Paleogene Lowstand Systems Tract Sand Deposits of the Eastern Gulf Coastal Plain: Potential Reservoir Facies in the Offshore Northeastern Gulf of Mexico

Ernest A. Mancini

Department of Geological Sciences, University of Alabama, Box 870338, Tuscaloosa, Alabama 35487

ABSTRACT

Characterization of Paleogene stratigraphic sequences in the eastern Gulf Coastal Plain involving outcrop and well log studies resulted in the recognition of six Upper Paleocene (Selandian) and Eocene (Ypresian-Lutetian) third-order unconformity-bounded depositional sequences. These sequences include the Naheola Formation (Midway Group), the Nanafalia, Tuscahoma, and Hatchetigbee formations (Wilcox Group), and the Tallahatta Formation (Claiborne Group). The Paleogene depositional history of the eastern Gulf was dominated by fluvial-deltaic, marginal marine, and marine shelf sedimentation. The deposits of the systems tracts inherent to these Paleogene sequences consist of lowstand fluvial-deltaic, estuarine, tidal-influenced, and coastal barrier cross-bedded sand of 40-100 ft (12-30 m) in thickness; transgressive nearshore marine shelf glauconitic sand and marl of 10-40 ft (3-12 m) in thickness; and highstand fluvial-deltaic, marginal marine, tidal-influenced, and marine shelf sand, silt, clay, and lignite of 100-250 ft (30-76 m) in thickness. Stratigraphic architecture was formed primarily as a result of changes in base level. With a relative fall in sea level, the shelf was subaerially exposed and incisement through fluvial processes occurred. A subsequent relative rise in sea level and creation of accommodation space resulted in filling the shelf incisements and incised valleys. During these times of erosion and deposition, Paleogene sand bypassed the shelf and accumulated in deepwater settings as lowstand fan and wedge facies. These potentially quartz-rich sand facies are priority petroleum reservoir targets in the offshore northeastern Gulf of Mexico.

INTRODUCTION

Paleogene depositional history of the eastern Gulf Coastal Plain (central and southern Mississippi, and southwestern Alabama) was dominated by fluvial-deltaic, marginal marine, and marine shelf sedimentation. A river-dominated delta complex developed in Mississippi, and this system prograded across southwestern Alabama. Jurassic salt movement and withdrawal influenced subsidence and sediment accommodation in this area. Marine incursions during this time punctuated fluvial-deltaic and marginal marine deposition resulting in a series of recognizable and mappable depositional sequences (Mancini and Tew, 1995).

The purpose of this paper is to characterize these Paleogene (Upper Paleocene to Middle Eocene) depositional sequences and inherent systems tracts recognized in the eastern Gulf Coastal Plain using outcrop and well log and core studies, to utilize this characterization to identify lowstand systems tract deposits in this onshore area, and to project the presence of these potential sandstone reservoir facies into the offshore northeastern Gulf

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of Mexico. Correlation of these strata was achieved through biostratigraphic correlation using planktonic foraminifera and calcareous nannoplankton. See Mancini and Oliver (1981), Mancini (1984), Mancini and Waters (1986), and Mancini and Tew (1991) for a discussion of Paleogene biostratigraphy for strata in the eastern Gulf Coastal Plain area.

STRATIGRAPHY

In the eastern Gulf Coast Plain, the Paleogene (Selandian to Lutetian) section consists of the Midway, Wilcox, and Claiborne groups (Fig. 1). The Naheola Formation of the Midway Group is of interest in this study. This formation includes marginal marine and tidal-influenced carbonaceous, micaceous, laminated clay, silt, and lignite of 110 ft (34 m) in thickness of the Oak Hill Member of the Naheola Formation (Figs. 2A-C) that is unconformably overlain by estuarine and tidal-influenced micaceous, quartzose, cross-bedded, very fine- to coarse-grained sand of 40 ft (12 m) in thickness of the “Coal Bluff sand” of the Naheola Formation (Fig. 2B). The quartz grains are angular to subrounded and moderately to poorly sorted (Hidle, 1986).

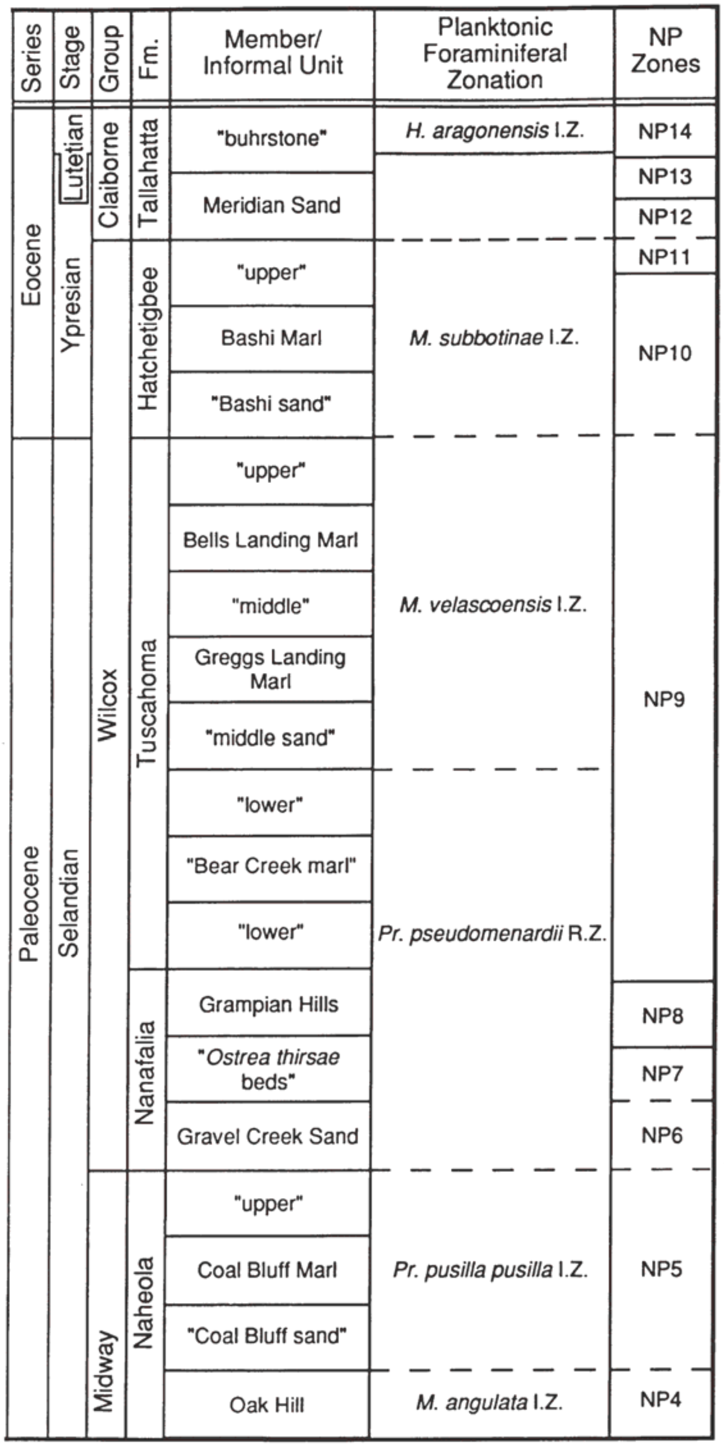
The overlying Wilcox Group includes the Nanafalia, Tuscahoma, and Hatchetigbee formations. The lower member, the Gravel Creek Sand Member, of the Nanafalia Formation consists of fluvial-deltaic and coastal barrier micaceous, quartz-rich, cross-bedded, fine- to coarse-grained sand of 60 ft (18 m) in thickness (Fig. 2D) that unconformably overlies marginal marine, laminated silt, clay, and lignite of the upper part of the Coal Bluff Marl Member of the Naheola Formation. The quartz grains are subangular to rounded, moderately to well-sorted, and are associated with quartz pebbles and clay clasts in the basal Gravel Creek beds (Hidle, 1986). The middle member, “*Ostrea thirsae* beds,” disconformably overlies the Gravel Creek Sand Member (Fig. 2D). These middle Nanafalia beds consist of nearshore marine shelf calcareous, glauconitic, fossiliferous, fine-grained sand and silty marl of 40 ft (12 m) in thickness and are conformably overlain by marginal marine and nearshore marine indurated silty carbonaceous clay interbedded with glauconitic sand and marl of 100 ft (30 m) in thickness of the Grampian Hills Member of the Nanafalia Formation. Marginal marine laminated silty clay and glauconitic, fossiliferous, sand and marl of the lower Tuscahoma Sand conformably overlies the Nanafalia Formation. These lower Tuscahoma beds are overlain unconformably by fluvial and estuarine micaceous, quartzose, cross-bedded, fine- to medium-grained sand of 40 ft (12 m) in thickness. The middle Tuscahoma includes nearshore marine shelf calcareous, glauconitic, fossiliferous, fine-grained sand and marl of the Greggs Landing Marl (7 ft or 2 m in thickness) and Bells Landing Marl (10 ft or 3 m in thickness) members. The Bells Landing Member disconformably overlies marginal marine clay and silt of the upper part of the Greggs Landing Marl Member. The fluvial-deltaic, marginal marine, and tidal-influenced laminated clay, silt, sand, and lignite beds of 250 ft (76 m) of the upper Tuscahoma Sand conformably overlie the Bells Landing Marl Member. Coastal barrier micaceous, quartzose, cross-bedded, fine- to medium-grained sand, or nearshore marine shelf calcareous, glauconitic, fossiliferous, fine-grained sand and marl of 20 ft (6 m) in thickness (Bashi Marl Member) of the Hatchetigbee Formation unconformably overlie the Tuscahoma Sand. The upper Hatchetigee marginal marine and tidal-influenced carbonaceous, laminated clay, silt, and sand of 230 ft (70 m) in thickness conformably overlie the Bashi Marl Member.

Coastal barrier micaceous, quartz-rich, cross-bedded, fine- to coarse-grained sand of 100 ft (30 m) in thickness of the Meridian Sand Member of the Tallahatta Formation of the Claiborne Group unconformably overlies the Hatchetigbee Formation. Marine shelf indurated clay (“buhrstone”) of 115 ft (35 m) of the upper Tallahatta conformably overlies the Meridian Sand Member.

SEQUENCE STRATIGRAPHY

Baum and Vail (1988) described 18 third-order unconformity-bounded depositional sequences from the Paleogene section in the Gulf Coastal Plain, and Mancini and Tew (1991) recognized 21 depositional sequences in Paleocene through Oligocene strata in the eastern Gulf Coastal Plain. Six of these sequences are characterized in this paper (Fig. 3). These descriptions are, in part, from Mancini and Tew (1995).

Sequence 1 consists of the “Coal Bluff sand” and Coal Bluff Marl Member of the Naheola Formation. The base of this sequence is marked by a subaerial unconformity at the top of the Oak Hill Member of the Naheola Formation (Fig. 2B). The sequence includes lowstand (micaceous, quartzose, cross-bedded, very fine- to coarse-grained sand), transgressive (calcareous, glauconitic, fossiliferous, fine-grained sand and marl), and highstand (laminated silt, clay, and lignite) systems tract deposits. The lowstand sand deposits have a discontinuous but



Series	Stage	Group	Fm.	Member/ Informal Unit	Planktonic Foraminiferal Zonation	NP Zones
Eocene	Lutetian	Claiborne	Tallahatta	"buhrstone"	*H. aragonensis* I.Z.	NP14
	Ypresian			Meridian Sand		NP13 NP12
		Wilcox	Hatchetigbee	"upper"	*M. subbotinae* I.Z.	NP11 NP10
				Bashi Marl		
				"Bashi sand"		
Paleocene	Selandian		Tuscahoma	"upper"	*M. velascoensis* I.Z.	NP9
				Bells Landing Marl		
				"middle"		
				Greggs Landing Marl		
				"middle sand"		
				"lower"	*Pr. pseudomenardii* R.Z.	
				"Bear Creek marl"		
				"lower"		
			Nanafalia	Grampian Hills		NP8
				"*Ostrea thirsae* beds"		NP7
				Gravel Creek Sand		NP6
		Midway	Naheola	"upper"	*Pr. pusilla pusilla* I.Z.	NP5
				Coal Bluff Marl		
				"Coal Bluff sand"		
				Oak Hill	*M. angulata* I.Z.	NP4

Figure 1. Upper Paleocene to Middle Eocene lithostratigraphy and biostratigraphy for the eastern Gulf Coastal Plain (from Mancini and Tew, 1995, reproduced with permission of the Society of Economic Paleontologists and Mineralogists).

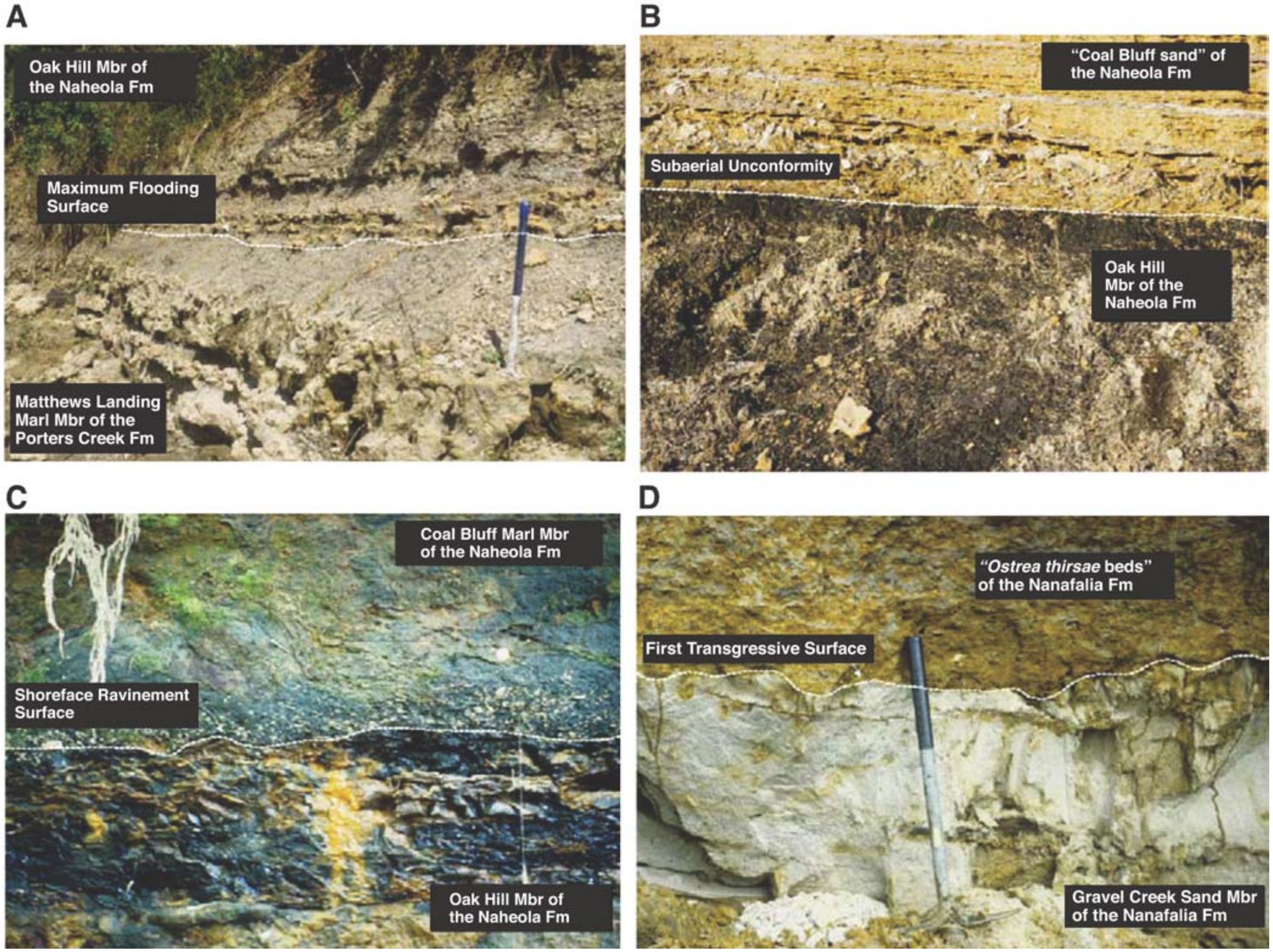


Figure 2. Photographs of Upper Paleocene outcrops in southwest Alabama showing physical surfaces: (A) Maximum flooding surface associated with the condensed section in the Oak Hill Member of the Naheola Formation. (B) Subaerial unconformity at the contact of the Oak Hill Member and "Coal Bluff sand" of the Naheola Formation. (C) Shoreface ravinement surface at the contact of the Oak Hill Member and Coal Bluff Marl Member of the Naheola Formation. (D) First transgressive surface at the contact of the Gravel Creek Sand Member and "*Ostrea thirsae* beds" of the Nanafalia Formation.

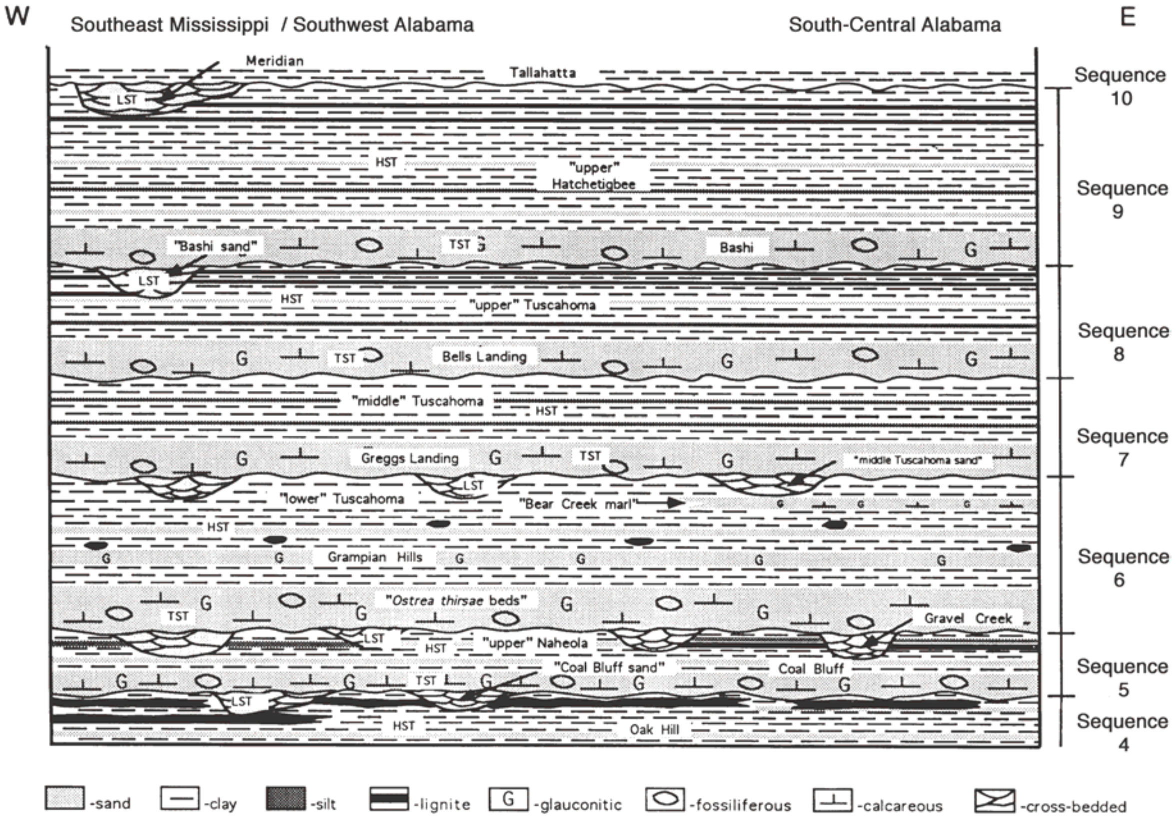


Figure 3. Upper Paleocene to Middle Eocene sequence stratigraphy and inherent systems tracts for the eastern Gulf Coastal Plain (from Mancini and Tew, 1995, reproduced with permission of the Society of Economic Paleontologists and Mineralogists). LST = lowstand sytems tract, TST = transgressive systems tract, and HST = highstand systems tract.

regional distribution. At localities where the lowstand sand is absent, glauconitic sand and marl of the transgressive systems tract unconformably overlie lignite of the Oak Hill highstand systems tract (Fig. 2C). The contact between the lowstand and transgressive systems tract deposits is disconformable.

Sequence 2 consists of the Nanafalia Formation and lower part of the Tuscahoma Sand. The base of this sequence is marked by a subaerial unconformity at the top of the Coal Bluff Marl Member. The sequence includes lowstand (micaceous, quartz-rich, cross-bedded, fine- to coarse-grained sand of the Gravel Creek Sand Member), transgressive (calcareous, glauconitic, fossiliferous, fine-grained sand and silty marl of the "*Ostrea thirsae* beds"), and highstand (clay and silt interbedded with glauconitic sand and marl of the Grampian Hills Member and lower part of the Tuscahoma Sand) systems tract deposits. The contact between the lowstand and transgressive systems tract deposits is disconformable (Fig. 2D). The lowstand sand deposits have a discontinuous but regional distribution. At localities where the lowstand sand is absent, glauconitic sand and marl of the transgressive systems tract unconformably overlie lignite associated with the highstand systems tract of the upper part of the Coal Bluff Marl Member.

Sequence 3 consists of the lower part of the middle section of the Tuscahoma Sand. The base of this sequence is marked by a subaerial unconformity in the Tuscahoma Formation. The sequence includes lowstand (micaceous, quartzose, cross-bedded, fine- to medium-grained sand), transgressive (calcareous, glauconitic, fossiliferous, fine-grained sand and marl of the Greggs Landing Marl Member), and highstand (laminated clay and silt) systems tract deposits. The contact between the lowstand and transgressive systems tract deposits is disconformable. The lowstand sand deposits have a discontinuous but regional distribution. At localities where the lowstand sand is absent, glauconitic sand and marl of the Greggs Landing transgressive systems tract unconformably overlie laminated clay and silt of the underlying highstand systems tract.

Sequence 4 consists of the upper part of the middle section of the Tuscahoma Sand. The base of this sequence is marked by a disconformity at the base of the Bells Landing Marl Member. The sequence includes transgressive (calcareous, glauconitic, fossiliferous sand and marl of the Bells Landing Marl Member) and highstand (laminated clay, silt, sand, and lignite) systems tract deposits. No lowstand system tract deposits were recognized in this sequence.

Sequence 5 consists of the Hatchetigbee Formation. The base of this sequence is marked by a subaerial unconformity at the top of the Tuscahoma Sand. The sequence includes lowstand (micaceous, quartzose, cross-bedded, fine- to medium-grained sand), transgressive (calcareous, glauconitic, fossiliferous, fine-grained sand and marl of the Bashi Marl Member), and highstand (laminated clay, silt, and sand) systems tract deposits. The contact between the lowstand and transgressive systems tract deposits is disconformable. The lowstand sand deposits have a discontinuous but regional distribution. At localities where the lowstand sand is absent, glauconitic sand and marl of the transgressive systems tract unconformably overlie clay, silt, and lignite of the Tuscahoma highstand systems tract. The contact between the lowstand and transgressive systems tract deposits is disconformable.

Sequence 6 consists of the Talahatta Formation. The base of this sequence is marked by a subaerial unconformity at the top of the Hatchetigbee Formation. The sequence includes lowstand (micaceous, quartzose, cross-bedded, fine- to coarse-grained sand of the Meridian Sand), transgressive (indurated clay), and highstand (silty clay) systems tract deposits. The contact between the lowstand and transgressive systems tract deposits is disconformable. The lowstand sand deposits have a discontinuous but regional distribution. At localities where the lowstand sand is absent, clay of the transgressive systems tract unconformably overlies clay and silt of the Hatchetigbee highstand systems tract. The contact between the lowstand and transgressive systems tract deposits is disconformable.

In summary, the deposits of the above described systems tracts inherent to the Paleogene sequences consist of lowstand fluvial-deltaic, estuarine, tidal-influenced, and coastal barrier cross-bedded sand of 40-100 ft (12-30 m) in thickness; transgressive nearshore marine shelf glauconitic sand and marl of 10-40 ft (3-12 m) in thickness; and highstand regressive fluvial-deltaic, tidal-influenced, and marginal marine sand, silt, clay, and lignite of 100-250 ft (30-76 m) in thickness. Stratigraphic architecture was formed primarily as a result of changes in base level (sea level). With a relative fall in sea level, the shelf was subaerially exposed and incisement through fluvial processes occurred. A subsequent relative rise in sea level and creation of accommodation space resulted in filling the shelf incisements and incised valleys. During these times of erosion and deposition, Paleogene sand bypassed the shelf and accumulated in deepwater settings as lowstand fan and wedge facies. See Mancini and Tew (1993) for a discussion of the factors controlling the architecture of these sequences.

APPLICATION

The lowstand sand facies associated with five of the Upper Paleocene to Middle Eocene depositional sequences have potential as sandstone reservoirs in the offshore northeastern Gulf of Mexico. These potential reservoir facies are predicted to occur in deepwater settings as lowstand fan and wedge sandstone accumulations. Of these potential hydrocarbon targets, the quartz-rich sand facies of the Gravel Creek Sand Member of the Nanafalia Formation of the Wilcox Group appear to have the highest reservoir potential of these lowstand deposits. These sediments accumulated in fluvial-deltaic and coastal barrier environments in the onshore eastern Gulf Coastal Plain where they attained a thickness of 60 ft (18 m). The Gravel Creek Sand Member serves as an aquifer in Alabama, and the Wilcox is a hydrocarbon reservoir in Mississippi. Wilcox reservoirs have porosities of 15-35% and permeabilities of 200-600 millidarcies (mD) (Mancini et al., 2008). Although these Wilcox sand facies have a discontinuous distribution, they can be detected and mapped in the subsurface throughout the region. Therefore, the sedimentary characteristics and petrophysical properties of the Gravel Creek Sand Member facies give these deposits a high priority as a potential petroleum reservoir target in the offshore northeastern Gulf of Mexico.

CONCLUSIONS

Characterization of Paleogene stratigraphic sequences in the eastern Gulf Coastal Plain resulted in the recognition of six Upper Paleocene to Middle Eocene Midway, Wilcox, and Claiborne third-order unconformity-bounded depositional sequences.

Paleogene sand bypassed the shelf and accumulated in deepwater settings as lowstand fan and wedge facies. Potentially quartz-rich sand facies accumulated in these deepwater settings as lowstand fan and wedge facies as a result of these deposits bypassing the shelf during times of relative fall in sea level followed by a subsequent rise.

These deepwater sand facies are potential priority petroleum reservoir targets in the offshore northeastern Gulf of Mexico.

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