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# Lithofacies Characterization of Sedimentary Succession from Oligocene to Early Miocene Age in X2 Well, Greater Ughelli Depo Belt, Niger Delta, Nigeria

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**Abstract** One hundred and ninety (190) ditch cutting samples of depth range within 20 ft-11820 ft (6.09m-3603.7m) from X2 Well Greater Ughelli Depo Belt, Niger Delta Basin were subjected to sedimentological analysis, with a view to characterizing the sedimentary succession penetrated by the drill. The ditch cutting samples were analyzed using reflected light microscope for lithologic description. The sedimentological analysis reveals forty nine (49) lithozones and seven (7) lithofacies units, deduced based on their mineralogical composition; textural properties; fossil content; and the homogeneity and heterogeneity of the lithofacies units. The major lithofacies units penetrated in the well are sandstone, shaly sand, sandy shale, clay, sandy clay, clayey sand and shale. Its associated minerals include quartz, feldspar and glauconite. Identification of the petroleum play elements and hydrocarbon potential of the X2Well were equally proposed in the Agbada formation within depth (1371.9m – 3603.7m) containing two (2) probable reservoir rocks (Zone 7, with thickness 18.3 meters and zone 15 with thickness 146.4 meters) and six (6) probable source rocks (Zone 2, 4, 6, 8, 10, 12).

***Keywords:*** *Lithofacies, lithozones, Maturity, Depositional environment, Niger Delta Basin*

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## 1. Introduction

The X2 well, is located in the Greater Ughelli Depo Belt, Niger Delta Basin (Figure 1), which lies between latitudes 4° N and 6° N and longitudes 3° E and 9° E in the south-south geopolitical region of Nigeria [1]. The delta complex contains a sedimentary thickness of over 12,000m, which consists of three anachronous Lithostratigraphic units. Exploration activities have been in the past, concentrated in the Eocene-Pliocene sequence, but as the delta becomes better understood, exploration efforts are gradually being shifted to both the offshore (Pliocene-Pleistocene sections) and the flanks of the delta where cretaceous prospects are expected. Since the early seventies, stratigraphic analysis of the Pliocene-Eocene series of the Niger Delta has focused mainly on the regional scale depositional history [2]. The development of the delta has been dependent on the balance between the rate of sedimentation and the rate of subsidence [3]. This study was undertaken to identify and describe the Lithofacies, sedimentary processes and paleodepositional environment.

### 1.1. Background of Study

The X2 well, is located in the Greater Ughelli Depo Belt, Niger Delta Basin. The Greater Ughelli is one of the Depo Belt in the Niger delta Basin [4]. The Niger Delta is in the Gulf of Guinea on the west coast of Central Africa. The Cenozoic Niger Delta is located at the intersection of the Benue Trough and the South Atlantic Ocean where a triple junction developed during the separation of South America and Africa in the Late Jurassic [5].

### 1.2. Geology of the Study Area

The Niger Delta Basin occupies the Gulf of Guinea continental margin in equatorial West Africa between Latitude $3^0$ N and $6^0$ N and Longitude $5^0$ E and $8^0$ E. The clastic wedge of the Niger Delta formed along a failed arm of a triple junction system (aulacogen) that originally developed during the break-up of the South American and African plates in the late Jurassic [4]. It ranks among the world's most prolific petroleum producing Tertiary Deltas. Previous works have reviewed the stratigraphy, Sedimentology, structural configuration and paleo-environment and the impact on the petroleum system of the Niger Delta.

The Niger Delta is framed on the northwest by a subsurface continuation of the West African Shield, the Benin Flank. The eastern edge of the basin coincides with the Calabar Flank to the south of the Oban Masif [6]. Well sections through the Niger Delta generally display three vertical lithostratigraphic subdivisions: an upper delta top facies; a middle delta front lithofacies; and a lower

pro-delta lithofacies. These lithostratigraphic units correspond respectively with the Benin Formation (Oligocene-Recent), Agbada Formation (Eocene-Recent) and Akata Formation (Paleocene-Recent). The Akata Formation which is the basal lithostratigraphic unit is composed mainly of marine shales, with sandy and silty beds which are thought to have been laid down as turbidites and continental slope channel fills. It is estimated that the formation is up to 7,000 metres thick. [4,7,8]. Overlying the Basal unit is the Agbada Formation which has been proven to be the major petroleum-bearing unit in the Niger Delta. The formation consists mostly of shoreface and channel sands with minor shales in the upper part, and alternation of sands and shales in equal proportion in the lower part. The thickness of the formation is over 3,700 metres [4,7,8].

The top most Lithostratigraphic unit the Benin Formation is about 280 metres thick, but may be up to 2,100 metres in the region of maximum subsidence, and consists of continental sands and gravels [4,7,8].

From the Eocene to the present, the delta has prograded southwestward, forming depobelts that represent the most active portion of the delta at each stage of its development. These depobelts form one of the largest regressive deltas in the world with an area of some 300,000 km$^2$ a sediment volume of 500,000 km3 and a sediment thickness of over 10 km in the basin depocenter [7,8].

### 1.3. Materials and Method

The data and interpretations presented in this study were based on detailed examination of 190 ditch cuttings samples from X2 Well which represent the sedimentary succession of depth range within 20ft- 11820ft (6.09m-3603.7m). The samples were sedimentologically analysed using reflected light microscope with a view to characterizing the sedimentary succession penetrated by the drill. Sedimentary description was undertaken from bottom to top, and the various sedimentological parameters such as lithology, grain size, color, textures, fossil content in terms of plant remains and fossil fragments, few drops of HCl were added to small quantity of the sample at each depth intervals, to ascertain the presence of carbonates. Sorting was deduced in an attempt to reconstruct the paleoenvironments, hydrodynamics, and characterizing the various lithofacies encountered to construct the sedimentological model for the well.

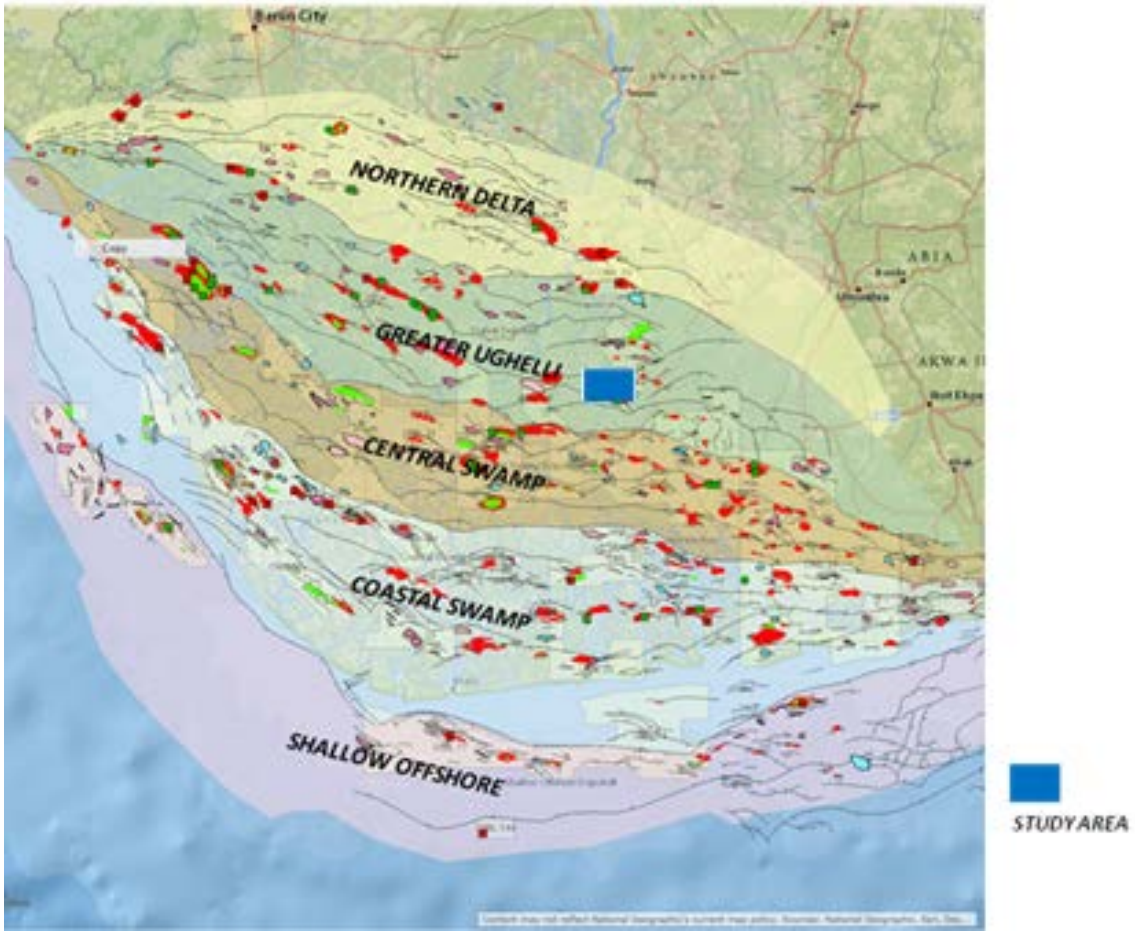



**Figure 1.** Map showing the distribution of Depo Belts within the Niger Delta and the location of the study area within the Greater Ughelli Depo belt [9]

## 2. Results

The result of the sedimentological analysis of 190 ditch cuttings samples from X2 Well in the Northern Delta Depobelt of the Niger Delta basin of depth range within 20ft- 11820ft (6.09m-3603.7m) is shown in figures below.

### 2.1. Interpretation and Discussion

In order to evaluate and characterize the subsurface samples recovered from X2 Well, detailed examination of 190 ditch cuttings samples from X2 Well which represent the sedimentary succession of depth range within 20ft- 11820ft (6.09m-3603.7m), were subjected to sedimentological analysis

using reflected light microscope. This was done with a view to characterizing the sedimentary succession penetrated by the drill and various sedimentary succession encountered were identified and described in Figure 2 to Figure 10.

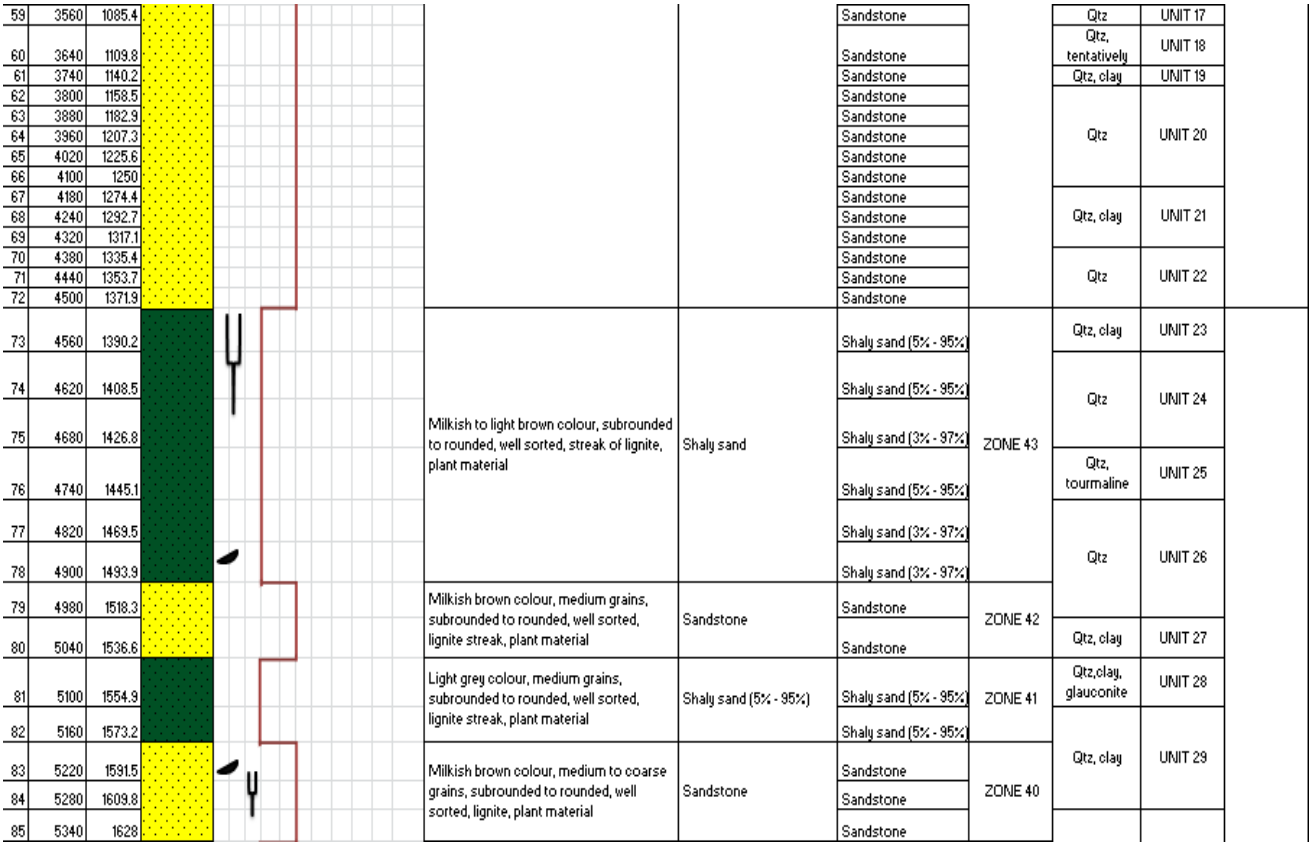
LITHOSTRATIGRAPHIC LOG OF X2 WELL

| S/N | DEPTH(FEET) | DEPTH(METER) | LITHOLOGY (Shale / Sand %) | TEXTURE: Grain size and other notes (structures, paleocurrents, fossils, colour) | LITHO FACIES | Shale / Sand Percentage | LITHO ZONES | ASSOCIATED MINERALS | ASSOCITED MINERAL UNIT | FORMATION |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 20 | 6.09 | | Whitish to light brown colour, medium to coarse grain, subangular to subrounded, moderately to well sorted, plant material | sandstone | Sandstone | ZONE 49 | Fe, quartz, feldspar | UNIT 1 | |
| 2 | 80 | 30.4 | | | | Sandstone | | Qtz, feldspar | UNIT 2 | |
| 3 | 140 | 42.7 | | | | Sandstone | | | | |
| 4 | 200 | 61 | | | | Sandstone | | | | |
| 5 | 260 | 79.3 | | | | Sandstone | | | | |
| 6 | 320 | 97.6 | | | | Sandstone | | | | |
| 7 | 380 | 115.9 | | | | Sandstone | | | | |
| 8 | 440 | 134.1 | | | | Sandstone | | | | |
| 9 | 500 | 152.4 | | | | Sandstone | | | | |
| 10 | 560 | 170.7 | | | | Sandstone | | | | |
| 11 | 620 | 189 | | | | Sandstone | | | | |
| 12 | 680 | 207.3 | | | | Sandstone | | | | |
| 13 | 740 | 225.6 | | | | Sandstone | | Qtz, mica, feldspar | UNIT 3 | |
| 14 | 800 | 243.9 | | | | Sandstone | | Qtz, feldspar | UNIT 4 | |
| 15 | 860 | 262.2 | | | | Sandstone | | | | |
| 16 | 920 | 280.5 | | | | Sandstone | | | | |
| 17 | 980 | 298.8 | | | | Sandstone | | | | |
| 18 | 1040 | 317.1 | | | | Sandstone | | | | |
| 19 | 1100 | 335.4 | | | | Sandstone | | | | |
| 20 | 1160 | 353.7 | | | | Sandstone | | | | |
| 21 | 1220 | 371.9 | | | | Sandstone | | | | |
| 22 | 1280 | 390.2 | | | | Sandstone | | | | |
| 23 | 1340 | 408.5 | | | | Sandstone | | | | |
| 24 | 1400 | 426.8 | | | | Sandstone | | | | |
| 25 | 1460 | 445.1 | | | | Sandstone | | Quartz | UNIT 5 | |
| 26 | 1520 | 463.4 | | | | Sandstone | | | | |
| 27 | 1580 | 481.7 | | Very fine to medium grain, sandy clay rich in carbonate | sandy clay | sandy clay (20% - 80%) | ZONE 48 | Qtz, clay, carbonate | UNIT 6 | |

**Figure 2.** Lithostratigraphy analysis of samples from X2 Well, Greater Ughelli Depo-Belt (6.09m-4817m)

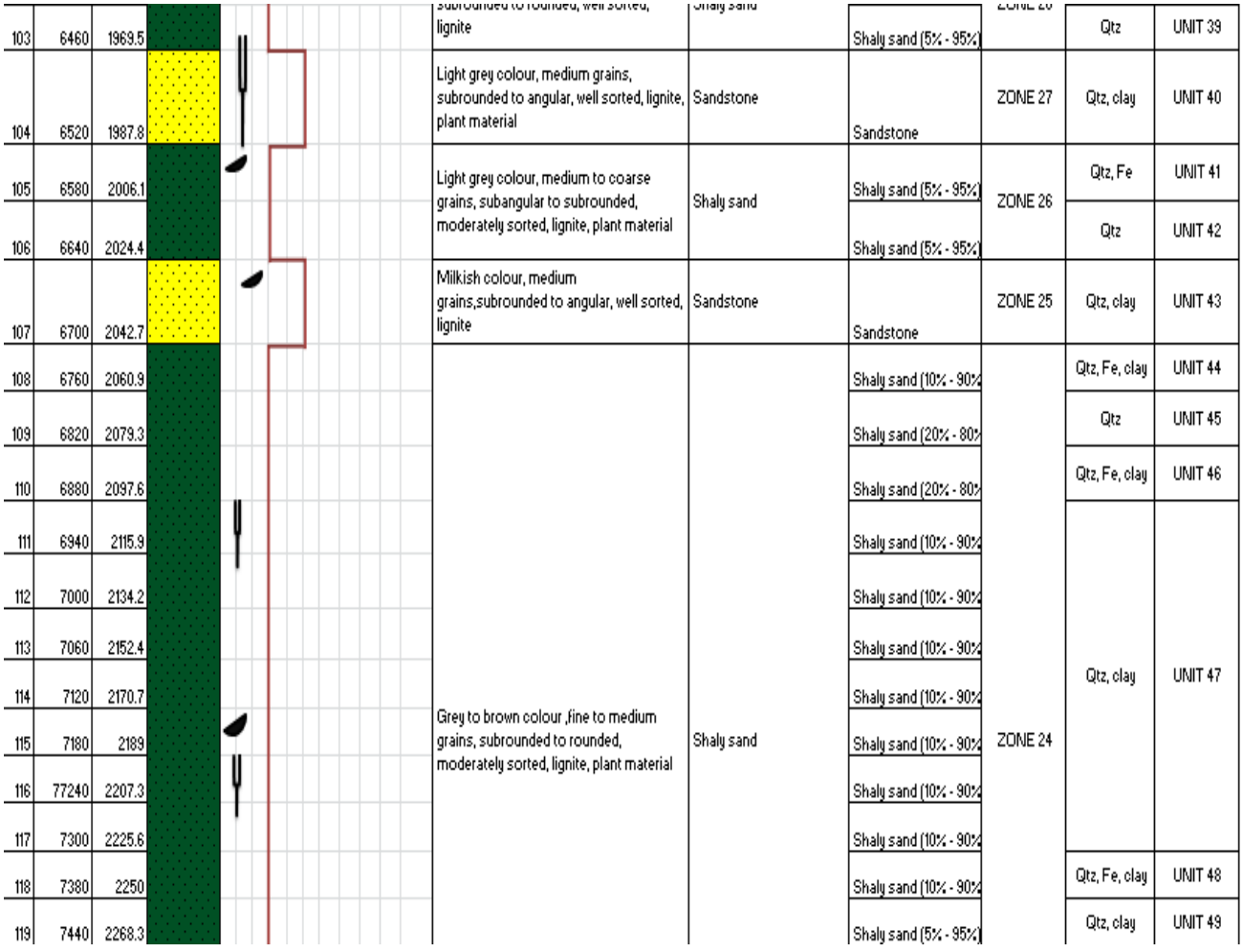
| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 28 | 1640 | 500 | | milkish to light brown colour, medium to coarse grain, subangular to subrounded, poorly sorted, plant material | clayey sand | clayey sand (20% - 80%) | ZONE 47 | Qtz, clay | UNIT 7 | BENIN FORMATION |
| 29 | 1700 | 518.3 | | | | clayey sand (20% - 80%) | | | | |
| 30 | 1760 | 536.6 | | | | clayey sand (20% - 80%) | | | | |
| 31 | 1820 | 554.9 | | | | clayey sand (15% - 85%) | | Qtz, clay, carbonate | UNIT 8 | |
| 32 | 1880 | 573.2 | | milkish to light brown colour, medium to coarse grain, subrounded to angular, moderately to well sorted | sandstone | sandstone | ZONE 46 | Qtz, clay | UNIT9 | |
| 33 | 1940 | 591.5 | | | | sandstone | | Qtz, clay, carbonate | UNIT 10 | |
| 34 | 2000 | 609.6 | | milkish to brown colour, medium to coarse grain, subrounded to subangular, moderately sorted | clayey sand | clayey sand (3% - 97% | ZONE 45 | Qtz, feldspar, carbonate | UNIT 11 | |
| 35 | 2060 | 628.1 | | Milkish to light brown colour, medium to coarse grains, subrounded to rounded, moderately to well sorted, lignite streak | Sandstone | sandstone | ZONE 44 | Qtz, feldspar | UNIT 12 | |
| 36 | 2120 | 646.3 | | | | sandstone | | | | |
| 37 | 2180 | 664.6 | | | | sandstone | | Qtz, Fe | UNIT 13 | |
| 38 | 2240 | 682.9 | | | | Sandstone | | Qtz, feldspar | UNIT 14 | |
| 39 | 2300 | 701.2 | | | | Sandstone | | | | |
| 40 | 2360 | 719.5 | | | | Sandstone | | | | |
| 41 | 2420 | 737.8 | | | | Sandstone | | | | |
| 42 | 2480 | 756.09 | | | | Sandstone | | | | |
| 43 | 2540 | 774.4 | | | | Sandstone | | | | |
| 44 | 2600 | 792.7 | | | | Sandstone | | | | |
| 45 | 2660 | 810.9 | | | | Sandstone | | | | |
| 46 | 2720 | 829.26 | | | | Sandstone | | | | |
| 47 | 2780 | 847.6 | | | | Sandstone | | Qtz | UNIT 15 | |
| 48 | 2840 | 865.9 | | | | Sandstone | | | | |
| 49 | 2900 | 884.2 | | | | Sandstone | | | | |
| 50 | 2960 | 902.4 | | | | Sandstone | | | | |
| 51 | 3020 | 920.7 | | | | Sandstone | | | | |
| 52 | 3080 | 939 | | | | Sandstone | | | | |
| 53 | 3140 | 957.3 | | | | Sandstone | | | | |
| 54 | 3200 | 975.6 | | | | Sandstone | | | | |
| 55 | 3260 | 993.9 | | | | Sandstone | | | | |
| 56 | 3320 | 1012.2 | | | | Sandstone | | | | |
| 57 | 3420 | 1042.7 | | | | Sandstone | | Qtz, clay | UNIT 16 | |
| 58 | 3500 | 1067.1 | | | | Sandstone | | | | |

**Figure 3.** Lithostratigraphy analysis of samples from X2 Well, Greater Ughelli Depo-Belt (500m-1067.1m)



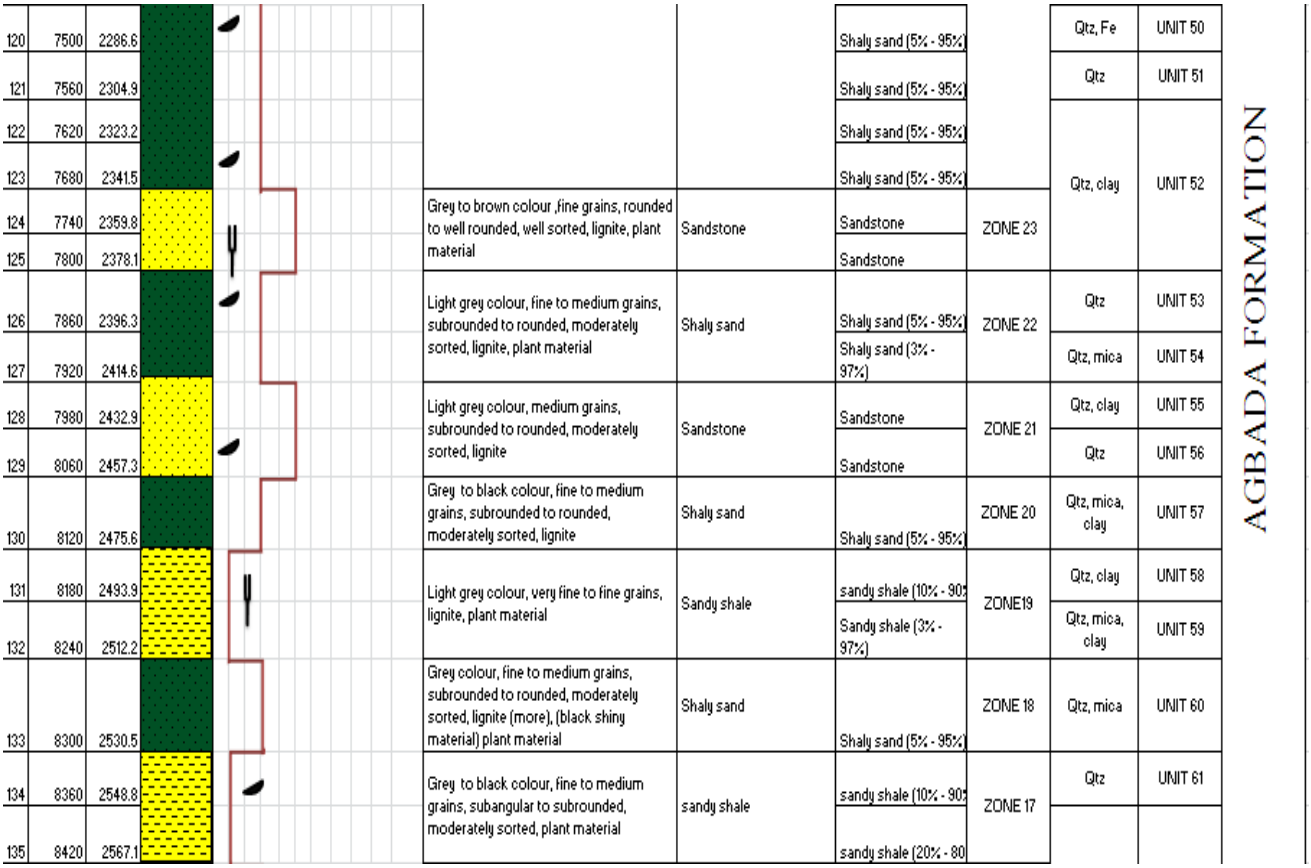
| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 59 | 3560 | 1085.4 | | | | Sandstone | | Qtz | UNIT 17 |
| 60 | 3640 | 1109.8 | | | | Sandstone | | Qtz, tentatively | UNIT 18 |
| 61 | 3740 | 1140.2 | | | | Sandstone | | Qtz, clay | UNIT 19 |
| 62 | 3800 | 1158.5 | | | | Sandstone | | | |
| 63 | 3880 | 1182.9 | | | | Sandstone | | | |
| 64 | 3960 | 1207.3 | | | | Sandstone | | Qtz | UNIT 20 |
| 65 | 4020 | 1225.6 | | | | Sandstone | | | |
| 66 | 4100 | 1250 | | | | Sandstone | | | |
| 67 | 4180 | 1274.4 | | | | Sandstone | | | |
| 68 | 4240 | 1292.7 | | | | Sandstone | | Qtz, clay | UNIT 21 |
| 69 | 4320 | 1317.1 | | | | Sandstone | | | |
| 70 | 4380 | 1335.4 | | | | Sandstone | | | |
| 71 | 4440 | 1353.7 | | | | Sandstone | | Qtz | UNIT 22 |
| 72 | 4500 | 1371.9 | | | | Sandstone | | | |
| 73 | 4560 | 1390.2 | Milkish to light brown colour, subrounded to rounded, well sorted, streak of lignite, plant material | Shaly sand | | Shaly sand (5% - 95%) | ZONE 43 | Qtz, clay | UNIT 23 |
| 74 | 4620 | 1408.5 | | | | Shaly sand (5% - 95%) | | Qtz | UNIT 24 |
| 75 | 4680 | 1426.8 | | | | Shaly sand (3% - 97%) | | | |
| 76 | 4740 | 1445.1 | | | | Shaly sand (5% - 95%) | | Qtz, tourmaline | UNIT 25 |
| 77 | 4820 | 1469.5 | | | | Shaly sand (3% - 97%) | | Qtz | UNIT 26 |
| 78 | 4900 | 1493.9 | | | | Shaly sand (3% - 97%) | | | |
| 79 | 4980 | 1518.3 | Milkish brown colour, medium grains, subrounded to rounded, well sorted, lignite streak, plant material | Sandstone | | Sandstone | ZONE 42 | | |
| 80 | 5040 | 1536.6 | | | | Sandstone | | Qtz, clay | UNIT 27 |
| 81 | 5100 | 1554.9 | Light grey colour, medium grains, subrounded to rounded, well sorted, lignite streak, plant material | Shaly sand (5% - 95%) | | Shaly sand (5% - 95%) | ZONE 41 | Qtz,clay, glauconite | UNIT 28 |
| 82 | 5160 | 1573.2 | | | | Shaly sand (5% - 95%) | | Qtz, clay | UNIT 29 |
| 83 | 5220 | 1591.5 | Milkish brown colour, medium to coarse grains, subrounded to rounded, well sorted, lignite, plant material | Sandstone | | Sandstone | ZONE 40 | | |
| 84 | 5280 | 1609.8 | | | | Sandstone | | | |
| 85 | 5340 | 1628 | | | | Sandstone | | | |

**Figure 4.** Lithostratigraphy analysis of samples from X2 Well, Greater Ughelli Depo-Belt(1065.4m-1628m)



| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 103 | 6460 | 1969.5 | lignite | Shaly sand | | Shaly sand (5% - 95%) | ZONE 28 | Qtz | UNIT 39 |
| 104 | 6520 | 1987.8 | Light grey colour, medium grains, subrounded to angular, well sorted, lignite, plant material | Sandstone | | Sandstone | ZONE 27 | Qtz, clay | UNIT 40 |
| 105 | 6580 | 2006.1 | Light grey colour, medium to coarse grains, subangular to subrounded, moderately sorted, lignite, plant material | Shaly sand | | Shaly sand (5% - 95%) | ZONE 26 | Qtz, Fe | UNIT 41 |
| 106 | 6640 | 2024.4 | | | | Shaly sand (5% - 95%) | | Qtz | UNIT 42 |
| 107 | 6700 | 2042.7 | Milkish colour, medium grains,subrounded to angular, well sorted, lignite | Sandstone | | Sandstone | ZONE 25 | Qtz, clay | UNIT 43 |
| 108 | 6760 | 2060.9 | Grey to brown colour ,fine to medium grains, subrounded to rounded, moderately sorted, lignite, plant material | Shaly sand | | Shaly sand (10% - 90% | ZONE 24 | Qtz, Fe, clay | UNIT 44 |
| 109 | 6820 | 2079.3 | | | | Shaly sand (20% - 80% | | Qtz | UNIT 45 |
| 110 | 6880 | 2097.6 | | | | Shaly sand (20% - 80% | | Qtz, Fe, clay | UNIT 46 |
| 111 | 6940 | 2115.9 | | | | Shaly sand (10% - 90% | | Qtz, clay | UNIT 47 |
| 112 | 7000 | 2134.2 | | | | Shaly sand (10% - 90% | | | |
| 113 | 7060 | 2152.4 | | | | Shaly sand (10% - 90% | | | |
| 114 | 7120 | 2170.7 | | | | Shaly sand (10% - 90% | | | |
| 115 | 7180 | 2189 | | | | Shaly sand (10% - 90% | | | |
| 116 | 77240 | 2207.3 | | | | Shaly sand (10% - 90% | | | |
| 117 | 7300 | 2225.6 | | | | Shaly sand (10% - 90% | | | |
| 118 | 7380 | 2250 | | | | Shaly sand (10% - 90% | | Qtz, Fe, clay | UNIT 48 |
| 119 | 7440 | 2268.3 | | | | Shaly sand (5% - 95%) | | Qtz, clay | UNIT 49 |

**Figure 5.** Lithostratigraphy analysis of samples from X2 Well, Greater Ughelli Depo-Belt(1969.5m-2268.3m)

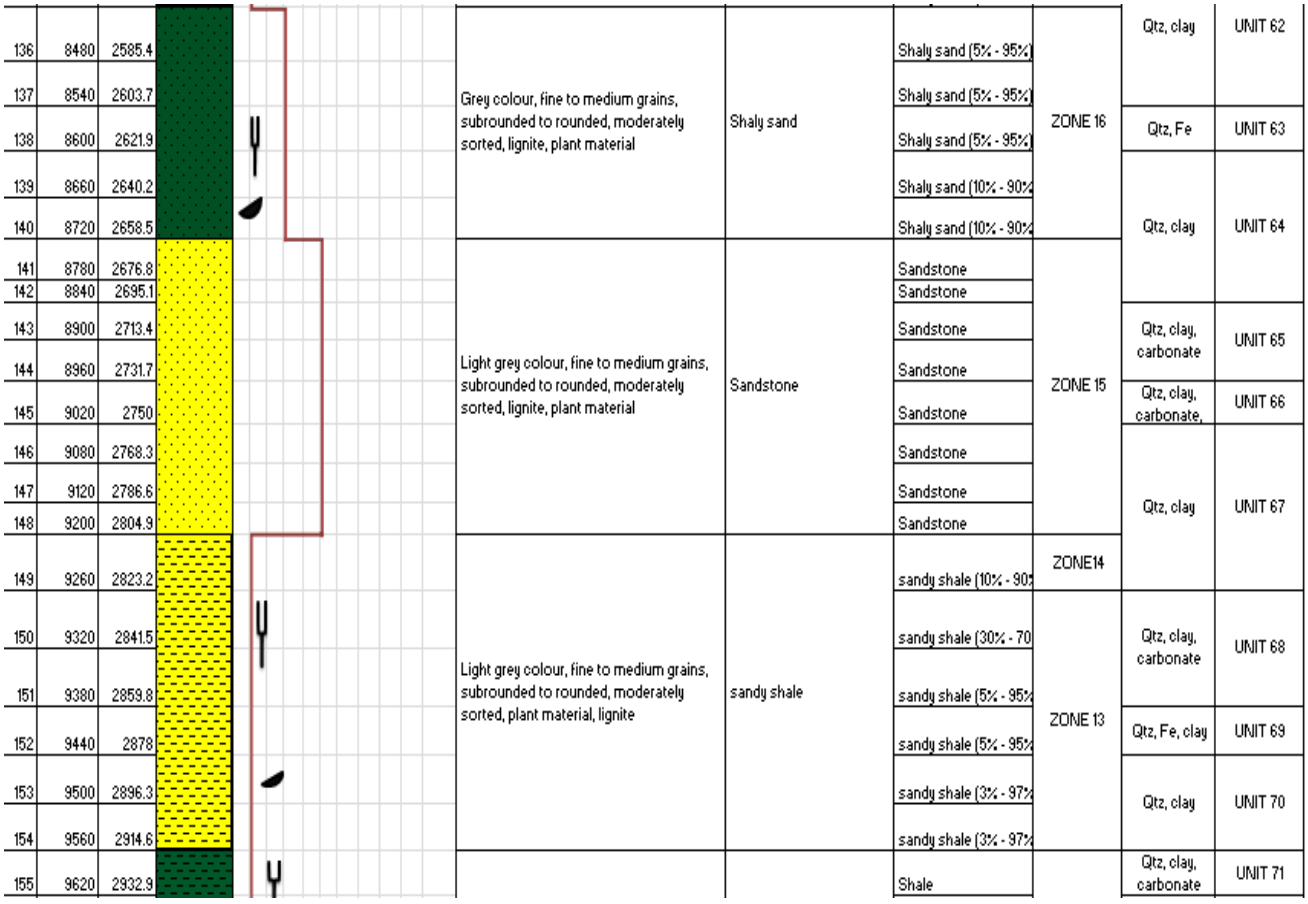



| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 120 | 7500 | 2286.6 | | | Shaly sand (5% - 95%) | | Qtz, Fe | UNIT 50 | AGBADA FORMATION |
| 121 | 7560 | 2304.9 | | | Shaly sand (5% - 95%) | | Qtz | UNIT 51 | |
| 122 | 7620 | 2323.2 | | | Shaly sand (5% - 95%) | | Qtz, clay | UNIT 52 | |
| 123 | 7680 | 2341.5 | | | Shaly sand (5% - 95%) | | | | |
| 124 | 7740 | 2359.8 | Grey to brown colour ,fine grains, rounded to well rounded, well sorted, lignite, plant material | Sandstone | Sandstone | ZONE 23 | | | |
| 125 | 7800 | 2378.1 | | | Sandstone | | | | |
| 126 | 7860 | 2396.3 | Light grey colour, fine to medium grains, subrounded to rounded, moderately sorted, lignite, plant material | Shaly sand | Shaly sand (5% - 95%) | ZONE 22 | Qtz | UNIT 53 | |
| 127 | 7920 | 2414.6 | | | Shaly sand (3% - 97%) | | Qtz, mica | UNIT 54 | |
| 128 | 7980 | 2432.9 | Light grey colour, medium grains, subrounded to rounded, moderately sorted, lignite | Sandstone | Sandstone | ZONE 21 | Qtz, clay | UNIT 55 | |
| 129 | 8060 | 2457.3 | | | Sandstone | | Qtz | UNIT 56 | |
| 130 | 8120 | 2475.6 | Grey to black colour, fine to medium grains, subrounded to rounded, moderately sorted, lignite | Shaly sand | Shaly sand (5% - 95%) | ZONE 20 | Qtz, mica, clay | UNIT 57 | |
| 131 | 8180 | 2493.9 | Light grey colour, very fine to fine grains, lignite, plant material | Sandy shale | sandy shale (10% - 90% | ZONE19 | Qtz, clay | UNIT 58 | |
| 132 | 8240 | 2512.2 | | | Sandy shale (3% - 97%) | | Qtz, mica, clay | UNIT 59 | |
| 133 | 8300 | 2530.5 | Grey colour, fine to medium grains, subrounded to rounded, moderately sorted, lignite (more), (black shiny material) plant material | Shaly sand | Shaly sand (5% - 95%) | ZONE 18 | Qtz, mica | UNIT 60 | |
| 134 | 8360 | 2548.8 | Grey to black colour, fine to medium grains, subangular to subrounded, moderately sorted, plant material | sandy shale | sandy shale (10% - 90% | ZONE 17 | Qtz | UNIT 61 | |
| 135 | 8420 | 2567.1 | | | sandy shale (20% - 80 | | | | |

**Figure 6.** Lithostratigraphy analysis of samples from X2 Well, Greater Ughelli Depo-Belt(2286.6m-2567.1m).

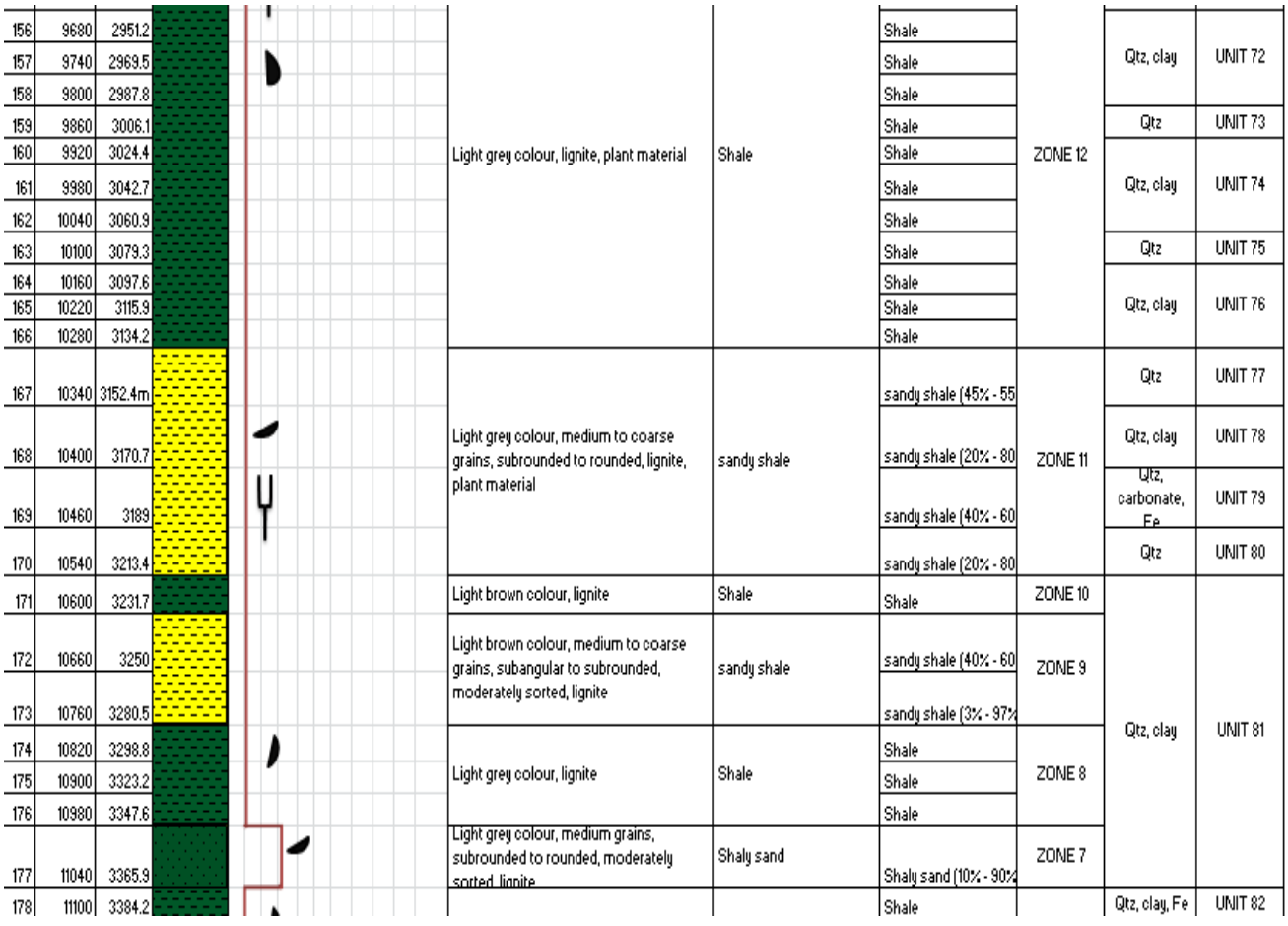
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 136 | 8480 | 2585.4 | Grey colour, fine to medium grains, subrounded to rounded, moderately sorted, lignite, plant material | Shaly sand | Shaly sand (5% - 95%) | ZONE 16 | Qtz, clay | UNIT 62 |
| 137 | 8540 | 2603.7 | | | Shaly sand (5% - 95%) | | | |
| 138 | 8600 | 2621.9 | | | Shaly sand (5% - 95%) | | Qtz, Fe | UNIT 63 |
| 139 | 8660 | 2640.2 | | | Shaly sand (10% - 90% | | Qtz, clay | UNIT 64 |
| 140 | 8720 | 2658.5 | | | Shaly sand (10% - 90% | | | |
| 141 | 8780 | 2676.8 | Light grey colour, fine to medium grains, subrounded to rounded, moderately sorted, lignite, plant material | Sandstone | Sandstone | ZONE 15 | | |
| 142 | 8840 | 2695.1 | | | Sandstone | | | |
| 143 | 8900 | 2713.4 | | | Sandstone | | Qtz, clay, carbonate | UNIT 65 |
| 144 | 8960 | 2731.7 | | | Sandstone | | | |
| 145 | 9020 | 2750 | | | Sandstone | | Qtz, clay, carbonate, | UNIT 66 |
| 146 | 9080 | 2768.3 | | | Sandstone | | Qtz, clay | UNIT 67 |
| 147 | 9120 | 2786.6 | | | Sandstone | | | |
| 148 | 9200 | 2804.9 | | | Sandstone | | | |
| 149 | 9260 | 2823.2 | Light grey colour, fine to medium grains, subrounded to rounded, moderately sorted, plant material, lignite | sandy shale | sandy shale (10% - 90% | ZONE14 | | |
| 150 | 9320 | 2841.5 | | | sandy shale (30% - 70 | ZONE 13 | Qtz, clay, carbonate | UNIT 68 |
| 151 | 9380 | 2859.8 | | | sandy shale (5% - 95% | | | |
| 152 | 9440 | 2878 | | | sandy shale (5% - 95% | | Qtz, Fe, clay | UNIT 69 |
| 153 | 9500 | 2896.3 | | | sandy shale (3% - 97% | | Qtz, clay | UNIT 70 |
| 154 | 9560 | 2914.6 | | | sandy shale (3% - 97% | | | |
| 155 | 9620 | 2932.9 | | | Shale | | Qtz, clay, carbonate | UNIT 71 |

**Figure 7.** Lithostratigraphy analysis of samples from X2 Well, Greater Ughelli Depo-Belt (2585.4m-2932.9m)



| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 136 | 8480 | 2585.4 | Grey colour, fine to medium grains, subrounded to rounded, moderately sorted, lignite, plant material | Shaly sand | Shaly sand (5% - 95%) | ZONE 16 | Qtz, clay | UNIT 62 |
| 137 | 8540 | 2603.7 | | | Shaly sand (5% - 95%) | | | |
| 138 | 8600 | 2621.9 | | | Shaly sand (5% - 95%) | | Qtz, Fe | UNIT 63 |
| 139 | 8660 | 2640.2 | | | Shaly sand (10% - 90% | | Qtz, clay | UNIT 64 |
| 140 | 8720 | 2658.5 | | | Shaly sand (10% - 90% | | | |
| 141 | 8780 | 2676.8 | Light grey colour, fine to medium grains, subrounded to rounded, moderately sorted, lignite, plant material | Sandstone | Sandstone | ZONE 15 | | |
| 142 | 8840 | 2695.1 | | | Sandstone | | | |
| 143 | 8900 | 2713.4 | | | Sandstone | | Qtz, clay, carbonate | UNIT 65 |
| 144 | 8960 | 2731.7 | | | Sandstone | | | |
| 145 | 9020 | 2750 | | | Sandstone | | Qtz, clay, carbonate, | UNIT 66 |
| 146 | 9080 | 2768.3 | | | Sandstone | | Qtz, clay | UNIT 67 |
| 147 | 9120 | 2786.6 | | | Sandstone | | | |
| 148 | 9200 | 2804.9 | | | Sandstone | | | |
| 149 | 9260 | 2823.2 | Light grey colour, fine to medium grains, subrounded to rounded, moderately sorted, plant material, lignite | sandy shale | sandy shale (10% - 90% | ZONE14 | | |
| 150 | 9320 | 2841.5 | | | sandy shale (30% - 70 | ZONE 13 | Qtz, clay, carbonate | UNIT 68 |
| 151 | 9380 | 2859.8 | | | sandy shale (5% - 95% | | | |
| 152 | 9440 | 2878 | | | sandy shale (5% - 95% | | Qtz, Fe, clay | UNIT 69 |
| 153 | 9500 | 2896.3 | | | sandy shale (3% - 97% | | Qtz, clay | UNIT 70 |
| 154 | 9560 | 2914.6 | | | sandy shale (3% - 97% | | | |
| 155 | 9620 | 2932.9 | | | Shale | | Qtz, clay, carbonate | UNIT 71 |

**Figure 8.** Lithostratigraphy analysis of samples from X2 Well, Greater Ughelli Depo-Belt(6.09m-3603.7m).



| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 156 | 9680 | 2951.2 | Light grey colour, lignite, plant material | Shale | Shale | ZONE 12 | Qtz, clay | UNIT 72 |
| 157 | 9740 | 2969.5 | | | Shale | | | |
| 158 | 9800 | 2987.8 | | | Shale | | | |
| 159 | 9860 | 3006.1 | | | Shale | | Qtz | UNIT 73 |
| 160 | 9920 | 3024.4 | | | Shale | | Qtz, clay | UNIT 74 |
| 161 | 9980 | 3042.7 | | | Shale | | | |
| 162 | 10040 | 3060.9 | | | Shale | | | |
| 163 | 10100 | 3079.3 | | | Shale | | Qtz | UNIT 75 |
| 164 | 10160 | 3097.6 | | | Shale | | Qtz, clay | UNIT 76 |
| 165 | 10220 | 3115.9 | | | Shale | | | |
| 166 | 10280 | 3134.2 | | | Shale | | | |
| 167 | 10340 | 3152.4m | Light grey colour, medium to coarse grains, subrounded to rounded, lignite, plant material | sandy shale | sandy shale (45% - 55 | ZONE 11 | Qtz | UNIT 77 |
| 168 | 10400 | 3170.7 | | | sandy shale (20% - 80 | | Qtz, clay | UNIT 78 |
| 169 | 10460 | 3189 | | | sandy shale (40% - 60 | | Qtz, carbonate, Fe | UNIT 79 |
| 170 | 10540 | 3213.4 | | | sandy shale (20% - 80 | | Qtz | UNIT 80 |
| 171 | 10600 | 3231.7 | Light brown colour, lignite | Shale | Shale | ZONE 10 | Qtz, clay | UNIT 81 |
| 172 | 10660 | 3250 | Light brown colour, medium to coarse grains, subangular to subrounded, moderately sorted, lignite | sandy shale | sandy shale (40% - 60 | ZONE 9 | | |
| 173 | 10760 | 3280.5 | | | sandy shale (3% - 97% | | | |
| 174 | 10820 | 3298.8 | Light grey colour, lignite | Shale | Shale | ZONE 8 | | |
| 175 | 10900 | 3323.2 | | | Shale | | | |
| 176 | 10980 | 3347.6 | | | Shale | | | |
| 177 | 11040 | 3365.9 | Light grey colour, medium grains, subrounded to rounded, moderately sorted, lignite | Shaly sand | Shaly sand (10% - 90% | ZONE 7 | | |
| 178 | 11100 | 3384.2 | | | Shale | | Qtz, clay, Fe | UNIT 82 |

**Figure 9.** Lithostratigraphy analysis of samples from X2 Well, Greater Ughelli Depo-Belt (29512m-3384.2m)

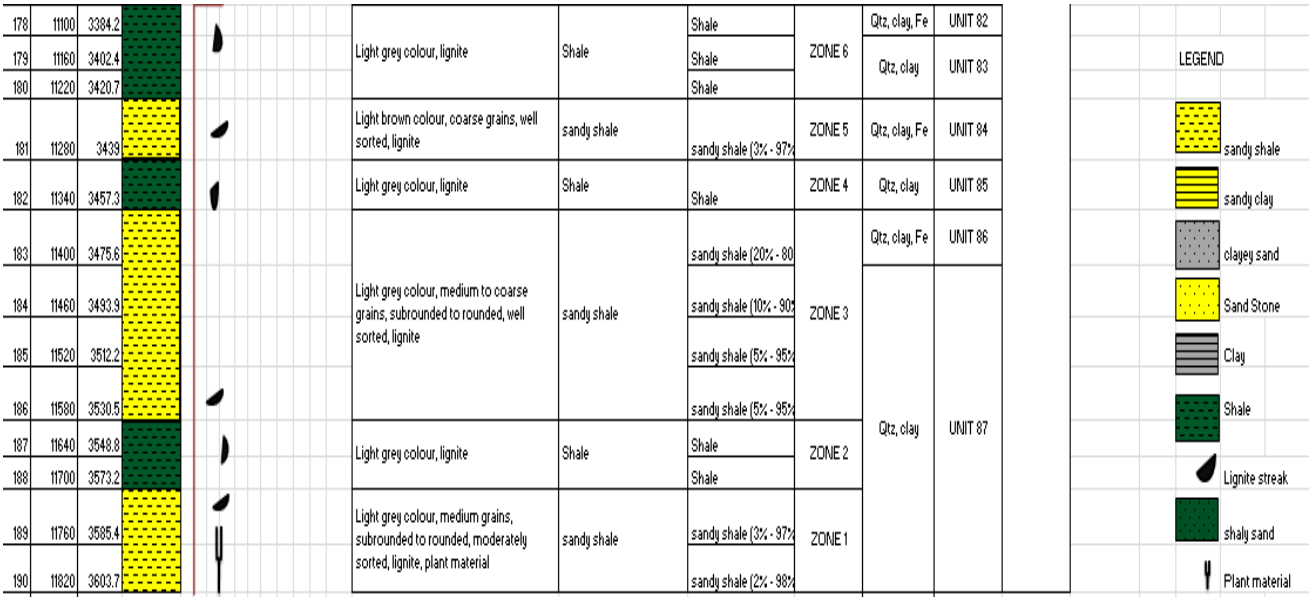



**Figure 10.** Lithostratigraphy analysis of samples from X2 Well, Greater Ughelli Depo-Belt (3384.2m-3603.7m)

## 2.2. Lithofacies Description and Interpretation

The sedimentological analysis revealed forty nine (49) lithozones and seven (7) lithofacies units, deduced based on their mineralogical composition, textural properties, fossil content, homogeneity and heterogeneity of the lithofacies units (Figure 2 to Figure 10). The major lithofacies units penetrated in the well are sandstone, shaly sand, sandy shale, sandy clay, clayey sand and shale. Its associated minerals include: quartz, feldspar and glauconite.

## 2.3. Environment of Deposition

Within 20ft-4500 (6.09m-1371.9m), the major lithofacies units penetrated are clay, clayey sand, sandstone, sandy clay, which are milkfish to light brown colour, medium to coarse grain, subrounded to angular, moderately to well sorted. Within 4560ft-11820 (1371.9m-3603.7m), the major lithofacies units penetrated are shaly sand, sandy shale and shale, which are Milk brown colour, medium grains, subrounded to rounded, well sorted, lignite streak and presence of plant material. It could be inferred that X2 Well that ranges from 6.09m – 1371.9m belongs to Benin Formation (sand/clay)which is continental while 1371.9m – 3603.7m belongs to Agbada Formation (alternation of sand and shale) which is of Parallic Environment.

The sedimentological results suggest sediments deposition in a high (6.09m – 1371.9m) to low (1371.9m – 3603.7m) energy environments which range between continental to transitional and marine environments.

## 2.4. Maturity

The maturity of sediment encountered in X2 well were determined based on their textural (sorting and rounding) and compositional maturity (minerals present).

The sediment found in X2 well are mainly medium to coarse grain, subrounded to subangular, moderately sorted. Thus, the sediment in X2 well can be describe to be mature base on their textural and compositional properties (presence of a stable mineral i.e. quartz).

# 3. Depositional Model

Sedimentary characteristics used to identify depositional environment in X2 well are similar to those defined by [6]. The recognized depositional environments include: distributary channel, marine shelf and prodelta. Using grain size; fossil fragments and vertical sequence (Figure 2 to Figure 10).

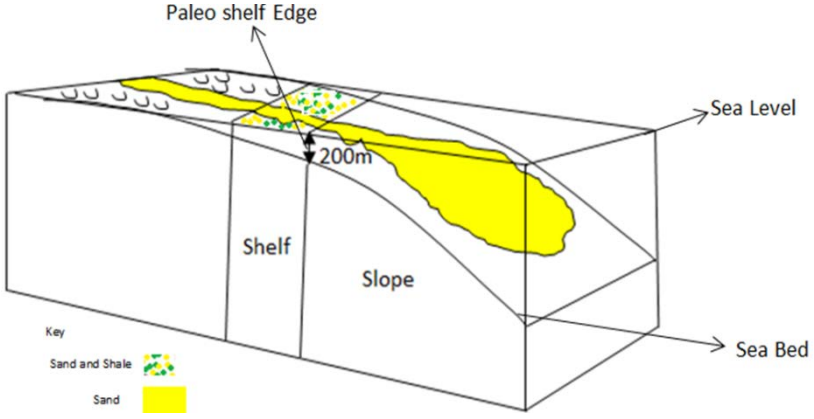



**Figure 11.** Proposed paleodepositional model for the deposition of X2 well sediment in the shelfal environment

### 3.1. Implication for Hydrocarbon Exploration

The potential reservoir and source rocks in the X2 well are within the Agbada formation [4,8], within 4560ft-11820 (1371.9m-3603.7m), the major lithofacies units penetrated within this depth are shaly sand, sandy shale and shale. The hydrocarbon play elements of X2 Well have been identified in the Agbada formation within depth (1371.9m – 3603.7m) containing two (2) probable reservoir rocks (Zone 7, with thickness 18.3 meters and zone 15 with thickness 146.4 meters) and six (6) probable source rocks (Zone 2, 4, 6, 8, 10, 12).

## 4. Conclusion

Sedimentological studies afford a holistic evaluation and characterization of sedimentary succession and are useful in petroleum exploration. It also provides information needed to propose a depositional model, determine environment of deposition, rock type and maturity of sediments. From the sedimentological evaluation of ditch cutting samples from X2 well, It can be inferred that sediment within 6.09m – 1371.9m belongs to Benin Formation (intercalation of sand and clay) which is typical of the continental environment while within 1371.9m – 3603.7m belongs to Agbada Formation (alternation of sand and shale) which is of Paralic Environment. The sedimentological results also suggest that the sediments were deposition in a high to low energy environments, which range between continental to transitional and marine environments. Thus, the sediment in X2 well can be described to be mature base on their textural and compositional properties. Sediments encountered in the X2 well were deposited in the shelfal environments. The source rocks are slope to marine shelf deposits while the sandstone are progradational and retrogradational deposits that belong to the Agbada formation may serve as a probable reservoir rocks.

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