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Research Article

APPLICATION OF TRACE FOSSIL IN CHARACTERIZATION OF ABAN-01RESERVOIR ROCKS, OFFSHORE NIGER DELTA

Odelugo L. N[1], Etu-Efeotor J. O[2] and Okengwu K. O[2]

[1, 2, 2] *Department of Geology, University of Port Harcourt, Port Harcourt, Nigeria*

ABSTRACT

Trace fossils are reflective responses to environmental, sedimentary and bathymetric variations. This paper emphasizes the application of trace fossils in the characterization of reservoir rocks for effective exploration and exploitation. Study recognized a spread of thirteen distinctive traces fossilsof the *Cruziana to Skolithos* and *Macaronichnus* ichnofacies assemblages suggestive of a range of the shallow marine depositional settings with the facies with the most trace fossil occurrence demonstrated an enhancedreservoir quality.

INTRODUCTION

Trace fossils reflects sedimentary responses and as such are reflective indicators of environmental, sedimentological and bathymetric variations. (Pemberton *et al*., 1992) and has been applied greatly to infer depositional environment and trends in the absence of logs (Mcllroy, 2004; Odelugo *et al.,* 2016).

Trace fossils such as the Macaronichnus were produced by organisms capable of dwelling within high energy hydrodynamic mobile sand environments (Goldring, 1995). Organisms that dwell within the high energy environments are known to create simple vertical to U-shaped burrows, categorized as Skolithos ichnofacies assemblage usually pellet lined to protect and keep the burrow walls stable from the inimical environmental conditions.

Studies have shown that core samples from the Niger Delta display varieties of both vertical and horizontal trace structures with thoroughly-sparsely bioturbated sandstones (Jackson *et al*., 2013; Odelugo *et.al*. 2016). Pollard *et al.* (1993) revealed that the pellet lined Ophiomorpha burrows of the Skolithos assemblage is observed to occur in Near-shore environment wherever the sediment is primarily of sand sized grains. The type of sediment in which Ophiomorpha trace is found can be used to differentiate between the offshore, shoreface and the estuarine sedimentary environments (Pollard *et al.* (1993).

Studies indicated that the greatest population and diversity of trace fossil assemblages occur within the lower shoreface to upper offshore with fewer and simpler vertical traces observed occurring within the delta top while the more complex three dimensional spread of facies are recognized in the deeper marine environmental setting making trace fossils important paleoecological indicators (Core Lab (1996).

Study Area:

The study area is situated in the offshore depobelt within latitudes 4^0N-5^0N and longitude 7^0E-8^0E of the Niger Delta sedimentary basin as shown in Figure 1.0.

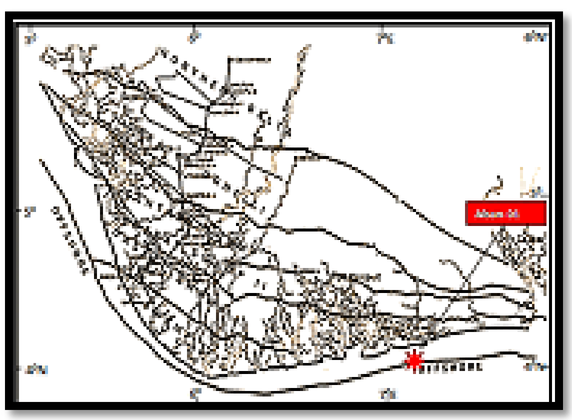


Figure 1.0: Location map of the study Area

(Modified from Nwozor *et al.,* 2013)

Study Samples:

The study core sample (plate 1.0) reveals a coarsening upwards depositional sequence with transition from a basal darker brownish-grey 1.1ft shale interval with strong to complete bioturbation with beddings completely disturbed showcasing abundant white patches recognized as *Chondrites* trace fossil of the *Cruziana* ichnofacies, an overlying thick lighter grey colored shales with little to no bioturbation through muddy heterolithic sand-rich facies, interbedded mud laminaes, moderate to common bioturbation and well-kept-up wavy beds overlaying a hummocky bed interval to an uppermost clearer fine grained overlying light brown 4.7ft thick of sand-rich facies with uncommon to moderate, low to discrete traces and beddings still distinct (Howard & Reineck, 1972).

Plate 1.0: study core sample

Method of Study:

The key study process includes core description, Lithofacies/Ichnofacie grouping and analysis. Assessment of the reservoir quality of the study samples. Analysis and reconstruction of depositional environment and trends.

Table1.0: Quantification of Bioturbation intensity (Howard & Reineck, 1972)

Bioturbation Index (BI)	Percentage Bioturbation	Classification
0	0	*No bioturbation.*
1	1-4	*Sparse bioturbation. Bedding distinct, few discrete traces and/or escape structures.*
2	5-30	*Low bioturbation. Bedding distinct, low trace density, escape structures often common.*
3	31-60	*Moderate bioturbation. Bedding boundaries sharp, traces discrete, overlap rare.*
4	61-90	*High bioturbation. Bedding boundaries indistinct, high trace density with overlap common.*
5	91-99	*Intense bioturbation. Bedding completely disturbed (just visible), limited reworking, later burrows discrete.*
6	100	*Complete bioturbation. Sediment reworking due to repeated overprinting.*

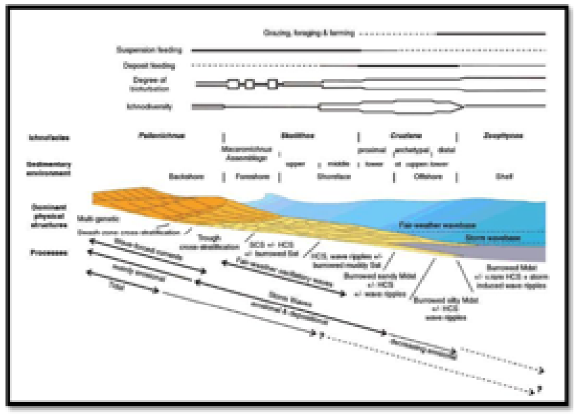


Figure 2.0: Distribution of Ichnofacies, structures and depositional processes (MacEachern *et al* (2005)

RESULTS AND DISCUSSION

Core Description:

The Aban-01 samples shows dominance of sand-rich facies and subordinate thick mud-rich facies (Table 2.0) with an upwards transition from thick massive mudstones into muddy and an interval of a cleaner laminated sandstones as represented in Plate 1.0. The well-defined shallowing upwards trend indicated progradation of the delta with a basinward shift of shoreline and migration of facies belts.

Core	Depth (ft.)	Thickness	Core Description
ONE	6662.00-6662.26	0.26	*Strongly bioturbated very fine sub-angular sandstone grains, well sorted with Common trace fossil occurrences*
	6662.26-6663.59	1.33	*Moderately bioturbated very clean parallel laminated very fine sandstone grains, sub-angular and well sorted with common escape trace and local skolithos*
	6663.59-6665.00	1.41	*Moderately bioturbated hummocky laminated and wavy very fine sandstone, sub-angular and well sorted*
	6665.00-6666.69	1.69	*Strongly bioturbated sandstone with local interlaminated sand, mud and silts laminaes, sub-angular and well sorted*
	6666.69-6667.20	0.51	*Bioturbated sand heteroliths, very fine with common trace fossil occurrence, sub-angular and well sorted*
	6667.20-6671.41	4.21	*Lowly bioturbated and laminated massive dark grey silty shales, sub-angular and well sorted.*
	6671.41-6672.10	0.69	*Strongly bioturbated and laminated massive dark grey, well sorted silty Shales, sub-angular and well sorted*

Table 2.0: Aban-01 study Core Description

Lithofacies Analysis:

By adopting Reijers *et al.* (1993) lithofacies classification scheme The Aban-01 sedimentary succession was grouped into six (6) lithofacies assemblages that are bioturbated overall (Plate 4.3); bioturbated very-fine grained sandstones (Sb), bioturbated parallel laminated very-fine sandstones (Spb), bioturbated cross-bedded hummocky rippled very-fine sandstone (Shxb), bioturbated wave-rippled cross-bedded sand heteroliths (Hswxb), bioturbated Parallel-laminated mudstone (Mpb) and bioturbated massive mudstone (Mb) as shown in Table 4.4 and Plate 2.0. The Aban-01 lithofacies displayed a dominance of sand-rich lithofacies (62.5%) with subordinate very thick mud-rich facies (37.5%).

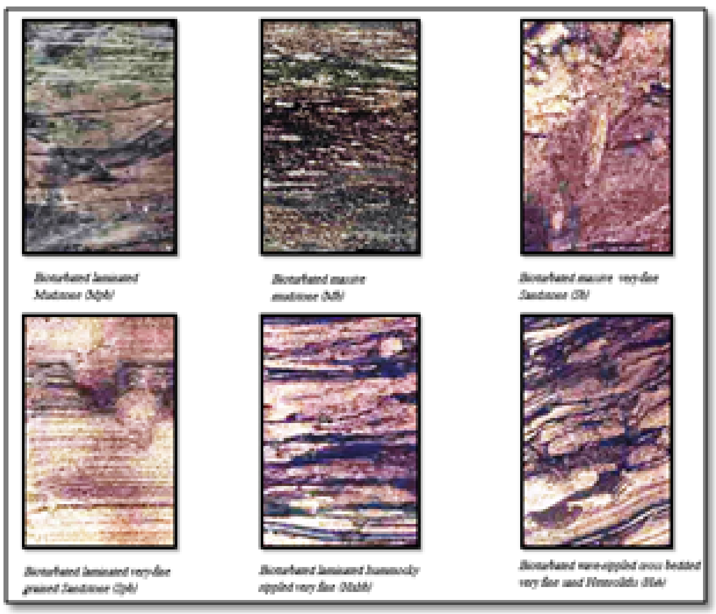


Plate 2.0: Lithofacies identified in the Aban-01 study cores samples

Table 2.0: Lithofacies Analysis

Facies Group	Facies No.	Lithofacies Description	Facies Code
Sandstone	1	*Bioturbated massive very fine sandstone*	Sb
	2	*Bioturbated laminated very fine sandstones*	Spb
	3	*Bioturbated cross-bedded hummocky rippled very fine sandstone*	Shxb
Heteroliths	4	*Bioturbated wave-rippled cross bedded very fine sand Heteroliths*	Hswxb
Mudstone	5	*Bioturbated laminated mudstone*	Mpb
	6	*Bioturbated massive mudstone*	Mb

Ichnofacies Analysis:

The ichnofacies observed in the highly bioturbated Aban-01 core succession with percentage occurrence of 5-99% and intensities in the range of 1-5BI (Tables 3.0; 4.0) includes different assemblages of trace fossils recognized as *escape traces, Asterosoma, Rhyzocorralium, Arenicolites, Ophiomorpha, Asterosoma, Teichichnus, Palaeophycus, Planolites, Macaronichnus, Skolithos associations* with abundant *Chondrites* typical of mudstone facies and suggestive of a range of *Skolithos, Macaronichnus and Cruziana* assemblages occurring from the marginal marine to distal offshore marine (MacEachern *et al.,* 2005) depositionalenvironments (Plate 3.0)

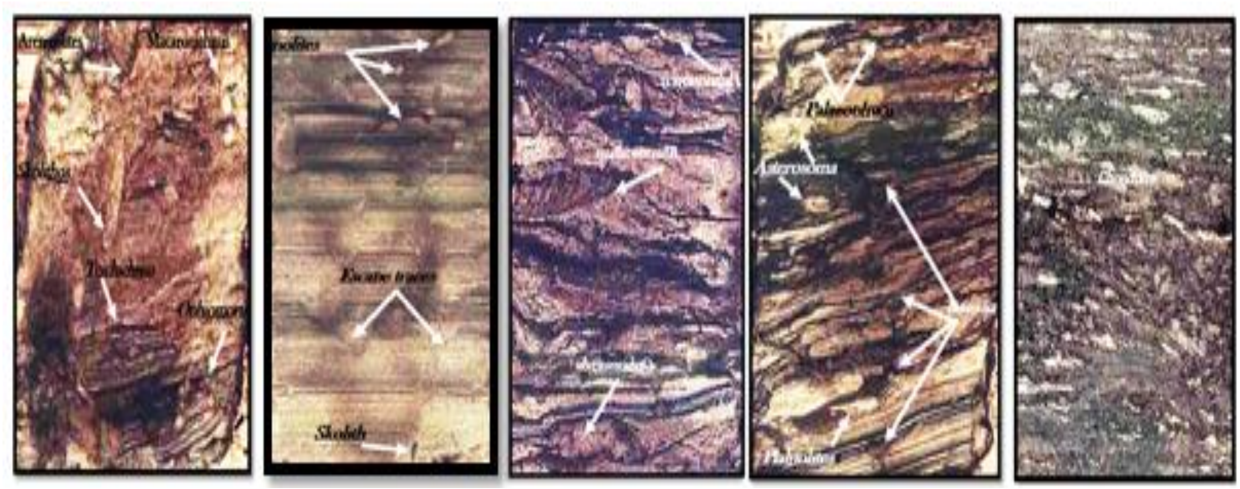


Plate 3.0: Trace structures as observed in the sample of study

Table 3.0: Ichnofacie Analysis

Core cut	Depth Ft.	Bioturbation Percentage & intensity (BI)	Trace fossil/Ichnological Description	Trace fossil/ Ichnofacies Assemblages
	6462.00-6462.26	61-90% (4-BI)	*Strongly bioturbated very fine sandstone, moderately-well sorted with common Asterosoma, Ophiomorpha, Skolithos, Planolites, Macaronichnus and Arenicolites*	*Macaronichnus And Skolithos*
	6462.26-6463.59	5-30% (2-BI)	*Bioturbated clean laminated very fine sandstone well sorted with local Skolithos and common Escape traces.*	*Skolithos/ Cruziana*
	6463.59-6465.00	31-60% (3-BI)	*Moderately bioturbated hummocky cross bedded, very fine sandstone. Moderately sorted with common Teichichnus, Rhizocorallium, Planolite Ophiomorpha and Skolithos.*	
[illegible]	6465.00-6466.69	5-30% (2-BI)	*Moderately bioturbated wavy cross bedded sandstone well sorted with sand/mud laminae, common Teichichnus, Rhyzocorralium and Asterosoma.*	*Skolithos/ Cruziana*
	6466.69-6467.20	5-30% (2-BI)	*Bioturbated wavy cross bedded muddy very fine sandstone with common Thalassinoides, Planolite, Asterosoma And Ophiomorpha*	
	6467.20-6471.41	1-4% (1-BI)	*Laminated dark grey silty mudstone with little or no bioturbation of local Chondrites.*	
	6471.41-6472.10	91-99% (5-BI)	*Strongly bioturbated dark grey, well sorted silty mudstone with abundant Chondrites.*	*Cruziana*

Table 4.0: Summary of trace fossils observed in the Study Xena-14 and Aban-01 samples

S/N	TRACE FOSSILS	DESCRIPTION	ABAN-01 Offshore
1	*Skolithos*	***Simple*** *vertical to sub-vertical burrows with smooth walls*	√
2	*Thalassinoides*	***Lined*** *network of branching to interconnected burrows.*	√
3	*Ophiomorpha*	***Straight*** *but sometimes Y shaped vertical to inclined, curved to straight pellet lined burrows*	√
4	*Teichichnus*	***Non****-branching unlined vertical burrow with laminations*	√
5	*Rosselia*	***Vertical*** *multi-lined burrows with a cone in cone structure that point downwards*	√
6	*Rhizocorallium*	***Non****-branching horizontal to slightly inclined U shaped trace with spreite*	√
7	*Planolites*	***Horizontal*** *unlined burrows with fills different from the host sediments*	√
8	*Palaeophycus*	***Horizontal*** *lined burrow tubes with burrow fill same as host sediments*	√
9	*Cruziana*	***Escape trace like long*** *herring bone like burrows*	√
10	*Chondrites*	*Tree root like traces branching from a central point.*	√
11	*Macaronichnus*	*Pellet like horizontal unlined burrows with infill similar to host sediment*	√
12	*Arenicolites*	***Simple*** *vertical to slightly inclined U shaped burrows*	√
13	*Asterosoma*	***Lens*** *shaped burrows arranged around a central axial*	√

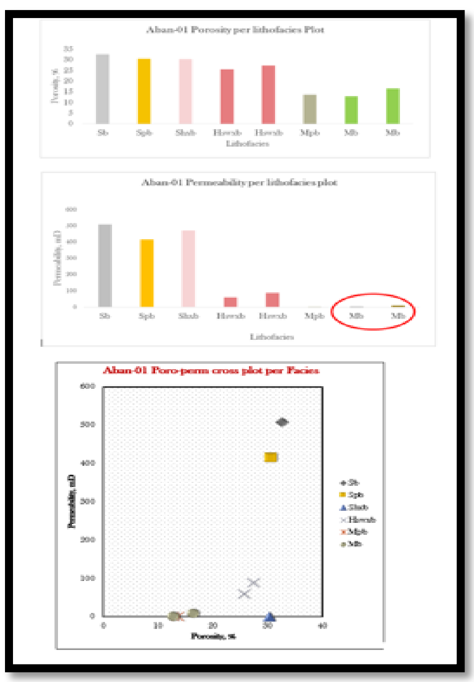
Depositional Environment:

The well-defined coarsening/shallowing upwards sequence of the Aban-01 with the occurrence of trace fossils such as the abundant white patches recognized as *Chondrites*of the *Cruziana* assemblage the lower shale interval and the upwards spread of the *skolithos and Macaronichnus* assemblages recognized within the mud-rich heterolithic and upper cleaner sand-rich lithofacies with well-preserved wavy and hummocky beds indicated progradation of the delta with a landwards shift of shoreline and migration of facies belts from the basal low energy setting of the proximal offshore towards the coastal region of the marginal marine environments(Howard & Reineck, 1972). In integrating the lithofacies and Ichnofacies (Tables. 2.0 and 3.o),a shallow marine depositional environment with transition from offshore to onshore was construed.

Facies Control on Reservoir Porosity& Permeability:

The porosity/permeability perfacies plot demonstrated that porosity ranged from 12.8% to 32.5% with an average of 23.7% which is interpreted as good to excellent (Dresser Atlas, 1982). While the permeability values ranged from 2.0mD to 508mD which is interpreted as poor to very good with an average value of 194.12mD

The Poro-perm cross plot demonstrated that the strongly bioturbated massive fine sand facies interval revealed good to excellent petrophysical attributes interpreted as deposits of low energy distal shorefacewhile the mud-rich intervals showedthe least petrophysical values comparatively with slightly remarkable enhanced values for the mud intervals with strong bioturbation and associated trace structures indicating low energy of the proximal offshore fair weather zone with slow rate of deposition (MacEachern *et al.* (2005).



CONCLUSIONS

Trace fossil analysis was applied to characterize and define the Aban-01 sample.The intervals with strong bioturbation and trace fossil occurrence irrespective oflithotypes showed enhanced petrophysical character andwas able to establish that the presence and extent of trace fossil cannot be overstated in areas of reservoir characterization for fecund exploration and production.

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