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LITHOFACIES CHARACTERIZATION AND HYDROCARBON PLAY ELEMENTS OF OLIGOCENE-EARLY MIOCENE SEDIMENTS

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ABSTRACT

Lithofacies characterization and hydrocarbon play elements of Oligocene to early Miocene sediments in Greater Ughelli Depo belt Niger Delta Basin were carried out using a total of One hundred and ninety (190) Ditch cutting samples, with the aim of identifying the lithofacies and hydrocarbon play elements for the well succession. The sediments were characterize on the basis of colour, texture (grain size, shape and sorting), mineral types and accessories. A total of thirty (30) lithofacies zones which include: Sandstone, Shale, Sandy Clay, Clayey Sand, Sandy Shale and Shaly Sand facies was defined. Chemicals/ Associated minerals present at different depth are Iron oxide, Carbonate, Mica, Pyrite, Coal and Glauconite. Eleven (11) probable reservoir rocks and twelve (12) probable source rocks were identified in the well with the source rocks acting as stratigraphic traps to the probable reservoir rocks.

Keywords: Lithofacies, reservoir rocks, source rocks, Oligocene, early Miocene

1. INTRODUCTION

Petroleum has been a key source of energy and a major contributor to the economic growth in most industrialized and developing countries. The Niger Delta Basin is economically important because of its petroliferous nature and the economy of Nigeria depends largely on the oil and gas derived from it. It is found in the Tertiary period in the geologic column, It lies mainly in the Gulf of Guinea to the south west of the Benue – Trough and constitutes the most important Cenozoic deltaic construction in the south Atlantic. The combination of source rock, lithologic types, structures and thermal history of the basin are favorable for the generation, accumulation and retention of hydrocarbons (Whiteman, 1982; Stacher P.

1995; Ekweozor C.M,2000).

This was rewarded in 1956 with the drilling of the first producing well at Oloibiri by Shell-BP, the sole concessionaire at the time (SNEPCO 2002). The tertiary Niger delta has prograded south west ward from Eocene to present forming depo belt that represent the most active portion of the delta at each stage of its development (Doust and Omatsola, 1990). The 12km thick Niger delta clastic wedge spans a 75,000 km^2 area in southern Nigeria and the Gulf of Guinea offshore Nigeria. This clastic wedge contains the 12^{th} largest known accumulation of recoverable Hydrocarbon with reserves exceeding 34billion barrels of oil and 93 trillion cubic feet of gas. The Niger delta province contains only one identified petroleum system (Kulke,1995;Ekweozor and Daukoru 1994),this system is referred to as the tertiary Niger delta (Akata - Agbada) petroleum system. Currently most of this petroleum is in the field that are onshore or on the continental shelf in waters less than 200m deep and occurs primarily in simple structures.

2. LITHOSTRATIGRAPHY OF NIGER DELTA

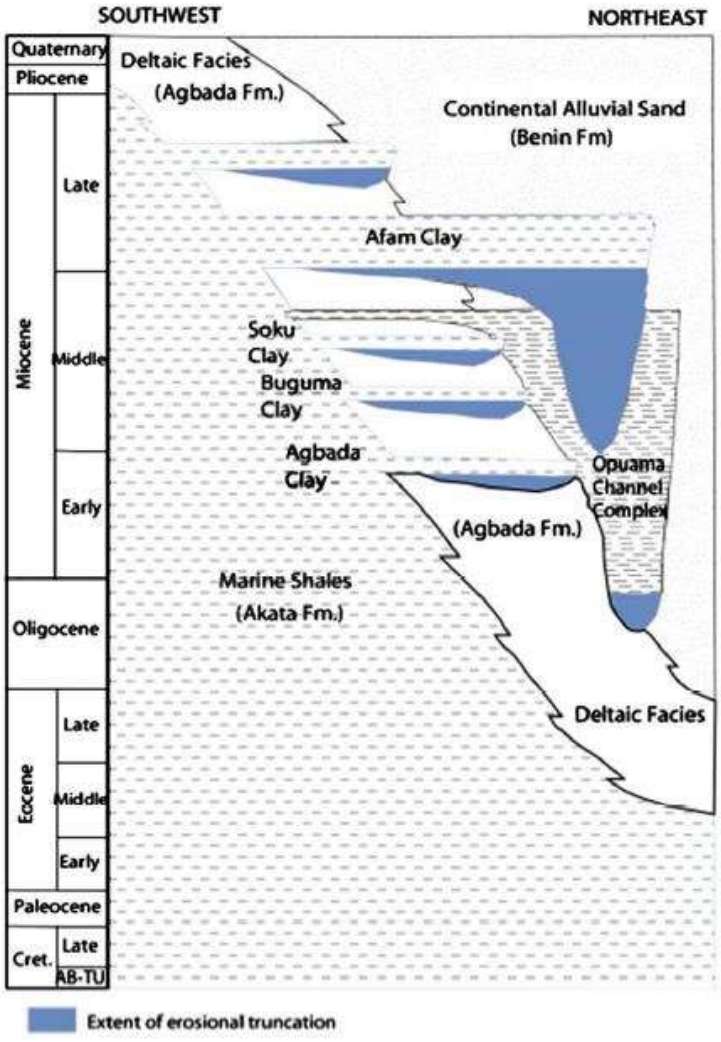

Figure 1. Stratigraphic column showing formations of the Niger Delta. (Doust and Omatsola, 1990).

The Tertiary section of the Niger Delta is divided into three formations, representing pro-grading depositional facies that are distinguished mostly on the basis of sand-shale ratios. The type sections of these formations are described in Short and Stäuble (1967) and summarized in a variety of papers (e.g. Avbobvo, 1978; Doust and Omatola, 1990; Kulke, 1995). However, the three stratigraphic units are: Akata Formation, Agbada Formation and Benin Formation (Short and Stauble, 1967). The three major lithostratigraphic units defined in the subsurface of the Niger Delta (Akata, Agbada and Benin Formations) becomes progressively younger farther into the basin, reflecting the overall regression of depositional environments within the Niger Delta clastic wedge. Stratigraphic equivalent units to these three formations are exposed in southern Nigeria. The formations reflect a gross coarsening-upward progradational clastic wedge (Short and Stauble, 1967), deposited in marine, deltaic, and fluvial environments (Weber and Daukoru, 1975; Weber, 1986).

3. AKATA FORMATION

This is the major time transgressive lithological unit of the Niger Delta, it is mainly a marine mud facies with turbidity sand and continental slope channel fills. The type section of the Akata Formation was defined in Akata 1 Well, 80 km east of Port Harcourt (Short and Stauble, 1967). A total depth of 11,121 feet (3, 680 m) was reached in the Akata 1 well without encountering the base of this formation. The top of the formation is defined by the deepest occurrence of deltaic sandstone beds (7,180 feetin Akata well). The formation underlies the whole of the Niger delta complex (Whiteman,1982, P.131). The Akata formation consist of dark grey shales and silts, with rare streaks of sand of probable turbidite flow origin (Doust and Omatsola, 1989). in the upper part, in some localities it tends to be sandy were it grades in to the Agbada formation. The formation is taught to range from 2000ft(610m) to 20,000ft(6,100m) in thickness (Merki 1972). The Akata formation is Paleocene to Recent in Age (Doust and Omatsola, 1989), rich in Planktic foraminifera which indicate deposition on a shallow marine shelf. Marine planktonic foraminifera make up to 50% of the microfauna assemblage and suggest shallow marine shelf deposition (Doust and Omatsola, 1989).

4. AGBADA FORMATION

Short and Stauble (1967) named the middle part of the tripartite Niger delta stratigraphic succession as the Agbada formation. the Agbada formation is defined in the Agbada 2well drilled about 11km north-northwest of Port Harcourt (Short and Stauble, 1967). The mangrove swamp to coastal barrier and fluviomarine zone of the present day delta constitute the surface exposure of the Agbada formation of recent age. The well reached a total depth of 9500 feet without penetrating the base of the formation (the base was defined as the top of the Akata Formation in Akata 1 well).the top of the formation is usually taken as the shallowest occurrence of shale bearing a brackish or marine fauna. The Agbada formation is often seen in seismic as an erosional surface demarcating it from the overlying unfaulted Benin sand. The lithologies consist of alternating sands, silts and shales arranged within ten to hundred feet successions

defined by progressive upward changes in grain size and bed thickness. The strata are generally interpreted to have formed in fluvial-deltaic environments. The formation ranges in age from Eocene to Pleistocene. The thickness of the Agbada formation varies greatly across the delta, Merki (1971) indicates a maximum thickness of 4,500m while Weber and Daukoru (1975) gave a range from 9,600ft to 14000ft (2,927m - 4,268m). The Agbada formation is thickest on the central swamp and coastal swamp depobelt which is where the Benin formation is also thickest and regarded as the zone of maximum subsidence. The sequence is associated with sedimentary growth faulting and contains the bulk of the hydrocarbon reservoirs. The top of the Agbada Formation is often defined as the base of fresh water sand.

5. BENIN FORMATION

The Benin Formation comprises the top part of the Niger Delta clastic wedge, from the Benin-Onitsha area in the north to beyond the present coastline (Short and Stauble, 1967). Its type section is Elele 1 Well, drilled about 38 km north-northwest of Port Harcourt (Short and Stauble, 1967). The top of the formation is the recent subaerially-exposed delta top surface and its base extends to a depth of 4600 feet. The base is defined by the youngest marine shale.

Shallow parts of the formation are composed entirely of non-marine sand deposited in alluvial or upper coastal plain environments during progradation of the delta (Doust and Omatsola, 1989). The formation thins basin ward and ends near the shelf edge. Although lack of preserved fauna inhibits accurate age dating, the age of the formation is estimated to range from Oligocene to Recent (Short and Stauble, 1967). It is a continental latest Oligocene to Recent deposit of alluvial and upper coastal plain that are up to 2000m thick (Avobovbo, 1978). It is deposited in the upper coastal plain environments following a southward shift of deltaic deposition into a new depobelt. Benin Formation is the youngest formation in the Niger Delta; the formation consists of massive, highly porous, freshwater bearing sandstones with local thin shale interbed which is considered to be of braided stream origin. the formation is identifiable in the subsurface on account of its high sand percentage (70-80%), few shale breaks which increase in frequency towards the base and the general absence of brackish water and marine faunas. The sand and sandstone of the Benin Formation are coarse to fine grain in general and are poorly sorted. The formation thins basinward and ends near the shelf edge.

6. AIM AND OBJECTIVES OF THE STUDY

AIM

The aim of this work is to erect a litho stratigraphic model and acquire geological information on the hydrocarbon play elements in the well.

OBJECTIVES:

- To establish a litholog /lithofacie model for the wells succession.
- To highlight reservoir rocks and source rocks present in the well

7. LOCATION OF THE STUDY AREA

The well is located in Greater Ughelli Depo belt, Niger delta basin southern Nigeria, it was drilled from 20ft (6.09m) to a depth of 11820ft (3603.7m). The sedimentary sequence of the wells collected at different depths show changes in lithological characteristics / properties, suggesting a period of transgression and regression events.

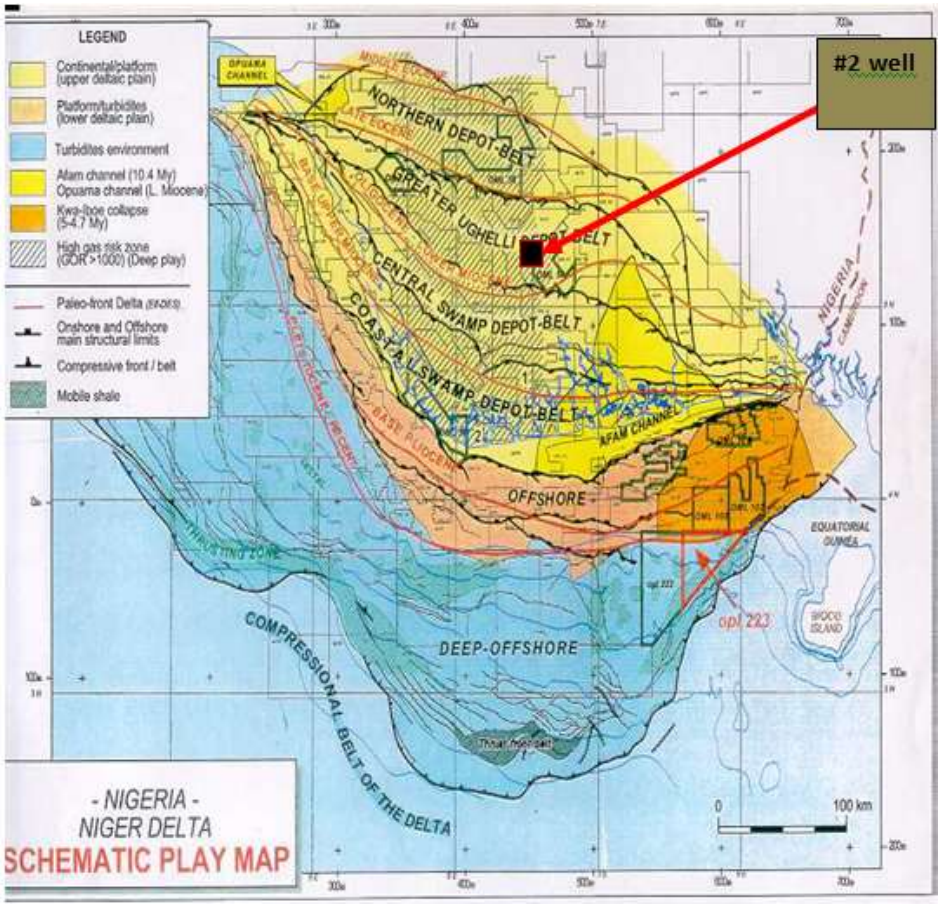

Figure 2: Location Map of #2 Well
Source: Nigerian Petroleum Development Company

8. SAMPLE COLLECTION/MATERIALS

The methodology of this study involves two phases. They are; sedimentologic study of sample collected and laboratory analyses of selected intervals from the well for Palynology analysis.

9. Equipment and Materials

This study was carried out on Ditch Cutting samples, obtained through permission from Nigerian Petroleum Development Company (NPDC). A total of One hundred and ninety (190) ditch cutting samples were gotten from the well, samples were collected at depth of 20feet (6.09m) to 11820feet (3603.7m) and retrieved at 60feet interval from the well.

10. Sedimentologic Description:

The first stage of the laboratory analysis was the lithological sample description. Washed (to remove the additives) samples were examined visually and under the microscope to determine the different lithology by considering the colour, texture (grain size, shape and sorting), mineral types and accessories such as mica, quartz, pyrite, iron oxide, glauconite and carbonaceous detritus . Diluted Hydrochloric acid was used to test for the presence of carbonate. Effervescence indicates the presence of carbonate in the sediment. Photomicrographs were taken at some depths to show some of the minerals in the sample as well as the lithofacies as shown in Plate 1 below.

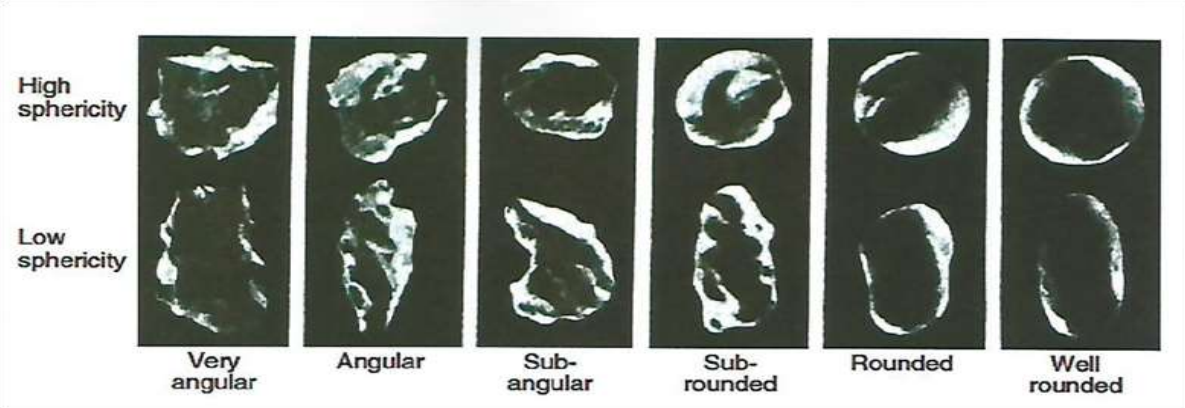

Figure 3: Grain Images for estimating the Roundness of Sedimentary particles (After Powers, 1953)

LITHOLOGS

- Grain size, Sorting & Shapes
- Lithofacies zone
- Homogenetic &Heterogenetic zone
- Associated minerals
- Sedimentary description using a lithfacies model

11. RESULTS AND INTERPRETATION

Samples were examined visually and under the microscope to determine the different lithofacies by considering the colour, texture (grain size, shape and sorting), which aided in the subdivision of the various sampled intervals into litofacies zone, homogeneous and heterogenous zones. Mineral/chemical types and accessories such as mica, quartz, pyrite, iron oxide, glauconite and carbonaceous detritus are also identified. Diluted hydrochloric acid was used to test or identify the presence of carbonate in the sediments. When dilute hydrochloric acid comes in contact with the sample if it effervescence it indicates the presence of carbonate in the sediment. A total of one hundred and ninety (190) ditch cutting samples were collected from the well at different intervals. The samples were lithologically described using a reflected light microscope in order to obtain the texture, sorting, color, shapes/roundness, mineral

composition, and post depositional diagenetic effect. These properties are vital for the analysis of lithofacies. Lithofacies is a means of classifying and grouping sedimentary deposits in such a way that objective differences, usually with genetic significance are highlighted. Consequently, a Geological model embracing Lithofacies, mineral associated, homogenetic and heterogenetic zones were generated for the Well's sedimentary succession. Two lithostratigraphic units - Benin and Agbada Formations were penetrated by the drill, with lithofacies units ranging from Sand, Claye sand, Shale, Shaly sand and Sandy Shale respectively. See Table 1

Table 1: SEDIMENTOLOGIC DESCRIPTION OF THE WELL SAMPLES

S/N	Depth (ft)	Lithology	Description
1	20	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subangular to subrounded, moderately sorted sand with cuticle present . Non calcareous.
2	80	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subangular to subrounded, moderately sorted sand with cuticle present . Non calcareous.
3	140	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subangular to subrounded, moderately sorted sand with cuticle present . Non calcareous.
4	200	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subangular to subrounded, moderately sorted sand with cuticle present . Non calcareous.
5	260	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subangular to subrounded, moderately sorted sand with cuticle present . Non calcareous.
6	320	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subangular to subrounded, moderately sorted sand with cuticle present . Non calcareous.
7	380	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subangular to subrounded, moderately sorted sand with cuticle present . Non calcareous.

8	440	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subangular to subrounded, moderately sorted sand with cuticle present . Non calcareous.
9	500	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subangular to subrounded, moderately sorted sand with cuticle present . Non calcareous.
10	560	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subangular to subrounded, moderately sorted sand with cuticle present . Non calcareous.
11	620	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subangular to subrounded, moderately sorted sand with cuticle present . Non calcareous.
12	680	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subangular to subrounded, moderately sorted sand with cuticle present . Non calcareous.
13	740	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subangular to subrounded, moderately sorted sand with cuticle present . Non calcareous.
14	800	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subangular to subrounded, moderately sorted sand with cuticle present . Non calcareous.
15	860	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subangular to subrounded, moderately sorted sand with cuticle present . Non calcareous.
16	920	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subangular to subrounded, moderately sorted sand with cuticle present . Non calcareous.
17	980	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subangular to subrounded, moderately sorted sand with cuticle present . Non calcareous.
18	1040	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subangular to subrounded, moderately sorted sand with cuticle present . Non calcareous.

19	1100	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subangular to subrounded, moderately sorted sand with cuticle present . Non calcareous.
20	1160	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subangular to subrounded, moderately sorted sand with cuticle present . Non calcareous.
21	1220	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subangular to subrounded, moderately sorted sand with cuticle present . Non calcareous.
22	1280	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subangular to subrounded, moderately sorted sand with cuticle present . Non calcareous.
23	1340	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subangular to subrounded, moderately sorted sand with cuticle present . Non calcareous.
24	1400	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subangular to subrounded, moderately sorted sand with cuticle present . Non calcareous.
25	1460	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subangular to subrounded, moderately sorted sand with cuticle present . Non calcareous.
26	1520	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subangular to subrounded, moderately sorted sand with cuticle present . Non calcareous.
27	1580	Sandy clay	Milky in colour clay with sand. Calcareous
28	1640	clayey sand	Milky in colour , translucent to opaque, medium to coarse grain, subangular to subrounded, poorly sorted sand with clay, cuticle present . Non calcareous
29	1700	clayey sand	Milky in colour , translucent to opaque, medium to coarse grain, subangular to subrounded, poorly sorted sand with clay, cuticle present . Non calcareous

30	1780	clayey sand	Milky in colour , translucent to opaque, medium to coarse grain, subangular to subrounded, poorly sorted sand with clay, cuticle present . Non calcareous
31	1820	clayey sand	Milky in colour , translucent to opaque, medium to coarse grain, subangular to subrounded, poorly sorted sand with clay, cuticle present . Non calcareous
32	1880	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subangular to subrounded, moderately sorted sand with cuticle present . calcareous
33	1940	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subangular to subrounded, moderately sorted sand with cuticle present . calcareous
34	2000	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subangular to subrounded, moderately sorted sand with cuticle present . calcareous
35	2060	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present . Non calcareous
36	2120	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present . Non calcareous
37	2180	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present . Non calcareous
38	2240	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present . Non calcareous
39	2300	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present . Non calcareous
40	2360	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present . Non calcareous

41	2420	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present . Non calcareous
42	2480	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present . Non calcareous
43	2540	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present . Non calcareous
44	2600	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present . Non calcareous
45	2660	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present . Non calcareous
46	2720	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present . Non calcareous
47	2780	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present . Non calcareous
48	2840	Sandstone	Milky in colour translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present. Non calcareous
49	2900	Sandstone	Milky in colour translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present. Non calcareous
50	2960	Sandstone	Milky in colour translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present. Non calcareous
51	3020	Sandstone	Milky in colour translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present. Non calcareous

52	3080	Sandstone	Milky in colour translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present. Non calcareous
53	3140	Sandstone	Milky in colour translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present. Non calcareous
54	3200	Sandstone	Milky in colour translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present. Non calcareous
55	3260	Sandstone	Milky in colour translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present. Non calcareous
56	3320	Sandstone	Milky in colour translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present. Non calcareous
57	3420	Sandstone	Milky in colour translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present. Non calcareous
58	3500	Sandstone	Milky in colour translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present. Non calcareous
59	3560	Sandstone	Milky in colour translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present. Non calcareous
60	3640	Sandstone	Milky in colour translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present. Non calcareous
61	3740	Sandstone	Milky in colour translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present. Non calcareous
62	3800	Sandstone	Milky in colour translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present. Non calcareous

63	3880	Sandstone	Milky in colour translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present. Non calcareous
64	3960	Sandstone	Milky in colour translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present. Non calcareous
65	4020	Sandstone	Milky in colour translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present. Non calcareous
66	4100	Sandstone	Milky in colour translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present. Non calcareous
67	4190	Sandstone	Milky in colour translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present. Non calcareous
68	4240	Sandstone	Milky in colour translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present. Non calcareous
69	4320	Sandstone	Milky in colour translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present. Non calcareous
70	4380	Sandstone	Milky in colour translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present. Non calcareous
71	4440	Sandstone	Milky in colour translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present. Non calcareous
72	4500	Sandstone	Milky in colour translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present. Non calcareous
73	4560	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticles and lignite streak present . Non calcareous

74	4620	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticles and lignite streak present . Non calcareous
75	4680	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticles and lignite streak present . Non calcareous
76	4740	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticles and lignite streak present . Non calcareous
77	4820	Shale	Light grey fissile shale. Non Calcareous
78	4900	Shale	Light grey fissile shale. Non Calcareous
79	4980	Sandstone	Milky in colour , translucent to opaque, medium grain, subrounded to rounded, well sorted sand with cuticles and lignite streak present . Non calcareous
80	5040	Sandstone	Milky in colour , translucent to opaque, medium grain, subrounded to rounded, well sorted sand with cuticles and lignite streak present . Non calcareous
81	5100	Shale	light grey fissile shale. Non Calcareous
82	5160	Sandstone	Milky in colour , translucent to opaque, medium grain, subrounded to rounded, moderately to well sorted sand with cuticles and lignite streak present . Non calcareous
83	5220	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subrounded to rounded, well sorted sand with cuticles and lignite streak present . Non calcareous
84	5280	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subrounded to rounded, well sorted sand with cuticles and lignite streak present . Non calcareous
85	5340	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subrounded to rounded, well sorted sand with cuticles and lignite streak present . Non calcareous

86	5400	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subrounded to rounded, well sorted sand with cuticles and lignite streak present . Non calcareous
87	5460	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subrounded to rounded, well sorted sand with cuticles and lignite streak present . Non calcareous
88	5520	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subrounded to rounded, well sorted sand with cuticles and lignite streak present . Non calcareous
89	5580	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subrounded to rounded, well sorted sand with cuticles and lignite streak present . Non calcareous
90	5640	Shale	Light grey fissile shale with cuticles and lignite streaks present Non calcareous
91	5700	Sandstone	Milky in colour, translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted, with, cuticles and lignite streak present. Non calcareous
92	5760	Shale	Light grey fissile shale with cuticles and lignite streaks present Non calcareous
93	5820	Sandstone	Milky in colour, translucent to opaque, medium to coarse grain, subrounded to rounded, moderately sorted sand with cuticles and lignite streak present. Non calcareous
94	5920	Sandstone	Milky in colour, translucent to opaque, medium to coarse grain, subrounded to rounded, moderately sorted sand with cuticles and lignite streak present. Non calcareous
95	5980	Sandstone	Milky in colour, translucent to opaque, medium to coarse grain, subrounded to rounded, moderately sorted sand with cuticles and lignite streak present. Non calcareous
96	6040	Sandstone	Milky in colour, translucent to opaque, medium to coarse grain, subrounded to rounded, moderately sorted sand with cuticles and lignite streak present. Non calcareous

97	6100	Sandstone	Milky in colour, translucent to opaque, medium to coarse grain, subrounded to rounded, moderately sorted sand with cuticles and lignite streak present . Non calcareous
98	6160	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subrounded to rounded, moderately sorted sand with cuticles and lignite streak present . Non calcareous
99	6220	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subrounded to rounded, moderately sorted sand with cuticles and lignite streak present . Non calcareous
100	6280	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subrounded to rounded, moderately sorted sand with cuticles and lignite streak present . Non calcareous
101	6340	Sandstone	Milky in colour , translucent to opaque, medium to coarse grain, subrounded to rounded, moderately sorted sand with cuticles and lignite streak present . Non calcareous
102	6400	Shale	light grey shale with lignite streak present. Non calcareous
103	6460	Sandstone	Milky in colour, translucent to opaque, medium grain, sub angular to subrounded, moderately sorted sand with lignite streak and cuticle present. Non calcareous
104	6520	Sandstone	Milky in colour , translucent to opaque, medium grain, sub angular to subrounded , moderately sorted sand with lignite streak and cuticle present . Non calcareous
105	6580	Sandstone	Milky in colour , translucent to opaque, medium grain, sub angular to subrounded , moderately sorted sand with lignite streak and cuticle present . Non calcareous
106	6640	Sandstone	Milky in colour , translucent to opaque, medium grain, sub angular to subrounded , moderately sorted sand with lignite streak and cuticle present . Non calcareous
107	6700	Sandstone	Milky in colour , translucent to opaque, medium grain, sub angular to subrounded , moderately sorted sand with lignite streak and cuticle present . Non calcareous

108	6760	Shaly sand	Milky in colour , translucent to opaque, medium grain, subangular to subrounded, moderately sorted sand with light grey shale, lignite streak and cuticle present. Non calcareous
109	6820	Shaly sand	Milky in colour , translucent to opaque, medium grain, subangular to subrounded, moderately sorted sand with light grey shale, lignite streak and cuticle present . Non calcareous
110	6880	Shaly sand	Milky in colour , translucent to opaque, medium grain, subangular to subrounded, moderately sorted sand with light grey shale, lignite streak and cuticle present . Non calcareous
111	6940	Sandstone	Milky in colour , translucent to opaque, medium grain, subrounded to rounded, moderately to well sorted sand with ,lignite streak and cuticle . Non calcareous
112	7000	Sandstone	Milky in colour , translucent to opaque, medium grain, subrounded to rounded, moderately to well sorted sand with ,lignite streak and cuticle . Non calcareous
113	7060	Sandstone	Milky in colour , translucent to opaque, medium grain, subrounded to rounded, moderately to well sorted sand with ,lignite streak and cuticle . Non calcareous
114	7120	Sandstone	Milky in colour , translucent to opaque, medium grain, subrounded to rounded, moderately to well sorted sand with ,lignite streak and cuticle . Non calcareous
115	7180	Sandstone	Milky in colour , translucent to opaque, medium grain, subrounded to rounded, moderately to well sorted sand with ,lignite streak and cuticle . Non calcareous
116	7240	Sandstone	Milky in colour , translucent to opaque, medium grain, subrounded to rounded, moderately to well sorted sand with ,lignite streak and cuticle . Non calcareous
117	7300	Sandstone	Milky in colour , translucent to opaque, medium grain, subrounded to rounded, moderately to well sorted sand with ,lignite streak and cuticle . Non calcareous
118	7380	Sandstone	Milky in colour , translucent to opaque, medium grain, subrounded to rounded, moderately to well sorted sand with ,lignite streak and cuticle . Non calcareous

119	7440	Shale	Light grey fissile shale. Non Calcareous
120	7500	Sandstone	Milky in colour , translucent to opaque, medium grain, subrounded to rounded, moderately to well sorted sand with ,lignite streak and cuticle . Non calcareous
121	7560	Sandstone	Milky in colour , translucent to opaque, medium grain, subrounded to rounded, moderately to well sorted sand with ,lignite streak and cuticle . Non calcareous
122	7620	Sandstone	Milky in colour , translucent to opaque, medium grain, subrounded to rounded, moderately to well sorted sand with ,lignite streak and cuticle . Non calcareous
123	7680	Sandstone	Milky in colour , translucent to opaque, medium grain, subrounded to rounded, moderately to well sorted sand with ,lignite streak and cuticle . Non calcareous
124	7740	Sandstone	Milky in colour , translucent to opaque, fine grain, rounded, well sorted sand with lignite streak and cuticle . Non calcareous
125	7800	Sandstone	Milky in colour , translucent to opaque, fine grain, rounded, well sorted sand with lignite streak and cuticle . Non calcareous
126	7860	Sandstone	Milky in colour , translucent to opaque, medium grain, subrounded to rounded, moderately to well sorted sand with lignite streak and cuticle . Non calcareousl
127	7920	Sandstone	Milky in colour , translucent to opaque, medium grain, subrounded to rounded, moderately to well sorted sand with lignite streak and cuticle . Non calcareousl
128	7980	Sandstone	Milky in colour , translucent to opaque, medium grain, subrounded to rounded, moderately to well sorted sand with lignite streak and cuticle . Non calcareousl
129	8060	Sandstone	Milky in colour , translucent to opaque, medium grain, subrounded to rounded, moderately to well sorted sand with lignite streak and cuticle . Non calcareousl

130	8120	Sandstone	Milky in colour , translucent to opaque, medium grain, subrounded to rounded, moderately to well sorted sand with lignite streak and cuticle . Non calcareousl
131	8180	Shale	Light grey fissile shale with lignite streak and cuticles. Non calcareous
132	8240	Shale	Light grey fissile shale with lignite streak and cuticles. Non calcareous
133	8300	Sandstone	Milky in colour , translucent to opaque, fine to medium grains, subrounded to rounded, moderately to well sorted sand with lignite streak and cuticles present.Non calcareous
134	8360	Shale	Grey fissile shale with cuticle present.Non calcareous
135	8420	Shale	Grey fissile shale with cuticle present.Non calcareous
136	8480	Sandstone	Milky in colour, translucent to opaque, fine to medium grains, subrounded to rounded, moderately to well sorted sand with lignite streak and cuticles present, Non calcareous
137	8540	Sandstone	Milky in colour , translucent to opaque, fine to medium grains, subrounded to rounded, moderately to well sorted sand with lignite streak and cuticles present, Non calcareous
138	8600	Sandstone	Milky in colour , translucent to opaque, fine to medium grains, subrounded to rounded, moderately to well sorted sand with lignite streak and cuticles present,Non calcareous
139	8660	Sandstone	Milky in colour , translucent to opaque, fine to medium grains, subrounded to rounded, moderately to well sorted sand with lignite streak and cuticles present, Non calcareous
140	8720	Sandstone	Milky in colour, translucent to opaque, fine to medium grains, subrounded to rounded, moderately to well sorted sand with lignite streak and cuticles present, Non calcareous
141	8780	Sandstone	Milky in colour , translucent to opaque, fine to medium grains, subrounded to rounded, moderately to well sorted sand with lignite streak and cuticle present. calcareous

142	8840	Sandstone	Milky in colour , translucent to opaque, fine to medium grains, subrounded to rounded, moderately to well sorted sand with lignite streak and cuticle present. calcareous
143	8900	Sandstone	Milky in colour , translucent to opaque, fine to medium grains, subrounded to rounded, moderately to well sorted sand with lignite streak and cuticle present. calcareous
144	8960	Sandstone	Milky in colour , translucent to opaque, fine to medium grains, subrounded to rounded, moderately to well sorted sand with lignite streak and cuticle present. calcareous
145	9020	Sandstone	Milky in colour , translucent to opaque, fine to medium grains, subrounded to rounded, moderately to well sorted sand with lignite streak and cuticle present. calcareous
146	9080	Sandstone	Milky in colour , translucent to opaque, fine to medium grains, subrounded to rounded, moderately to well sorted sand with lignite streak and cuticle present. calcareous
147	9120	Sandstone	Milky in colour , translucent to opaque, fine to medium grains, subrounded to rounded, moderately to well sorted sand with lignite streak and cuticle present. calcareous
148	9200	Sandstone	Milky in colour , translucent to opaque, fine to medium grains, subrounded to rounded, moderately to well sorted sand with lignite streak and cuticle present. calcareous
149	9260	Sandy shale	Light grey fissile shale with sand, lignite Streak and cuticles present. Non Calcareous
150	9320	Sandy shale	Light grey fissile shale with sand, lignite Streak and cuticles present. Calcareous
151	9380	Shale	Light grey fissile shale with lignite Streak and cuticles present. Calcareous
152	9440	Shale	Light grey fissile shale with lignite Streak and cuticles present. Calcareous
153	9500	Shale	Light grey fissile shale with lignite Streak and cuticles present. Calcareous

154	9560	Shale	Light grey fissile shale with lignite Streak and cuticles present. Calcareous
155	9620	Shale	Light grey fissile shale with lignite streak and cuticle, calcareous
156	9680	Shale	Light grey fissile shale with lignite streak and cuticle, Non calcareous
157	9740	Shale	Light grey fissile shale with lignite streak and cuticle, Non calcareous
158	9800	Shale	Light grey fissile shale with lignite streak and cuticle, Non calcareous
159	9860	Shale	Light grey fissile shale with lignite streak and cuticle, Non calcareous
160	9920	Shale	Light grey fissile shale with lignite streak and cuticle, Non calcareous
161	9980	Shale	Light grey fissile shale with lignite streak and cuticle, Non calcareous
162	10040	Shale	Light grey fissile shale with lignite streak and cuticle, Non calcareous
163	10100	Shale	Light grey fissile shale with lignite streak and cuticle, Non calcareous
164	10160	Shale	Light grey fissile shale with lignite streak and cuticle, Non calcareous
165	10280	Shale	Light grey fissile shale with lignite streak and cuticle, Non calcareous
166	10340	Sandy shale	light grey fissile shale with sand, lignite and plant material present. Non calcareous
167	10400	Sandy shale	light grey fissile shale with sand, lignite and plant material present. Non calcareous
168	10460	Sandy shale	light grey fissile shale with sand, lignite and plant material present. Non calcareous

169	10540	Sandy shale	light grey fissile shale with sand, lignite and plant material present. Non calcareous
170	10600	Shale	Light grey fissile shale with lignite streak. non calcareous
171	10660	Shale	Light grey fissile shale with lignite streak. non calcareous
172	10760	Sandstone	Milky in colour , translucent to opaque, medium to coarse grains, subangular to subrounded, moderately sorted sand with lignite streak .non calcareous
173	10820	Shale	Light grey fissile shale with lignite streak. non calcareous
174	10900	Shale	Light grey fissile shale with lignite streak . non calcareous
175	10980	Shale	Light grey fissile shale with lignite streak . non calcareous
176	11040	Sandstone	Milky in colour , translucent to opaque, medium grains, subrounded to rounded, moderately to well sorted sand with lignite streak .non calcareous
177	11100	Shale	Light grey fissile shale with lignite streak. non calcareous
178	11160	Shale	Light grey fissile shale with lignite streak. non calcareous
179	11220	Shale	Light grey fissile shale with lignite streak. non calcareous
180	11280	Shale	Light grey fissile shale with lignite streak. non calcareous
181	11340	Shale	Light grey fissile shale with lignite streak. non calcareous
182	11400	Shale	Light grey fissile shale with lignite streak. non calcareous
183	11460	Shale	Light grey fissile shale with lignite streak. non calcareous
184	11520	Shale	Light grey fissile shale with lignite streak. non calcareous
185	11580	Shale	Light grey fissile shale with lignite streak. non calcareous
186	11640	Shale	Light grey fissile shale with lignite streak. non calcareous
187	11700	Shale	Light grey fissile shale with lignite streak. non calcareous
188	11760	Shale	Light grey fissile shale with lignite streak. non calcareous
189	11820	Shale	Light grey fissile shale with lignite streak. non calcareous

12. LITHOFACIES ZONES

The concept of lithofacies as applied to sediments is a means of classifying and grouping sedimentary deposits in such a way that objective differences, usually with genetic significance are highlighted. A total of 30 lithofacies zones which include: Sandstone, Shale, Sandy Clay, Clayey Sand, Sandy Shale and Shaly Sand facies were defined and established on the basis of the lithologic types and mineralogical contents.

Lithofacies Zone 1 (3603.7m- 3365.9m)

This zone is characterized by Light grey fissile shale with lignite streak. non calcareous. Its thickness is 237.8m.

Lithofacies Zone 2 (3365.9m- 3347.6 m)

This zone is characterized by Milky in colour, translucent to opaque, medium grains, subrounded to rounded, moderately to well sorted sand with lignite streak non calcareous. Its thickness is 18.3m.

Lithofacies Zone 3 (3347.6 m-3280.5m)

This zone is characterized by Light grey fissile shale with lignite streak. non calcareous. Its thickness is 67.1m.

Lithofacies Zone 4 (3280.5m-3250m)

Milky in colour, translucent to opaque, medium to coarse grains, subangular to subrounded, moderately sorted sand with lignite streak. non calcareous , Its thickness is 30.5m.

Lithofacies Zone 5 (3250m-3213.4m)

This zone is characterized by Light grey fissile shale with lignite streak. non calcareous. Its thickness is 36.6m.

Lithofacies Zone 6 (3213.4m - 3134.2m)

This zone is characterized by light grey fissile shale with sand, lignite and plant material present. Non calcareous. Its thickness is 79.2m.

Lithofacies Zone 7 (3134.2m- 2841.5m)

This zone is characterized by Light grey fissile shale with lignite streak and cuticle, calcareous. Its thickness is 292.7m.

Lithofacies Zone 8 (2841.5m- 2804.9m)

This zone is characterized by Light grey fissile shale with sand, lignite Streak and cuticles present. Calcareous. Its thickness is 36.6m.

Lithofacies Zone 9 (2804.9m- 2567.1m)

This zone is characterized by Milky in colour, translucent to opaque, fine to medium grains, subrounded to rounded, moderately to well sorted sand with lignite streak and cuticle present. Calcareous. Its thickness is 237.8m.

Lithofacies Zone 10 (2567.1m- 2530.5m)

This zone is characterized by Grey fissile shale with cuticle present. Non calcareous. Its thickness is 36.6m.

Lithofacies Zone 11 (2530.5m- 2512.2m)

This zone is characterized by Milky in colour, translucent to opaque, fine to medium grains, subrounded to rounded, moderately to well sorted sand with lignite streak and cuticles present. Non calcareous. Its thickness is 18.3m.

Lithofacies Zone 12 (2512.2m- 2475.6m)

This zone is characterized by Light grey fissile shale with lignite streak and cuticles. Non calcareous. Its thickness is 36.6m.

Lithofacies Zone 13 (2475.6m- 2268.3m)

This zone is characterized by Milky in colour, translucent to opaque, medium grain, subrounded to rounded, moderately to well sorted sand with, lignite streak and cuticle. Non calcareous. Its thickness is 207.3m.

Lithofacies Zone 14 (2268.3m- 2250m)

This zone is characterized by Light grey fissile shale. Non Calcareous. Its thickness is 18.3m.

Lithofacies Zone 15 (2250m- 2097.6m)

This zone is characterized by Milky in colour, translucent to opaque, medium grain, subrounded to rounded, moderately to well sorted sand with, lignite streak and cuticle. Non calcareous. Its thickness is 152.4m.

Lithofacies Zone 16 (2097.6m-2042.7m)

This zone is characterized by Milky in colour, translucent to opaque, medium grain, subangular to subrounded, moderately sorted sand with light grey shale, lignite streak and cuticle present. Non calcareous. Its thickness is 54.9m.

Lithofacies Zone 17 (2042.7m- 1969.5m)

This zone is characterized by Milky in colour, translucent to opaque, medium grain, sub angular to subrounded, moderately sorted sand with lignite streak and cuticle present. Non calcareous Its thickness is 73.2m.

Lithofacies Zone 18 (1969.5m- 1932.9m)

This zone is characterized by light grey shale with lignite streak present. Non calcareous. Its thickness is 36.6m.

Lithofacies Zone 19 (1932.9m- 1756.1m)

This zone is characterized by Milky in colour, translucent to opaque, medium grain, subrounded to rounded, well sorted, with cuticle present. Non calcareous. Its thickness is 176.8m.

Lithofacies Zone 20 (1756.1m- 1737.8m)

This zone is characterized by Light grey fissile shale with cuticles and lignite streaks present Non calcareous Its thickness is 18.3m.

Lithofacies Zone 21 (1737.8m- 1719.5m)

This zone is characterized by Milky in colour, translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand, with, cuticles and lignite streak present. Non calcareous. Its thickness is 18.3m.

Lithofacies Zone 22 (1719.5m- 1701.2m)

This zone is characterized by Light grey fissile shale with cuticles and lignite streaks present Non

calcareous Its thickness is 18.3m.

Lithofacies Zone 23 (1701.2m - 1554.9m)

This zone is characterized by Milky in colour, translucent to opaque, medium to coarse grain, subrounded to rounded, well sorted sand with cuticles and lignite streak present. Non calcareous. Its thickness is 146.3m.

Lithofacies Zone 24 (1554.9m- 1536.6m)

This zone is characterized by light grey fissile shale. Non Calcareous. Its thickness is 18.3m.

Lithofacies Zone 25 (1536.6m- 1493.9m)

This zone is characterized by Milky in colour, translucent to opaque, medium grain, subrounded to rounded, well sorted sand with cuticles and lignite streak present. Non calcareous. Its thickness is 42.7m.

Lithofacies Zone 26 (1493.9m- 1445.1m)

This zone is characterized by Light grey fissile shale. Non Calcareous. Its thickness is 48.8m.

Lithofacies Zone 27 (1493.9m- 554.9m)

This zone is characterized by Milky in colour, translucent to opaque, medium to coarse grain, subrounded to rounded, moderately to well sorted sand with cuticle and lignite streak present, Non calcareous Its thickness is 939m.

Lithofacies Zone 28 (554.9m - 481.7m)

This zone is characterized by Milky in colour, translucent to opaque, medium to coarse grain, subangular to subrounded, poorly sorted sand with clay, cuticle present. Non calcareous. Its thickness is 73.2m.

Lithofacies Zone 29 (481.7m - 463.4m)

This zone is characterized by Milky in colour clay with sand. calcareous. Its thickness is 18.3m.

Lithofacies Zone 30 (463.4m - 6.09m)

This zone is characterized by Milky in colour, translucent to opaque, medium to coarse grain, subangular to subrounded, moderately sorted sand with cuticle present. Non calcareous. Its thickness is 457.31m.

13. HETEROGENETIC ZONE

The sampled intervals comprise of Ten (5) heterogenetic zones which comprises of Sandy clay, Clayey sand, shaly Sand and sandy shale,

14. HOMOGENETIC ZONE

The sampled intervals comprise of Twenty-seven (25) homogenetic zones which comprises of sand and shale.

15. HYDROCARBON PLAY ELEMENTS OF #2 WELL

Hydrocarbon play elements are traps which can be stratigraphic or structural (cap and seal), reservoir, source rocks and migration path. The hydrocarbon play elements of the well have been identified in the Agbada formation containing eleven (11) probable reservoir rocks which are **Litho zones** 2,4,9,11,13,15,17,19,21,23 and 25. Twelve probable source rocks were also identified in the well. In order of priority, the litho-zones containing probable reservoir and source rocks are discussed as follows: **Litho zones** 1,3,5,7,10,12,14,18,20,22,24 and 26.

Table 2: Lithostratigraphic model of the well succession

Check table at the end of article.

16. CONCLUSION

This research work combines sedimentologic (lithostratigraphy) and hydrocarbon play elements of well samples from Greater Ughelli Depo Belt, Niger Delta Basin. A total of One hundred and ninety (190) ditch cutting samples were collected from the well at different intervals. The samples were subjected to sedimentology analysis/ description. A total of thirty (30) lithofacies zones which include: Sandstone, Shale, Sandy Clay, Clayey Sand, Sandy Shale and Shaly Sand facies was defined base on the grain sizes, colour, shape, roundness and textural properties of the sediments as well as the identification of chemicals/ minerals which include: Iron oxide, Carbonate and Mica. Eleven (11) probable reservoir rocks and twelve probable source rocks were identified in the well.

PLATE 1
Associated Minerals Identified

The minerals present and identified in the sample include: Quartz, Iron oxide, Pyrite, Glauconite, Carbonate and Mica.

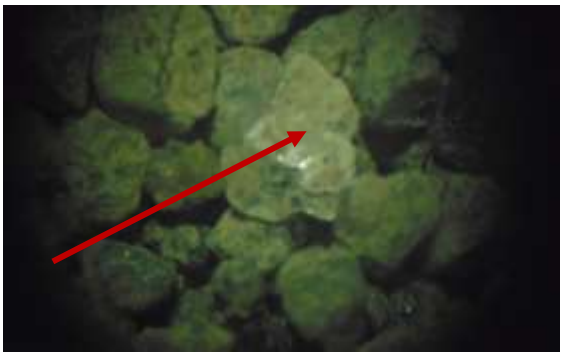

Plate 1: Mica

Plate II: Pyrite

Plate III: Quartz

Plate IV: Coal

Plate V: Glauconite

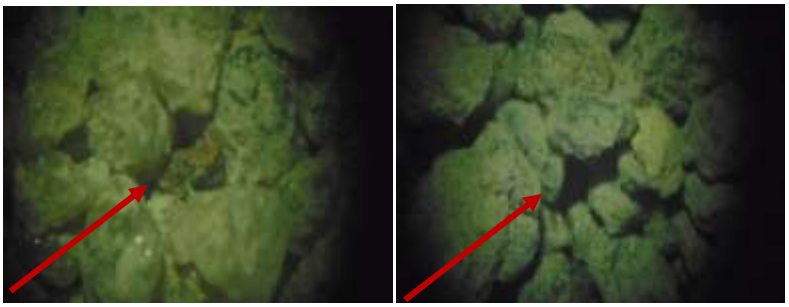

Plate VI: Iron Oxide **Plate VII: Shale**

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REFERENCES

Akpokodje, E.G., Etu-Efeotor, J.O and Olorunfemi, B.N. (1991). The composition and physical properties of some ceramic and pottery clays of South Eastern Nigeria. Journal. Mining and Geology. 27, pp 9-15.

Armstrong-Altrin, J.S. and Verma, S.P. 2005. Critical evaluation of six tectonic setting discrimination diagrams using geochemical data of Neogene sediments from known tectonic setting. Sedimentary Geology, 177(1-2), 115-129.

Avbovbo, A.A., 1978. Tertiary lithostratigraphy of Niger Delta: American Association of Petroleum Geologists Bulletin, vol. **62,** p. **295-306**.

Boggs, S. Jr., (2006). Principles of Sedimentology and Stratigraphy: Pearson education Inc. Upper Saddle Rivers, USA, ed P. 581.

Burke, K. C, Whiteman, A. J., 1973. Uplift, rifting and the break-up of Africa.*In*:Tarling, D. N. and Runcorn, S. K. (Eds.),Implication of continental drift to the earth sciences. *New York Academic Press*, pp. 734-755.

Burke, K. C., 1972. Longshore drift, submarine canyons, and submarine fans in the development of the Niger Delta.*American Association of Petroleum Geologists Bulletin,* vol. 56, pp. 1975-1983.

Burke, K. C., Dessauvagie, T. F. J. and Whiteman, A. J., (1972).Geological History of the Benue Valley and Adjacent Areas.*In*: Dessauvagie, T. F. J. and Whiteman, A. J. (Eds.), African Geology. *University of Ibadan Press, Nigeria*, pp. 187-206.

Chamley H (1990). Clay Sedimentology. Berlin, Germany: Springer- Verlag.

Condie, K.C. (1993) Chemical Composition and Evolution of the Upper Continental Crust: Contrasting Results from Surface Samples and Shales. Chemical Geology, 104, 1-37. http://dx.doi.org/10.1016/0009-2541(93)90140-E

Dickinson W.R, Beard I.S, Brakenridge G.R, Erjavec, J.I, Ferguson, R.C, Inman K.F, Knepp R.A, Lindberg F.A, Ryberg P.T (1983). Provenance of North American Phanerozoic sandstones in relation to tectonic setting. J Geol Soc America 94:222-235.

Doust,H. and Omatsola, E., (1990).NigerDelta.*In*: Edwards, J. D.and Santogrossi,P.A.(Eds.), Divergent/passive Margin Basins. *American Association of Petroleum Geologists Bulletin*, vol. 48, pp. 201-238.

Ejedawe, J. E., Coker, S. J. L., Lambert-Aikhionbare, D. O., Alofe, K. B. and Adoh, F. O., 1984. Evolution of Oil-generative Window and Oil and Gas Occurrence in Tertiary Niger Delta Basin.*American Association of Petroleum Geologists Bulletin*, vol. 68**(11)**, pp. 1744-1751.

Ekweozor, C. M., and Daukoru, E.M, (1994). Northern delta depobelt portion of the Akata-Agbada(!) petroleum system, Niger Delta, Nigeria, *in*, Magoon, L.B., and Dow, W.G., eds., The Petroleum System-From Source to Trap, AAPG Memoir 60: Tulsa, American Association of Petroleum Geologists, p. **599-614**.

Elsik, W. C. (1968a). Palynology of a Paleocene Rockdale lignite, Milam County, Texas, I. Morphology and taxonomy. *Pollen et Spores*, Vol. 10, pp. 263-314.

Enwerem, C. A. (1997). Biosignals from the EH fields and their applications to sequence stratigraphy. *Expl. Rept. SPDC*, Nigeria, No. XPMW/97.004.

Evamy, D. D., Haremboure, J., Kamerling, P., Knapp, W. A., Molloy, F. A. and Rowlands, P. H., (1978).Hydrocarbon Habitat of Tertiary Niger Delta. *AAPG Bulletin*, vol. 62, pp. 1-39.

Fregene T.J., Lucas F.A, and Onyeachonam N., "Biozonation and Sequence Stratigraphic Characterization of Sediments in X-well, JV-field Greater Ughelli Depo-belt Niger Delta Basin." Journal of Geosciences and Geomatics, vol. 9, no. 3 (2021): 96-109. doi: 10.12691/jgg-9-3-1.

Haq, B. U., Hardenbol, J. & VAIL, P. R. (1988): Mesozoic and Cenozoic chronostratigraphy and eustatic cycles. In: Sea-level –an integrated approach, Wilgus, C. K., Hasting, B. S., Kendall, C. G. St., Posamentia, H., Ross, C. A. and Van Wagoner (eds.). Jour. Soc. Econs. Paleotol.Mineral. Spec. Pub.; Vol. 42, p. 47–70

Hardage BA, Levey RA, Pendleton V, Simmons J, Edson R (1994) A 3–D seismic case history evaluating fluvially deposited thin-bed reservoirs in a gas-producing property. Geophysics 59: 1650–1665.

Klett, T. R., Ahlbrandt, T. S., Schmoker, J. and Dolton, G., (1997). Ranking of the World's oil and gas provinces by known petroleum volumes.U.S.*Geological* Survey Open-file Report-97-.463, CD-ROM.

Kulke, H., 1995. Nigeria, *in*, Kulke, H., ed., Regional Petroleum Geology of the World. Part II: Africa, America, Australia and Antarctica: Berlin, Gebrüder Borntraeger, p. **143-172**.

Maynard, J.B., Valloni, R., & Yu, H.S., (1982). Composition of modern deep sea sand from are related basins. Trench fore-arc Geology: Sedimentation and Tectonics on Modern and Ancient Active Plate Margins (Legget, J.K., eds), 21 – 40, Geological Society of America Special Paper. 284.

Morley, R. J and Flenley,J. R (1987). Late Cenozoic vegetation and environmental changes in the Malay Archipelago. In: Whitemore, T. C (ed.), Biogeographical evolusion of the Malay Archipelago Oxford Monographs on Biogeography, U.K., pp. 50-59.

Murat, R. C., (1972). Stratigraphy and Paleogeography of the Cretaceous and Lower Tertiary in Southern Nigeria. *In*: Dessauvagie, T. F. J. and Whiteman, A. J. (Eds.), African Geology. *University of Ibadan Press, Nigeria*, pp. 251-266.

Merki, P., 1971. Structural Geology of the Cenozoic Niger Delta. In Proc. First Conf. On African Geologu; Ibadan (Ed. Dassauvagie, T.F.J. and Whiteman, A.J.) Ibadan University Press. P. **251-266.**

Nwajide, C.S. (2013) Geology of Nigeria's Sedimentary Basins. CSS Bookshop Ltd., Lagos, 1-565.

Pettijohn, F. J., (1957). Sedimentary Rocks, 2nd edn, Harper and Row, New York. 628pp.

Pettijohn F.J (1975). Sedimentary Rocks. 2nd ed. New York, NY, USA: Harper and Row.

Pettijohn F.J, Potter P.E, Siever, R. (1972). Sand and Sandstones. 1st ed. New York, NY, USA: Springer-Verlag.

Pettijohn F.J, Potter P.E, Siever R (1987). Sand and Sandstones. 2nd ed. New York, NY, USA: Springer-Verlag.

Reijers, T. J. A., Petters, S. W. and Nwajide, C. S., (1997). The Niger Delta Basin, In: Selley RC, editor, African Basins-Sedimentary Basin of the World 3, Amsterdam. *Elsevier Science*, pp. 151-172.

Reyment, R.A., (1959). Notes on Cretaceous – Tertiary in Nigeria. Reports of the Twenty-first session. Interl. Geological Congress, p. **131-135.**

Reyment, R. A., (1965). Aspect of the Geology of Nigeria. *University of Ibadan Press*, Nigeria. 145p.

Risk, H. M. and Rhodes, E. G. (1985). From mangrove to petroleum precursors: An example from tropical North east Australia. AAPG Bull. Vol.69, No. 8, pp. 1230-1240.

Selley, R. C., (1985). Ancient Sedimentary Environments Cornell University Press, Ithaca, N.Y., Third Edition, 317 pp.

Short, K. C. and Stauble, A. J., (1967). Outline of Geology of Niger Delta. *American Association of Petroleum Geologists Bulletin*, vol. 51**(5),** pp. 761-779.

Sprague, A.R., Patterson, P.E., Hill, R.E., Jones, C.R., Campion, K.M., Van Wagoner, J.C., Sullivan, M.D., Larue, D.K., Feldman, H.R., Demko, T.M., Wellner, R.W., Geslin, J.K., (2002). The Physical Stratigraphy of Fluvial Strata: A Hierarchical Approach to the Analysis of Genetically Related Stratigraphic Elements for Improved Reservoir Prediction. (Abstract) AAPG Annual Meeting.

Ekweozor, C. M., and Daukoru, E.M, (1994). Northern delta depobelt portion of the Akata-Agbada(!) petroleum system, Niger Delta, Nigeria, *in*, Magoon, L.B., and Dow, W.G., eds., The Petroleum System-From Source to Trap, AAPG Memoir 60: Tulsa, American Association of Petroleum Geologists, p. **599-614**.

Stacher, P., (1995). Present understanding of the Niger Delta hydrocarbon habitat, *In*: Oti, M. N. and Postma, G. (Eds.), Geology of Deltas: Rotterdam, A.A. Balkema, pp. 257-267.

Stoneley, R., (1966). The Niger Delta in the light of the theory of continental drift. *Geological Magazine*, vol. 103**(3)**, pp. 386-397.

Totten M.W and Hanan M.A (1998). The accessory-mineral fraction of mud rocks and its significance for whole-rock trace element geochemistry. In: Schieber. J,Zimmerle .W,SethiP(eds) Shales and Mudstones 2: E. Schweizerbart'sche, Stuttgart, pp35–53

Weber, K. J. and Daukoru, E. M., (1975). Petroleum Geological Aspects of Niger Delta. *Tokyo. Ninth World Petroleum Congress Proceedings*, vol. 5**(2)**, pp. 209-221.

Whiteman, A. J., (1982). Nigeria: Its Petroleum Geology, Resources and Potential. *Graham and Trotman, London*. pp. 1-394.