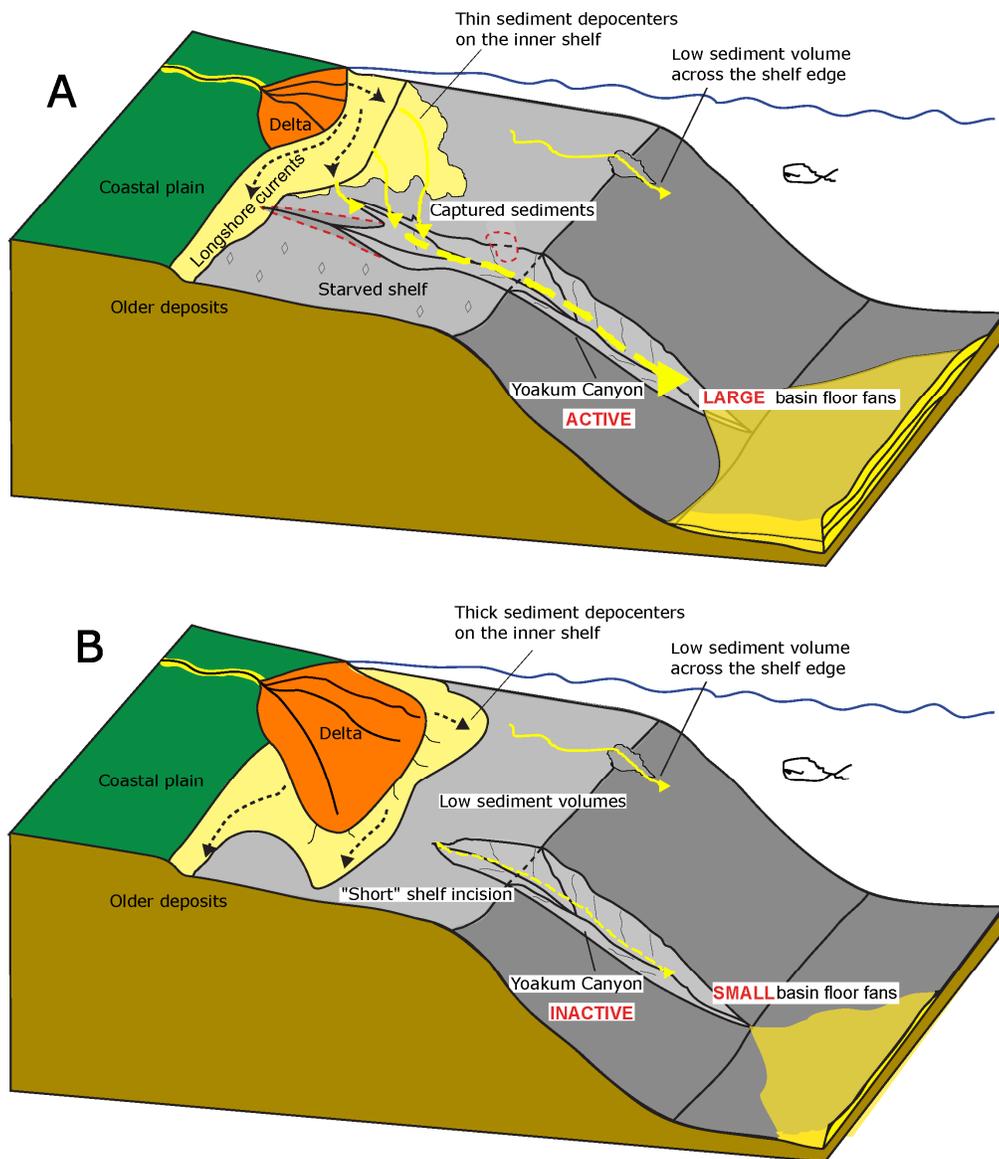
The Paleocene Yoakum channel is the largest and best-known Wilcox canyon. Present-day subsurface expression shows a V-shaped cross-sectional profile of the canyon cutting through late Paleocene Lower Wilcox and Middle Wilcox strata (Fig. 4). Wave-dominated Lower Wilcox Colorado A deltas reached the shelf edge, loaded the margin, and built in growth-faulted depo-



**Figure 6.** Well-based sandstone thickness maps for 4th-order cycles depicting depocenters and depositional environments of the San Antonio, Guadalupe, and Colorado deltas during late Lower Wilcox and Middle Wilcox times. Lower Wilcox C Delta (~1 Myr) is divided into three 4th-order cycles separated by two maximum flooding surfaces, C1 and C2. Middle Wilcox (2.7 Ma) is divided into six 4th-order cycles between the Yoakum and Big shales. (A) C2 to Dull Shale (oldest cycle). (B) C1 to C2. (C) C1 to Big Shale. (D) Wb to Big Shale. (E) Webb to Wb. (F) Y3 to Webb. (G) Y2 to Y3. (H) Y1 to Y2. (I) Y1 to Yoakum Shale (youngest cycle). The maximum sandstone thickness of individual deltaic complexes ranges from 8 m to 40 m. Individual depocenters show different architectures and an overall backstepping shoreline. White lines indicate shoreline positions. Cretaceous carbonate shelf margins (Sligo and Edwards) are shown in purple. The Wilcox outcrop belt is shown in orange.

centers (Zhang et al., 2022). Retrogressive failure destabilized the slope at the end of deposition of the A deltas. The Lavaca Canyon (Fig. 5A) acted as a conduit to transport the earliest Lower Wilcox sediments down the slope into the deep basin (Galloway and McGilvery, 1995; Ambrose and Dutton, 2018; White et al., 2019). However, during the next 3rd-order cycle, renewed progradation due to increased sediment supply from tectonically created relief and climatic changes (Hessler et al.,

2017; Sharman et al., 2023) advanced the deltaic shoreline even further downdip. The B deltas reached the shelf edge and infilled Lavaca Canyon, shutting down the sediment transport to the deepwater environment. Shelf margin building during the deposition of the B deltas loaded the shelf edge, and the delivery system remained docked near the shelf break, feeding sediment to the upper slope (Olariu and Ambrose, 2016). Wave-dominated deltas developed in growth-faulted compartments and formed thick (10s



**Figure 7. Block diagram showing shelf and slope incising Yoakum Canyon and fan system in the deepwater environment (modified after Fisher et al. [2021]). (A) Shelf-incising canyons connect shelf systems to the basin floor; the fans are large and the deltas are small during the time of canyon activity. (B) When the deltas built on the inner-middle shelf, small basin floor fans were formed. Sediments were deposited on the shelf, and the canyon remained mostly inactive, as it did not extend sufficiently shoreward to capture the sediment supply.**

of meters) depocenters at the shelf edge. As a consequence, it is thought that the Yoakum Canyon was inactive during this time with little downslope fan development. Detachment and downslope transport, by slumping or landsliding of shelf-derived sediments, initiated the Yoakum Canyon at the end of deposition of the B deltas. Canyon widening involved sidewall failure and retrogressive slumping of unsupported canyon walls, and a large proportion of the canyon fill sediments are the result of down-canyon mud and debris flows from the slopes of nearby deltas (Galloway et al., 1991). As a major transgression occurred during deposition of the C deltas and the entire Rockdale system moved landward, there was less sediment load at the shelf margin (Fig. 6). Extensive shore-zone systems and a predominantly muddy shelf and upper slope were developed during Middle Wilcox time (Fig. 6). Towards the end of the Middle Wilcox, the canyon was infilled by deltaic and shoreface sandstone bodies.

As described in Fisher et al. (2021), most shelf-incising canyons in passive margin basins dominated by large-scale progradations form with massive shelf margin failure, creating a shelf margin significantly out of grade, a condition requisite for these types of canyons to form. Continued progradation keeps the mar-

gin essentially in grade. Therefore, these canyons form during retrogradation or transgression. Shelf margin failure occurs continuously with large-scale progradation, and failure during retrogradation is necessary. Intensive shelf-incising canyons generally do not form during short periods of transgression, but rather cause only relatively minor retrogradational onlap on the failed slope (Fisher et al., 2021). However, a longer duration of transgression allows canyons to incise the shelf. These large-scale shelf and slope canyons acted as conduits and provided the deepwater deposits of the Paleocene Wilcox.

### Yoakum Canyon: Conduit for Deepwater Delivery

Although submarine canyons are large morphological features of the continental slope that serve as sediment conduits, their excavation does not significantly contribute to the growth of submarine fans (Sweet and Blum, 2016; Fisher et al., 2021). The volume of sediments (~330 km<sup>3</sup>) excavated from the Yoakum Canyon represents about 1% of the volume of the contemporaneous deepwater Wilcox fans. The calculated volume of sediment deposited in the western deepwater fan during the Lower Wilcox

is approximately 15,000 km<sup>3</sup>, and during the Middle Wilcox, about 25,000 km<sup>3</sup>, with a total volume of 40,000 km<sup>3</sup> of sediment (Sweet and Blum, 2011). Therefore, it is assumed that the remaining 99% was transferred from shelf depocenters and bypassed to the deep basin. The primary mechanisms for delivering shelf sediments to submarine canyons and the basin floor are longshore drifts from adjacent deltaic shorelines, which supply sediment to the head of the canyon (Fisher et al., 2021). The importance of short-term processes, such as storms and floods, for sediment reworking across-shelf and off-shelf delivery has been mentioned in many modern settings (Harris and Whiteway, 2011). The distal part of deltas or strandplains on the shelf may have served as feeders of sediments to the canyon head, though in most cases, some component of reworking by littoral drift was involved (Fisher et al., 2021). Similar to recent examples, it is proposed here that longshore currents moved sediments into the head of the Yoakum Canyon from adjacent Colorado deltas (Fig. 6).

Recent publications have proposed that the distance between the canyon head and the shoreline is a better indicator of the likelihood of sediment transfer to the deepwater environment (Sweet and Blum, 2016). Furthermore, the width of this zone may be directly related to the amount of sediment transported through submarine canyons to deepwater depositional sinks (Sweet and Blum, 2016). Canyons characterized by active sand transport have heads that are less than 5 km from the shoreline. In contrast, active deposition of silt- and clay-size sediment presumes canyon heads that are less than 40 km from the shoreline (Sweet and Blum, 2016). The older Middle Wilcox cycles show, on average, a distance of 44 km from adjacent Colorado deltas to the head of the Yoakum Canyon. Presumably, more mud would have been transported into the canyon from the distal part of the deltas on the shelf during this time. Late Lower Wilcox and late Middle Wilcox deltas may have served as feeders of sandstone since they were closer to the canyon head (Fig. 6). However, at times when the canyon was active, the deltaic depocenters would have accumulated small sediment volumes because the sediments were transported to deepwater via the canyon (Fisher et al., 2021). Mapping of the deltaic depocenters around Yoakum Canyon (Fig. 6) suggests that it was actively connected and delivering sediments from the shelf to the basin floor during 4th-order transgressive-regressive cycles of the late Lower Wilcox and Middle Wilcox. Once established, the canyon is maintained as a conduit as long as sediment is delivered to the canyon head during 4th-order regressions. Widening and possibly further migration landward occurs during 4th-order transgressions when the shelf is flooded due to the cessation of sediment supply. The size and location of Wilcox deltaic depocenters are good indicators for the timing of sediment bypass to the deepwater environment via Yoakum Canyon and the predictors of basin floor fan size.

### Impact of Climatic Variations on Shaping the Yoakum Canyon

Unlike modern Texas Gulf Coast deltas, the Wilcox delta systems were of a comparable scale to the modern Mississippi delta (Galloway et al., 2000; Snedden and Galloway, 2019). The direction and timing of sediment input suggest that sediments comprising these delta complexes were derived from the Laramide uplifts to the northwest (Winker, 1982; Sharman et al., 2023). The direct flux of sediment from hinterland sources through the fluvial feeder system accounts for the overwhelming amount of sediment necessary for the growth and development of deepwater fans (Sharman et al., 2023). Efficient bypass of sandy sediment across the Wilcox shelf margin nourished the large AlKeWa abyssal plain fan system (Galloway et al., 2000). Local variations in climate and shelf geometry produced conditions where the maximum sediment flux could occur along any position of the sea-level curve (Sweet and Blum, 2016). It is well-

documented that the Wilcox deposition occurred during a climatic greenhouse phase with high global sea levels (Miller et al., 2003). Climate and oceanographic reconstructions suggest that an absolute minimum in glacial volumes existed during this period (Sweet and Blum, 2016). During the late Paleocene, Lower Wilcox shifting shorelines produced recurrent regressive-transgressive high-order (~100,000 yr) sedimentary sequences (Olariu, 2023) under greenhouse conditions with many hyperthermal events (Sharman et al., 2023; Hessler et al., 2017). Recent palynological and geochemical studies (Smith et al., 2024; and ongoing research by the lead author and others) indicate an overall warm and humid paleoclimate for the Lower Wilcox in south-central Texas, with superimposed drier periods.

The absence of high-frequency sea-level fluctuations, combined with high sediment fluxes from large rivers, suggests that river mouths remained in proximity to either the shelf margin or canyon head for extended periods, regularly delivering sediment to submarine canyon slope channels and eventually to the basin floor (White et al., 2019). This connection enabled efficient, long-lived Wilcox sediment delivery to the basinal depositional sink, facilitating the development of thick basin floor fans.

## CONCLUSIONS

The large Paleocene Yoakum Canyon cut into the shelf margin and was active during multiple 4th-order cycles at the time of late Lower Wilcox and Middle Wilcox deposition. During this time, the shelf was flooded, and deltas in Colorado and Guadalupe depocenters were built on the inner and middle shelf. Extensive shore-zone systems and a predominantly muddy shelf and upper slope were developed during Middle Wilcox time. Longshore currents transported sediment into the head of the canyon from the adjacent Colorado delta. Towards the end of the Middle Wilcox, the canyon was infilled by deltaic and shoreface sandstone bodies. The excavation of the canyon produced approximately 330 km<sup>3</sup> of sediments, which represents only a fraction of the contemporaneous basin floor volume, suggesting significant bypass from shelf depocenters. The proposed model for Yoakum may be applicable to shelf-incising canyons on passive margins with large-scale progradation.

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