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Research Article

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Sedimentology and Reservoir Studies of Odirin Well, Niger delta, Nigeria

Acra E.J.[1], Unuavwodo Odirin[2], Adiela U.P.[3]

[1]Department of Geology, University of Port Harcourt, Nigeria
[1,2]Centre of Petroleum Geosciences, University of Port Harcourt, Nigeria
[3]Department of Petroleum Engineering, Nigerian Agip Oil Company, Port Harcourt, Nigeria

Abstract Reservoir characterization of the Odirin Well I was carried out using sedimentological attributes integrated reservoir quality of the sandbodies. Six lithofacies were recognized, namely laminated mudstone (ODI), Bioturbated sandstone (0D2), Wavy lenticular heterolith (0D3), Weavy bedded sandy heterolith (0D4), fine grained mm scale laminated sandstone (0D6), and lenticular muddy heterolith (0D7). Two hydrocarbon bearing reservoirs were also identified at depth 3160-3195ft (35ft) in Core I and at depth 3220-3226ft (6ft). The porosity values in Core 1 range from 12.6% - 41.1% with an average of 31% and permeability range of 21.9-1560md with an average 995md. Core 2 porosity values range from 20.5—38. 1 with an average of range of 18.9-2200 md with an average of 986md. The values show good to excellent porosity and very good permeabilities. The reservoir quality which is excellent is dependent on the facies, grain sizes and sorting which are fine to medium grained and a moderately depicting a moderately high energy environment. The bioturbation structures also enhance fluid flow, hence the high vertical permeability values. The various parameters above indicate deposition in a tidally influenced environment probably a distributary channel fill.

Keywords Sedimentology, Reservoir, Odirin Well, Nigeria

Introduction

Reservoir characterization is a multidisciplinary approach and integration of data sets in an attempt to improve exploration and exploitation of hydrocarbons [1]. Reservoir characterization has gained a tremendous due to the volume of hydrocarbon extracted by the understanding of the geometry, architecture, depositional histories and genesis of the sediments and their petrophysical attributes such as porosity, permeability, etc. Reservoir characterization tends to evaluate the capacity of the reservoir to hold and transmit fluid with the proper understanding of the architectural elements of depositional environment [2]. The complete understanding of the basin settings will enhance predictive hydrocarbon exploration.

Sedimentological depositional processes characterization gives an understanding of the geometry, grain size variation, stacking patterns based on facies changes and internal reservoir architecture of the individual reservoir horizons to discern a depositional model for the well [3].

Hence, a complete sedimentological and petrophysical characterization will give a better knowledge of the reservoir in terms of storage, flow properties as well as lead to delineation of reservoir performance.

Aim and Objectives

The works aim is to document the sedimentological and petrophysical characteristics of Odirin Well 1 in Ene field Eastern Niger Delta.

Location of Study Area

The area of study lies within latitudes 40 and 7° N and 3° and 9° E , 1982) (Fig. 1).

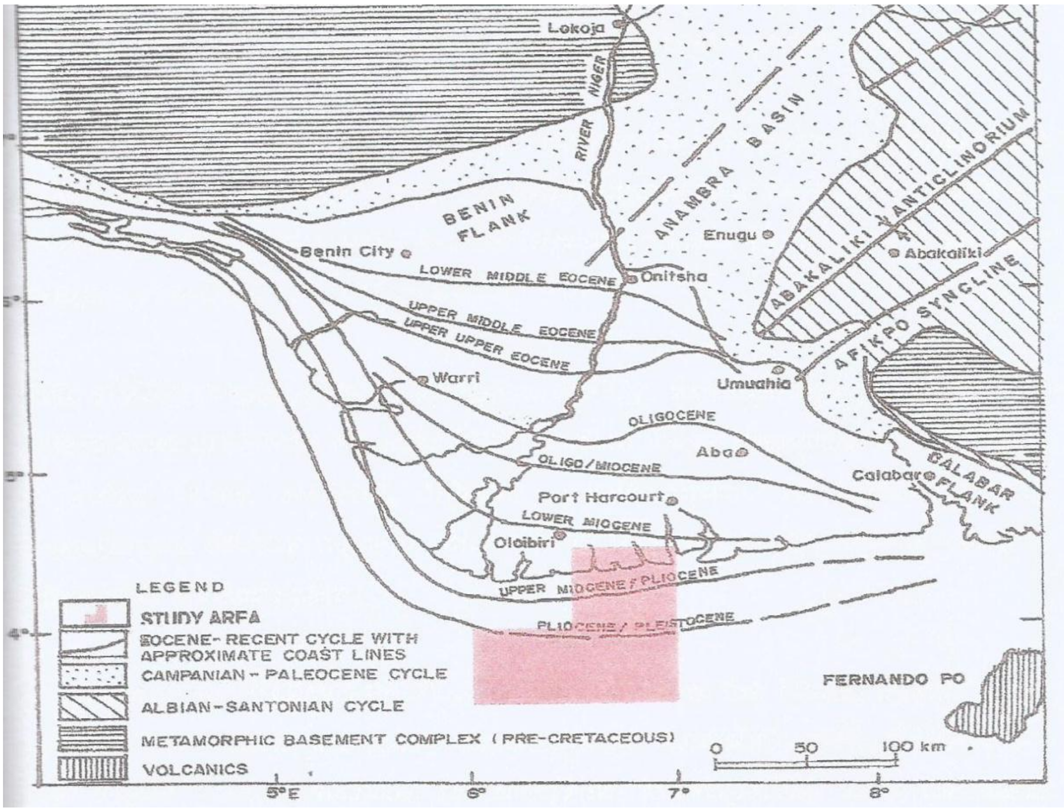

Figure 1: Location of Study Area

Materials and Methods

Sieve Analysis

The sieve method is a more general and widely accepted form of mechanical analysis aimed at determining the grain size, kurtosis, skewness, sorting and median of an entire deposition through collected samples [4]. The primary purpose of sieve analysis is to delineate particles size distribution in sands, so that one can have knowledge of:

- Frequencies of different sizes of particle present.
- Processes operating on the sediments at the time of deposition e.g. flow energy.
- Concentration of particles in suspension.

Sieve Analysis Procedure

Apparatus; set of sieve (2 mm-63 mm), sample plate, shake, oven and digital weighing balance.

Step 1: put the sample in a plate, record the mass of undried sample and plate separately.

Step 2: oven dry the sample

Step 3: record the dry mass of the sample and loosen the samples carefully if they are not.

Step 4: record the mass of each of empty sieve.

Step 5: stack the sieves in their proper order and place on a shaker and then empty dry sample into the topmost sieve and shake for 15 minutes.

Step 6: weigh each set of sieve with particle retained and record the mass.

Step 7: plot grain size distribution curve by plotting cumulative weight percentage (%) against class interval in Phi scale ϕ.

Step 8: plot histogram (depositional modality) by plotting corrected weight percentage (%) versus class interval Phi scale ϕ.

Statistical Formulae and Interpretation for Grain Size Parameters (modified from Folk and Ward, 1957 [1])

i. Graphic Mean (GM ϕ)

This is a measure of the average diameter of grains in the sediments. It is computed from e various size of particles spread through the values obtained.

$$\frac{\phi 16+\phi 50+\phi 84}{3}$$

GM ϕ Values	Interpretation
-1-0.00	Very coarse sand
0.0-1	Coarse sand
1.0-2.0	Medium sand
3.0-4.0	Very fine sand
4.0-5.0	Coarse silt

ii. Graphic Standard Deviation (GD ϕ)

This is a measure of the degree of sorting or the distribution about an average grain size. It is also a technique of characterizing the central segment of a curve".

$$\frac{\phi 84-\phi 16}{4}+\frac{\phi 95-\phi 5}{6.6}$$

GM ϕ Values	Interpretation
<0.35	Very well sorted
0.35-0.50	Well sorted
0.50-0.71	Moderately well sorted
1.00-2.00	Poorly sorted
>4.00	Extremely poorly sorted

Core Data Analysis

Odirin Well 1 was drilled to a total depth of 3245 ft. The sand bodies of interest were encountered at various depths 3157-3195ft and 3220-3232ft. The data for the study includes cores, cores photographs and wireline logs. It involves the use of a detailed core description, core photography and explanation of logs by the use of log motifs with correlation on a well to depth.

Procedure of Core Description

A core is a representative reservoir specimen which yields fundamental for effective exploration, description and exploitation [5-6]. A detailed sedimentological description involves a detailed characterization of the lithology, bed thickness, sedimentary structures, interpretation of depositional environment. This core description is useful for delineating rock type, thickness of facies, sedimentary structures, biogenic structures, texture and visible porosity type.

Already, slabbed core of above 110ft were displayed on 3ft trays and described serially from top to bottom. This involved making a depth plot on the sheet, inserting core numbers and drawing lines across the sheet and denoting the boundaries of the beds. Areas of core loss and uncored areas that are drilled out were indicated on the sheet by diagonal lines.

A visual estimate of percentage of shale was plotted in the description sheet and grain size analysis done using a comparator for grain size and thus plotted on the logging sheet. The diluted acid (HCI) was used to delineate the presence of carbon. Carbonate cementation was also determined and graded into different degrees as medium, hard or very hard. Other sedimentary structures like lenticular bedding, cross bedding, flaser bedding and ripple laminations were observed and plotted, irrespective of intensity Bioturbation features was seen.

Using the above parameters in conjunction with [7], lithofacies scheme and with the help of grain size trends, the lithofacies were determined. Major erosional breaks/boundaries were recorded using upright and inverted triangles to indicate coarsening upward and fining upward sequences respectively.

Results and Interpretation

Lithofacies Description

A lithofacies is a rock body which has distinct characteristics based on composition, bedding, textures, sedimentary structures, colour and biogenic structures. With reference to the features of the cored section of the Odirin Well 1, seven lithofacies were identified from cores using the reported method of classification [7].

A. Dark Grey Laminated Mudstone (MSd)

This lithofacies consists of a dark grey finely laminated mudstone containing sideritic nodules, shell fragments and a rip up clast structure originated due to quiet deposition. And if well preserved, the mudstones will form vertical permeability barriers and baffles.

B. Bioturbated Sandy Heterolith (SI)

This lithofacies are of greyish erosive base bioturbated clayey fine grained sandstone. The biotubation predominates the entire unit. The vertical burrows indicates *Ophiomorpha* hence delineates a channel influenced by tide.

C. Lenticular Bedded Heterolith (Mst)

This unit is brownish and sharp base very fine grained sandstone and siltstone. Horizontal beds are common with low angle cross lamination and lenticular bedding. Vertical and inclined burrows of *Ophiomorpha and I Rhizocorallium* are common.

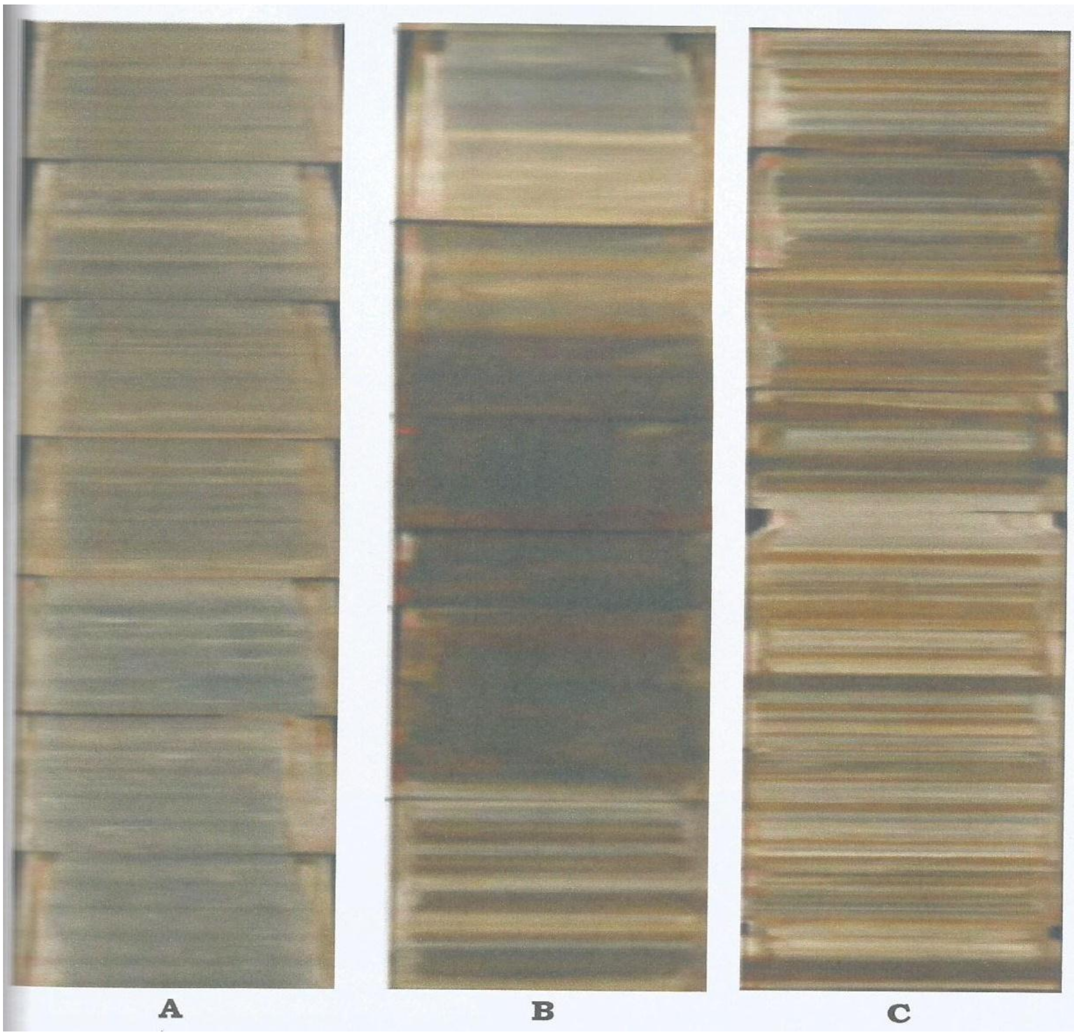

Figure 2: Core pictures (a) Laminated mudstone, (b) Bioturbated sandstone, (c) Wavy lenticular hetrolith

Lithofacies and Stacking Pattern

The Odirin Well 1 of the Ene field used in this work with the cored section seven district lithofacies (figure 2). The common lithofacies scheme used [7] combines depositional pattern, entire rock properties and fluid flow. Considering the above therefore, five main sandstone reservoirs are identified with two non reservoir bodies. The sandstone reservoir bodies are:

1. Bioturbated sandy heterolith
2. Bioturbated sandstone

3. Wavy bedded sandy heterolith
4. Fine grained mm scale laminated sandstones
5. Lenticular bedded heterolith

The entire cored section is dominated by various stacking patterns ranging a coarsening upward sequence, overlain by a fining upward sequence.

The individual cycles tend to display other sequences but an overall major upward sequence was displayed.

Table 1: Size parameters for Core 1, Odirin Well 1

Sample No.	Depth	Median	Mean	Sorting	Skewness	Kurtosis
1	3158	2.69	2.94	0.85	0.01	1.04
2	3159	2.71	2.86	0.82	0.02	1.07
3	3160	2.76	2.83	0.86	-0.02	1.03
4	3161	2.71	2.87	0.84	0.00	1.00
5	3162	2.57	2.83	0.76	0.01	1.01
6	3163	2.60	2.80	0.74	0.00	1.04
7	3164	2.68	2.74	0.84	0.01	1.07
8	3165	2.43	2.86	0.88	0.01	1.05
9	3167	2.54	2.81	0.85	-0.98	1.00
10	3168	2.88	2.84	0.83	0.01	1.01
11	3171	2.89	2.90	0.84	-0.02	1.04
12	3172	2.85	2.84	0.67	0.01	1.03
13	3174	2.52	2.54	0.00	0.94	0.73
14	3187	2.28	2.26	0.68	-0.01	0.94
15	3188	2.90	2.91	0.65	0.00	0.99

Table 2: Summary of Core porosity and Permeability values for the core

Sample No.	Depth	Core Porosity Data	Core Permeable Data
23H	3157	12.6	4.42
24 H	3158	22.4	9.42
25 H	3159	22.2	9.425
26 H	3160	28.0	16.9
28 H	3162	35.5	1220
29 H	3163	31.7	1200
30 H	3164	34.7	1560
31 H	3165	28.2	196
32 H	3166	34.8	1020
33 H	3167	33.8	1340
34 H	3168	32.9	4.73
35 H	3169	23.3	14.0
36 H	3170	24.5	3.33
37 H	3171	42.1	3.31
38 H	3172	21.2	3.29
41 H	3175	27.3	6.70
43 H	3177	30.9	67.5
44 H	3178	29.0	47.6
45 H	3179	36.7	78.5
48 H	3181	31.4	91.1
49 H	3184	36.2	26.9
54 H	3188	16.3	21.9
55 H	3189	29.3	77.1

Grain Size Analysis

Grain size analysis was carried out on the fifteen (15) representative samples from the horizontal core plugs 1 and 2 and statistical parameters were calculated and interpreted using reported equation [8].

(a) Mean (Mz)

The mean of sediment indicates the average diameter. From the analyzed samples, the mean values range from 3.194) (very fine) — 2.284ϕ (fine) with representative value of 2.89ϕ) (fine sand). From the analysis, it is inferred that deposition of sediments is in a low-energy environment.

(b) Sorting (So)

The sorting coefficient measures the span of distribution of the sediments around the mean value. The samples analyzed show a range of 1.23ϕ (poorly sorted) to 0.30ϕ (very well sorted) with a mean of 0.69ϕ moderately well sorted. The result shows that the deposition of sediment is in a moderate energy environment.

DEPOSITIONAL PROCESSES

The depositional process in a clastic environment is dependent on the hydrodynamic conditions operating at the time of deposition. Cumulative frequency curves were generated. From this study three major processes are identified from the curves. Traction or bed load, suspension load segment and saltation.

Plots of fifteen (15) samples show that all three processes occur within the depositional environment with saltation mode as the dominant process. The moderate standard deviation of the sample may be as a result of secondary interstitial materials which also tend to affect the size distribution. Fluvial sands are found to be deposited by suspension, traction, saltation and processes. While shoreface, tidally influenced channel sands and channel floor deposits are deposited by dominant saltation process.

Histograms were also constructed to show modal distribution. The histogram indicates a major unimodal distribution and minor bimodal distribution showing two phases of deposition representing a tidal cycle. It also suggests that the major unimodal distribution is the flood tide cycle with minor bimodal distribution representing the ebb tide cycle.

Depositional Environment

The reconstruction of the Palaeoenvironment is based on sedimentologic, stratigraphic and faunal features [5]. The main tool for delineating depositional condition of sediments is based on lithofacies interpretation.

The lithofacies stacking pattern shows a cycle of fining-upward-coarsening upward and fining upward sequences which indicates a transgressive-regressive sequence and also a fluctuating environment in terms of energy processes. In this study, mean grain size 2.280 (fine sand) shows sedimentation of a moderate energy environment. The sedimentary structures which include wave rippled, lenticular bedding and reactivation surface is indicative of a moderate or fluctuating energy of an environment of deposition. The occurrence of burrows or trace fossils of *Paleophycus*, *Diplocratarion*, *Ophiomopha* indicate sedimentation in a tidal influenced environment.

The overprint of the primary structures may be as a result of a better oxygenation with lower deposition rates. The Gamma log shape of dominant cylindrical or serrated shape indicates sedimentation in a sand-shale intercalated and moderate energy environment probably a braided fluvial channel or distributary channel fill. Therefore, from the structures above, the depositional environment is probably a shallow marine environment or a distributary channel fill.

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