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Tiber Deep (Keathley Canyon 102): New Insights into Upper Cretaceous Deepwater Plays in the Northern Gulf of Mexico, Part 1: Lithofacies and Reservoir Quality Trends

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ABSTRACT

The BP Keathley Canyon 102 #1 well (Tiber) encountered 1650 ft (500 m) of Upper Cretaceous deepwater sandstones and mudstones 345 miles (550 km) from coeval deltaic systems. The KC 102 #1 well logs, core photos, reservoir quality studies, and biostratigraphic data BP recently released to BOEM provide new insights into poorly understood Upper Cretaceous deepwater systems in the northern Gulf of Mexico, as well as the potential of this emerging play—recently tested at the BP Galapagos Deep Prospect in Mississippi Canyon Block 518.

While fluvial-deltaic sediments of the Upper Cretaceous Tuscaloosa Formation are well-known reservoirs, data from the deepwater deposits associated with these deltas are very limited. Earlier interpretations of a Cenomanian-Turonian age were made before biostratigraphic data had been released (Woolf, 2012; Snedden et al., 2016). Siliciclastic environments of the underlying Albian section of the Paluxy-Washita supersequence are even less well understood.

BP cut 235 ft (72 m) of core in the Eagle Ford–Tuscaloosa and Paluxy-Washita supersequences. The facies observed in this core differ in significant ways from sediments of the overlying Paleogene Wilcox Group, including: (1) the sandstones are coarser grained (upper fine to lower medium sand-size); (2) there is a significant component of coarse-grained sand and granules; (3) muddy sandstones (slurry deposits) are rare; and (4) sandstones are quartz-rich. The facies observed in core along with log motifs of the uncored interval suggest deposition in basin-floor submarine fans—in both distributary channel-fill and fan lobe sub-environments.

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Although these Cretaceous sandstones are thick and coarse-grained, they are also quartz cemented and have locally pervasive carbonate cements. As a result, reservoir quality is very poor with permeabilities <1 mD and porosities in the 2–10% range. If encountered under conditions of lower temperatures or with chlorite overgrowths, this would have reduced quartz cementation and would have lead to better reservoir quality.

INTRODUCTION

The Keathley Canyon 102 #1 well (Tiber) was drilled by BP in 2009 to a depth of 35,051 ft (10,683 m) (Figs. 1 and 2). At the time, it was the deepest well drilled in the Gulf of Mexico. It is one of a small number of wells to encounter Upper Cretaceous deepwater deposits in the northern Gulf of Mexico. Core, log, and biostratigraphic data from this well are significant because Upper Cretaceous deepwater systems in the Gulf of Mexico are not as well understood as the overlying Paleogene. The oldest of these deposits record a transition from carbonate-dominated to siliciclastic-dominated deposition of the Albian Paluxy-Washita supersequence (Fig. 3). Snedden et al. (2021) described the biostratigraphy, revised age model, and regional stratigraphic context of this well in a companion paper.

Upper Cretaceous fluvial deltaic deposits of the Cenomanian Eagle Ford–Tuscaloosa supersequence are well known from the subsurface of Louisiana where they are important reservoirs (Woolf, 2012; Snedden et al., 2016; Snedden and Galloway, 2019). There are relatively few deepwater penetrations of this section (Fig. 3A), so it is uncertain if significant volumes of sand were routed into deepwater from coeval Tuscaloosa deltas. The older Albian Paluxy-Washita depositional system is even less well understood in the deepwater environment. Mapping by Snedden

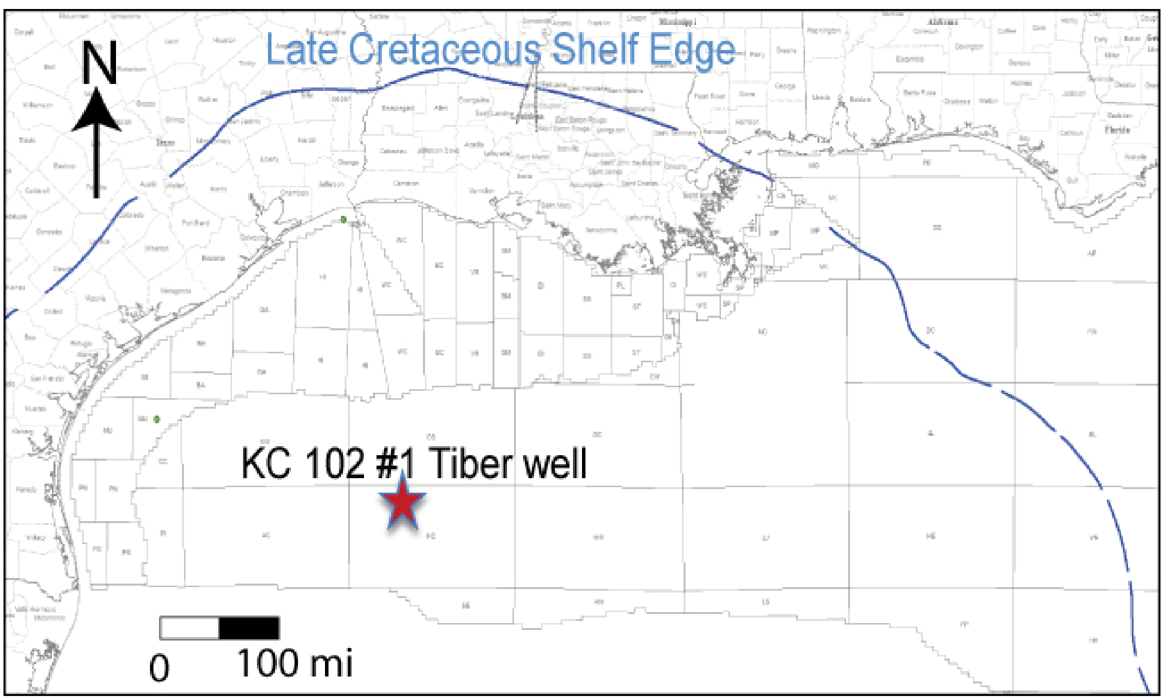


Figure 1. Map of the Gulf of Mexico showing the location of the KC 102 #1 well and the Late Cretaceous shelf edge from Snedden and Galloway (2019).

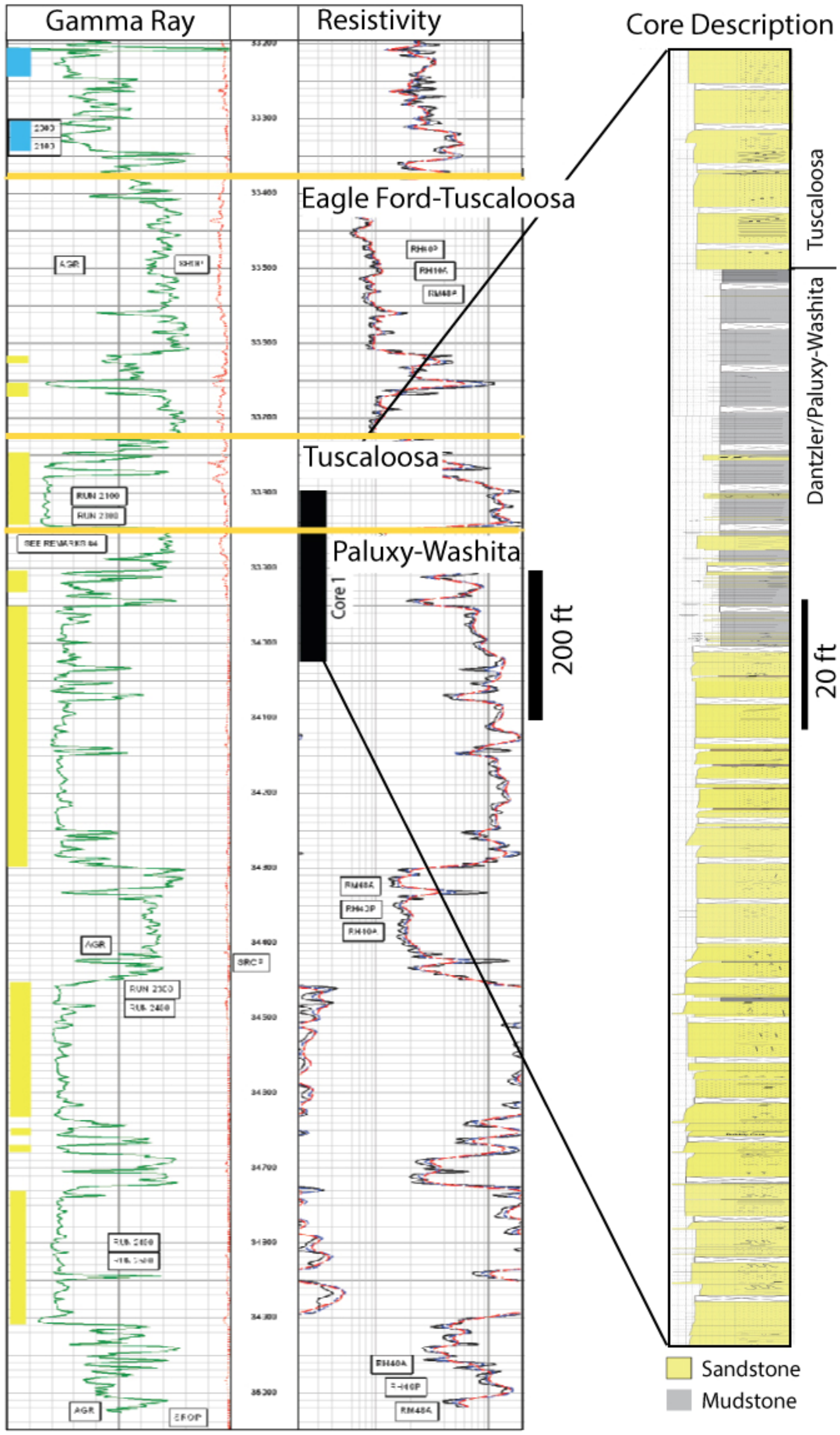
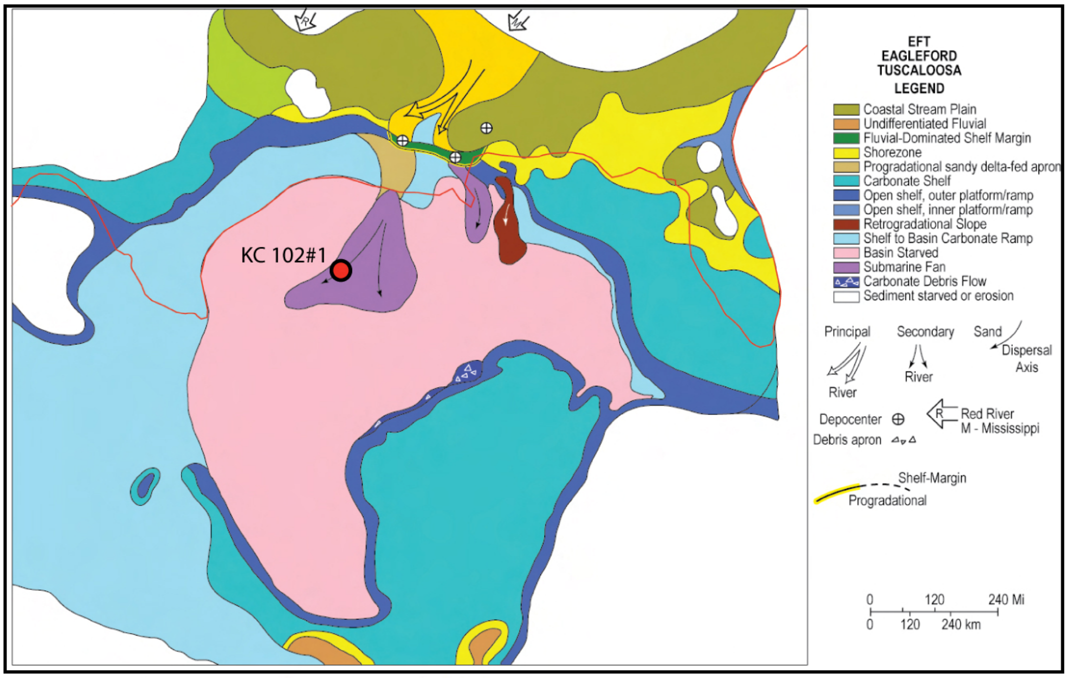


Figure 2. Wells logs showing the Cretaceous section in the KC 102 #1 well (left) and graphic log of the KC 102 #1 core (right).

A. Eagle Ford Tuscaloosa Paleogeography



B. Paluxy-Washita Paleogeography

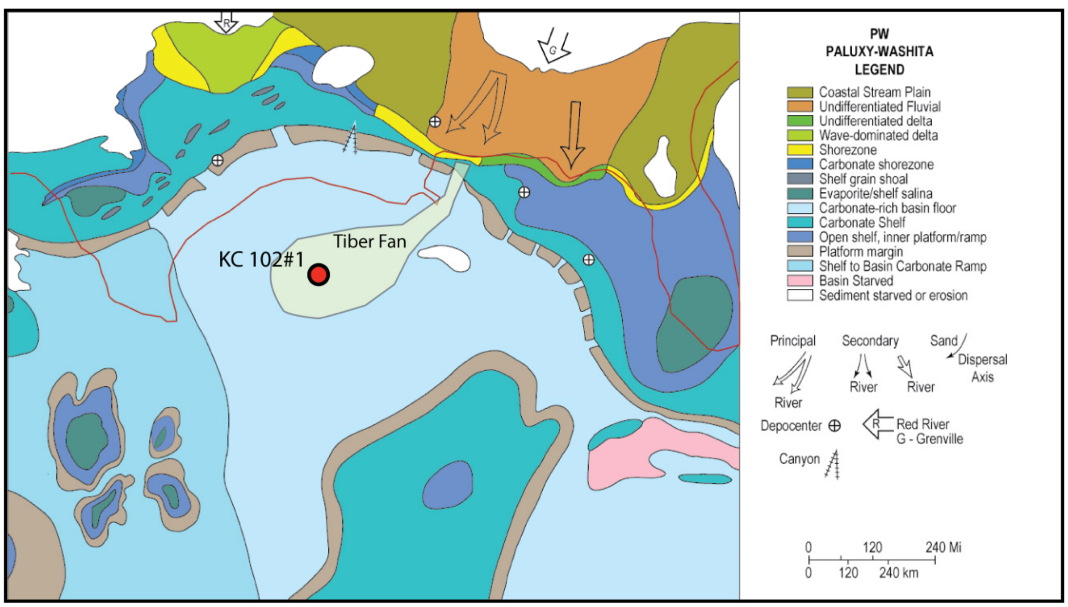


Figure 3. Upper Cretaceous paleogeographic maps of the northern Gulf of Mexico showing the location of the KC 102 #1 well in relation to key elements of the depositional system. (A) Cenomanian-Turonian Eagle Ford–Tuscaloosa supersequence. (B) Albian Paluxy-Washita supersequence. Paleogeographic maps from Snedden and Galloway (2019).

and Galloway (2019) suggested most of the northern Gulf of Mexico at this time was rimmed by a carbonate reef (i.e., the Stuart City Trend and eastward equivalents) and less well-defined siliciclastic input in the Main Pass area (Fig. 3B).

METHODS

BP released core photos, thin-section photos, porosity and permeability data, petrophysical logs, and biostratigraphic data from the Upper Cretaceous section in the KC 102 #1 well. These data were downloaded for interpretation from the BOEM website (https://www.data.boem.gov/). Of particular interest were biostratigraphic data from the Cretaceous interval and data from 235 ft (72 m) of conventional core taken in what we interpret as the Tuscaloosa sandstone and the Dantzler sandstones of the Albian Paluxy-Washita supersequence (Snedden et al., 2021). The well penetrated but did not core the Paluxy sandstone. These are the only publically released deepwater cores from this interval in the northern Gulf of Mexico. This core was described from the core photos using the thin-section photos that had a scale in mm to measure grain size.

RESULTS

The core was cut at the top of what is interpreted from logs to be a thickly bedded succession of sandstones and lesser amounts of mudstone (Fig. 2). The lower 145 ft (44 m) of core are composed of well-sorted, upper fine- to lower medium-grained, structureless sandstones ('Ta' following the Bouma classification) associated with lesser quantities of coarse-grained, poorly sorted sandstones ('S bed' of Lowe, 1982), and cross-bedded or low-angle laminated sandstones (Tb/Tt; Fig. 4). The most striking feature of these sandstones is their grain size (Fig. 5). Mean grain size is upper fine to lower medium. This is considerably coarser than the dominantly fine-grained sands of the overlying Wilcox Group (e.g., Marchand et al., 2015) but not unusual for Neogene deepwater Gulf of Mexico deposits. The presence of a significant component of coarse sand and granule-size quartz grains (Fig. 5) is something the lead author of this paper has only rarely seen in Neogene deepwater deposits from the Gulf of Mexico.

Biostratigraphic data suggest the cored interval cuts across the contact between the Tuscaloosa Formation and the Dantzler Formation. The upper part of the Paluxy-Washita is marked by 40 ft of laminated mudstone that decreases upward in silt and sand content and has no clear evidence of bioturbation (Fig. 3B). Unfortunately, the quality of the core photos is uniformly in the mudstone intervals of this core. This fine-grained interval may represent abandonment of the Paluxy-Washita submarine fans, although it doesn't display features seen in other deepwater condensed sections like reddening, increases in carbonate content, or intense bioturbation (Boulesteix et al., 2020). Direct sampling of the core will be needed to gain a better understanding of these deposits.

The overlying sandstones of the Tuscaloosa Formation are similar in terms of grain size and sedimentary structures to those of the underlying Dantzler Formation. Unlike the overlying Wilcox Group, muddy sandstones containing organic matter that we interpret as slurry deposits are rare. There could be two reasons for the dearth of slurry deposits. (1) Because the Cretaceous sandstones are coarser grained, they lack the silt and organic content seen in deepwater deposits of the Wilcox Group (e.g., Marchand et al., 2015). (2) The Cretaceous sandstones are generally well amalgamated with few interbedded mudstones, suggesting they were deposited in the updip portions of submarine fan lobes where slurry deposits are uncommon (slurry deposits generally occur on the lobe fringe; e.g., Haughton et al., 2009).

Facies, biostratigraphy, and depositional context indicate that these are deepwater deposits. While determining deepwater sub-environments from one well or core is fraught with uncertainty, the occurrence of coarse grains and current-generated sedimentary structures like cross-bedding and low-angle bedding suggests that some of these sands were deposited in channels.

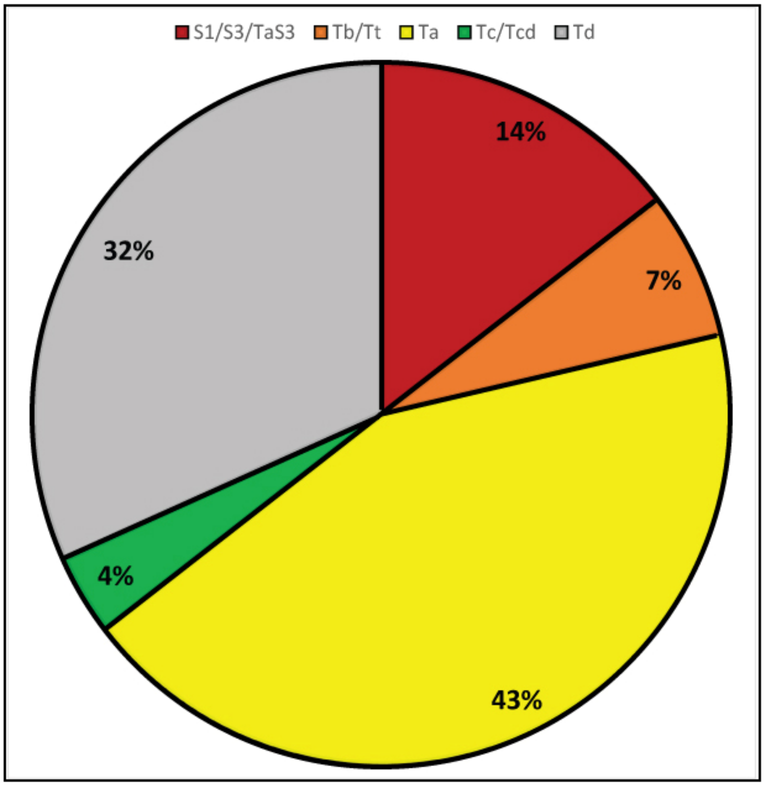


Figure 4. Pie diagram showing the distribution of facies observed in the KC 102 #1 core. S1/S3/TaS3 = pebbly or granule-rich sandstones; Tb/Tt = planar-bedded or cross-bedded sandstones; Ta= structureless fine- to medium-grained sandstones; Tc/Tcd = ripple-laminated, fine- to very fine-grained sandstones and interlaminated mudstones; and Td = mudstones.

Given the thickness, vertical amalgamation and location of these sandstones, we interpreted them to be the deposits of an extensive, basin-floor submarine fan that was penetrated in the transition between feeder channels and lobes.

The occurrence of these thick, coarse-grained deepwater deposits 350 mi (563 km) far from the Upper Cretaceous shoreline has significant implications for understanding the Cretaceous paleo-geography of North America. Detrital zircon data suggest continental drainage into the Gulf was comparatively limited during the Cretaceous versus the Paleocene (Blum and Pecha, 2014). However, data from KC 102 #1 suggest this drainage system may have been larger than previously recognized. Regional paleogeographic mapping indicates substantial quantities of sand were sequestered in deltaic and shore-zone paleoenvironments north of the active (Albian) and relict (Ceno-Turonian) carbonate margins (Snedden et al., 2016; Snedden and Galloway, 2019).

In terms of reservoir quality, these rocks are tightly quartz cemented associated with a localized pervasive carbonate cement. Compaction and pore-filling cements result in porosity in the 2-10% range with air permeability < 1 mD (Fig. 6).

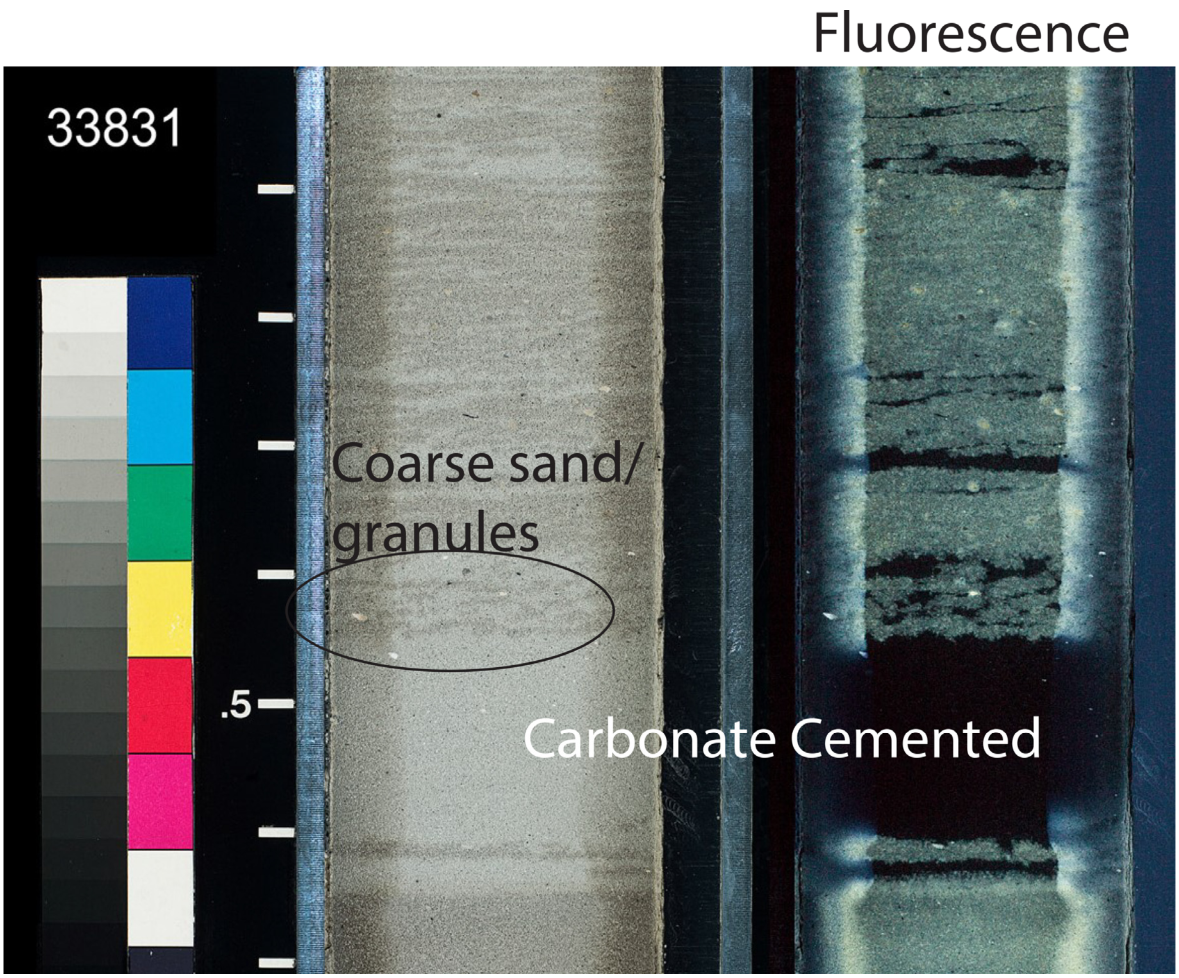


Figure 5. Photograph of core from depth 33,831 ft (10,311 m) showing coarse-grained sand-size quartz grains.

SUMMARY AND CONCLUSIONS

The occurrence of thick, amalgamated, coarse grained deepwater deposits in the interpreted Albian and Ceno-Turonian section of the KC 102 #1 well suggests a greater degree of delivery of sand to deepwater than previously known and the potential for more extensive Upper Cretaceous submarine fans in the northern Gulf of Mexico. Paleogeographic implications are especially significant for the Albian, a time when the Gulf of Mexico margin was largely rimmed with carbonates, limiting bypass due to reef blocking (Snedden and Galloway, 2019). Unfortunately, at the depths encountered in Keathley Canyon, even these quartzose, relatively coarse-grained sandstones have poor reservoir quality. In other areas with low heat flow due to shallower and/or later burial and proximity to salt bodies, these could be effective reservoirs for oil and gas.

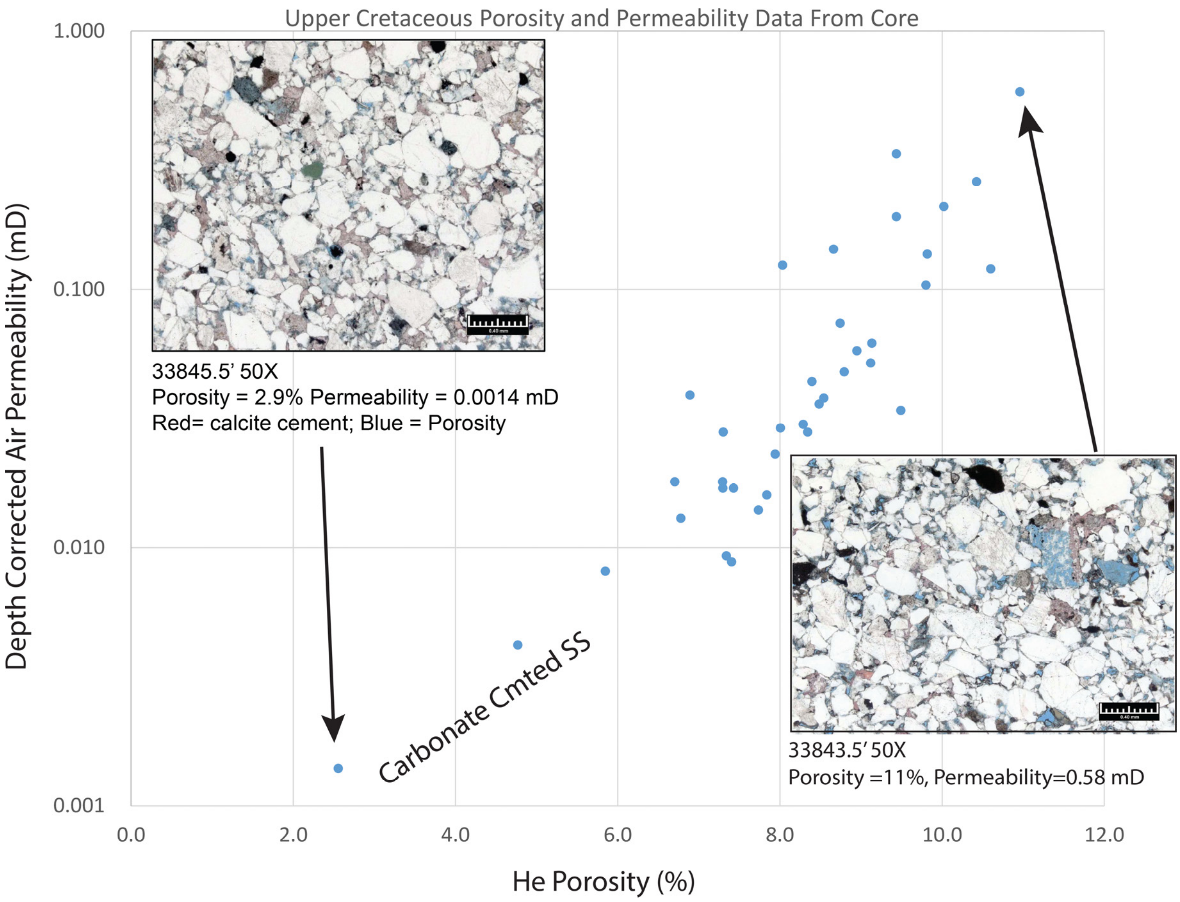


Figure 6. Porosity/permeability cross-plot of data from core in the Albian section of KC 102 #1. Thin-section photographs show that low porosity sandstones are highly carbonate cemented. Higher porosity sandstones are quartz cemented and lack carbonate cement. Sandstones seen in both thin-sections are poorly sorted and contain some coarse sand-size quartz clasts.

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