Ichnofacies and Reservoir Properties of Shoreline Deposit in the Coastal Swamp Depobelt of the Niger Delta*

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Abstract

Core samples from a shoreline deposit, which is one of the reservoirs of the Coastal Swamp Depobelt of the Niger Delta, were studied to assess the effect of burrowing on the reservoir quality. The abundance and diversity of trace fossil assemblages across the shoreline sediments were evaluated and integrated with known porosity and permeability values derived from core plugs to assess the effect of burrowing on permeability and porosity of the reservoirs. Results show that strongly burrowed reservoir intervals posses higher porosity and permeability values when compared with sparsely burrowed intervals. Whereas burrowed sediments of middle shoreface have permeability values between 177md and 967md, and porosity values within the range of 24% to 28.7%, sparsely burrowed middle sandstone units display permeability and porosity readings that range between 5.63md and 137md and 12.8% to 25.6% respectively. Similarly, burrowed sandstone units of the lower shoreface possess permeability values of 20md to 70md and porosity values of 20% to 23.7% while the sparsely burrowed lower shoreface sandstone units have permeability and porosity readings that range between 8.13md and 25.40md and 19.4 to 23.8% respectively. These findings suggest an important relationship between biogenic sedimentary structures and reservoir quality.

Introduction

Ichnology, the study of the ‘tracks, trails and burrows’ made by animals in various substrates, has grown tremendously in the last five decades as researchers have continued to expand its importance in sedimentologic studies. The utility of trace fossils is not limited to the interpretation of paleoenvironments, paleobathymetry, and paleoecological stress. Recent works have shown that ichnology can be applied to allostratigraphy (Pemberton et. al., 1992a) and sequence stratigraphy for delineation of key stratal surfaces (Bockelie, 1991;

Pemberton et. al., 1992a; Pemberton et. al., 1992b; MacEachern et. al., 1992; Taylor and Gawthorpe, 1993; Pemberton and MacEachern, 1995). Furthermore, trace-fossils can impact reservoir quality. Researchers, such as Gingras et al (2002), Gingras et al (2004a), and Gingras et al (2005), have applied ichnology to reservoir fluid flow using advanced methods and techniques. Gingras et al (2004b) demonstrated that burrowed dolomitic limestone of the Yeoman Formation in the Williston Basin possess good flow conduits because of the pathways created by the burrows.

In this study an attempt is made to illustrate the characteristics of the shoreline facies in the Coastal Swamp Depobelt of the Niger Delta, using ichnology and to assess the effect of bioturbation on reservoir quality of the shoreline sediments. The study also addresses the relationship between trace-fossil assemblages and depositional facies in the shoreline deposits. It also documents the pattern and style of bioturbation within the shoreline deposits and assesses the effect of horizontal burrows and intense bioturbation on the lower and middle shoreface.

Methodology

This study focuses on core samples of 7.5cm in diameter and about 53m long covering depth intervals of 2637.1-2620m; 3302.5-3284m; and 3581-3563m. The samples were obtained from well 13 of the Beta Field in the Coastal Swamp Depobelt (Figure 1). Each of the core samples was slabbed into one-third and two-thirds sections, with the one-third section mounted permanently with epoxy resin on core boxes (0.9m long in each box) and studied for sedimentological and paleontological description while the two-thirds section was digitally photographed under white and ultra-violet light prior to description to obtain improved visualization of chosen ichnological features.

Porosity and permeability results from core samples were obtained from the Location Sample Services (LSS) laboratory where the study was done. Each of the core samples was also calibrated to the wireline logs to establish characteristic wireline signatures.

Results

Foreshore, Shoreface and Offshore Facies Associations

Six facies associations of the shoreline deposits were observed based on the lithology, physical and biogenic sedimentary structures. The facies associations include foreshore, upper shoreface, proximal and distal middle shoreface, lower shoreface and offshore facies associations.

Permeability and Porosity Results

The porosity and permeability results from core samples incorporated into the ichnofacies studies to assess the effect of burrowing on reservoir quality are shown in Table 1.

Interpretation and Discussion

A summary interpretation of the shoreline facies associations and the petrophysical results based on Dresser Atlas (1985) and Wichtl (1990) is given in Table 2. The information in Table 2 shows that although the foreshore and upper shoreface are poorly burrowed, they have very good to excellent porosity and permeability. These high petrophysical values are thought to be due to the effect of the grain texture such as sorting and low clay content. Wave action is significant within these intervals resulting in textural maturity, good sorting and well rounded grains (Tucker, 1991). The porosity and permeability values for the middle shoreface vary from fair to very good.

The sparsely burrowed proximal middle shoreface has lower porosity and permeability values when compared with the well burrowed distal middle shoreface, even though the latter has mudstone lenses which should lower vertical permeability. This result suggests that the increase in bioturbation may have increased the porosity and permeability level in the distal middle shoreface. Generally, clay content in shoreline sands increases with depth as the clay minerals act as buffers to fluid flow. The interconnectivity between burrows in this case has enhanced permeability. Gingras et al. (1999) demonstrated that higher degrees of bioturbation can increase effective permeability in a reservoir. Table 2 further shows that low permeability values are observed in the least burrowed proximal lower shoreface when compared with the intensely burrowed distal lower shoreface.

Conclusion

The summary of petrophysical results presented in Table 2 shows that highly burrowed horizons possess higher porosity and permeability values than sparsely burrowed intervals of the same lithologic unit. This suggests that the act of bioturbation, which can be referred to as ‘sediment-mixing activities’, enhances the permeability and porosity of a sediment by creating flow conduits and increasing the surface area of the sediment, thereby enhancing reservoir homogeneity.

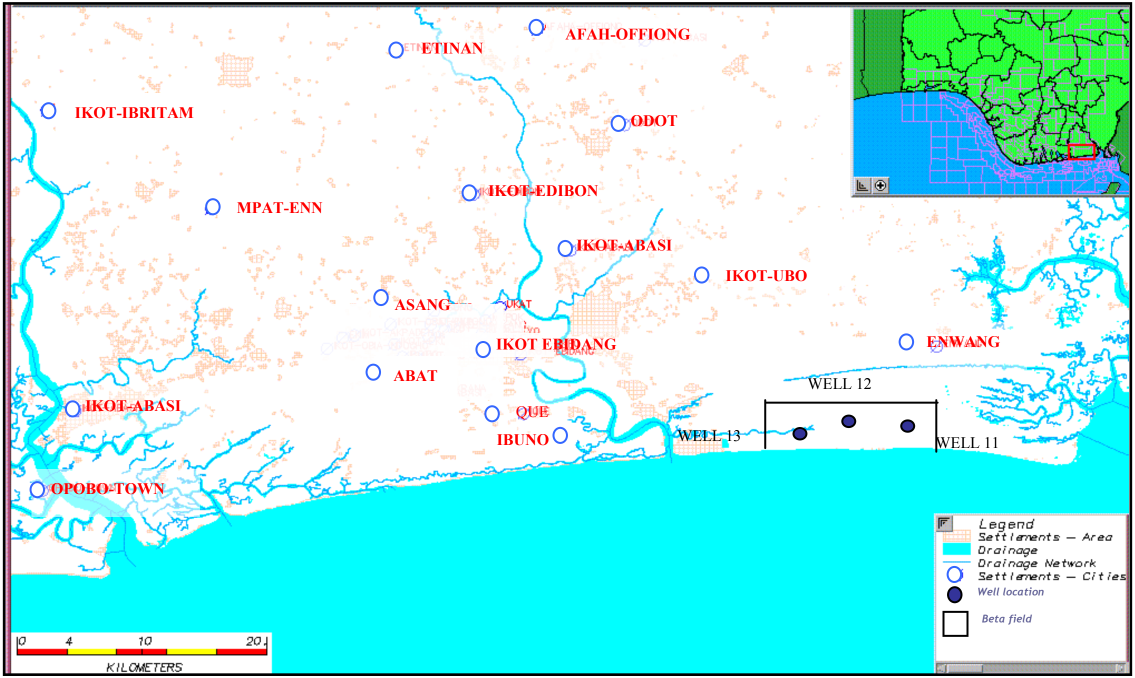

Figure 1. Map showing the studied field and well locations.

Environment of deposition	Burrow Abundance	Depth (m)	Permeability mD	Porosity %	Bulk Density gm/cc
Foreshore	Absent	2634.17	358	24.2	2.65
	Absent	2634.43	1360	27.0	2.64
	Absent	2634.75	1670	28.0	2.65
	Absent	2635.05	1580	27.8	2.65
	Absent	2635.36	1800	27.7	2.65
	Absent	2636.00	2170	27.7	2.65
	Absent	2636.29	1390	27.0	2.69
Upper Shoreface	Absent	2632.00	192	26.9	2.67
	Absent	2632.31	231	26.3	2.67
	Low	2632.62	243	26.2	2.68
	Low	2632.92	236	25.1	2.66
	Low	2633.23	321	24.8	2.66
	Low	2633.53	421	26.8	2.65
	Low	2633.87	3120	28.8	2.65
Proximal Middle Shoreface	Low	2628.66	25.4	23.8	2.67
	Low	2628.95	8.13	19.4	2.66
	Low	2629.37	137	25.6	2.67
	Low	2629.57	10	24.4	2.67
	Low	2629.84	5.63	16.6	2.66
	Low	2630.15	20.7	21.7	2.66
	Low	2630.85	7.79	20.6	2.67
	Sparse	2631.10	21.8	12.8	2.69
	Sparse	2631.40	5.66	15.8	2.66
	Sparse	2631.70	9.35	18.5	2.66
Distal Middle Shoreface	Moderate	2620.14	177	24.8	2.66
	Moderate	2620.43	660	28.7	2.66
	High	2620.76	967	28.5	2.66
	High	2621.08	770	27.0	2.65
	High	2621.36	359	25.8	2.64
Proximal Lower Shoreface	Low	2622.95	8.13	19.4	2.66
	Low	2622.66	25.4	23.8	2.67
	Moderate	2622.47	42.8	23.5	2.69
Distal Lower Shoreface	High	2623.65	162	23.7	2.65
	High	2623.75	37.45	21.2	2.67
	High	2623.97	20.6	20.4	2.69
	High	2624.16	65.9	22.5	2.65
	High	2624.26	45.3	21.6	2.67

Table 1. Results of porosity and permeability values obtained from studied core.

Facies Association		Lithofacies Description	Degree of Bioturbation	Porosity(%)	Permeability (md)
Foreshore		Fine to medium grained sandstone, well sorted, low angle planar cross-beds and horizontal beds.	Absent	27-28 % Very good	1550-2170 md Excellent
Upper shoreface		Fine- to medium-grained sandstone, two pebbly layers with erosional surfaces, parallel and wave-ripple laminations.	Low	24-27% Very good	190-320 md Good to v. good
Middle shoreface	Proximal	Well-sorted, fine grained sandstone, planar to low-angle cross-beds.	Sparse	24-26% Very good	10-137 md Fair to good
	Distal	Alternation of wave-rippled laminated sandstone and thin mudstone band.	Well burrowed	24-29% Very good	177-967 md Good to v. good
Lower shoreface	Proximal	Alternation of well sorted very fine grained sandstone and mudstone.	Moderately burrowed	19-24% Good-v.good	8-26 md Fair to moderate
	Distal	Alternation of well sorted very fine grained sandstone and mudstone. Remnants of parallel and wave-ripple laminations.	Intensely burrowed	20-24% Very good	20-70 md Moderate to good

Table 2. Summary of the shoreline facies and petrophysical results for the studied core.

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