Archives of Petroleum & Environmental Biotechnology

Ozumba MB. Arch Pet Environ Biotechnol: APEB-132.

Review Article

DOI: 10.29011/ 2574-7614.100032

Potential Reservoir Rock Characteristics of the Sokoto Sector of the Iullemmeden Basin: Geological Similarities with The Niger Delta Petroleum Province and Prospects for Hydrocarbon Discovery

Bertram Maduka Ozumba*

Department of Geology, Federal University, Ndufu-Alike, Nigeria

***Corresponding author:** Bertram Maduka Ozumba, Department of Geology, Alex Ekwueme Federal University, Ndufu-Alike, Ikwo (FUNAI), Nigeria. Tel: +2348136576861; Email bertram.ozumba@sbcglobal.net

Citation: Ozumba MB (2018) Potential Reservoir Rock Characteristics of the Sokoto Sector of the Iullemmeden Basin: Geological Similarities with The Niger Delta Petroleum Province and Prospects for Hydrocarbon Discovery. Arch Pet Environ Biotechnol: APEB-132. DOI: 10.29011/ 2574-7614.100032

Received Date: 03 March, 2018; **Accepted Date:** 08 March, 2018; **Published Date:** 14 March, 2018

Abstract

Sokoto area falls within the south eastern margin of the wider Iullemmeden Basin, an intracratonic basin, which is surrounded to the east and south by the Precambrian Basement Complex. The different formations in the basin are Gundumi, Illo, Taloka, Dukamaje, Wumo, Dange, Kalambaina, and Gwandu. Well exposed rock sections had spurred the search for petroleum in early colonial times but the poor showing of the sedimentary thicknesses of the earliest boreholes discouraged the explorers and led to a southward movement. The area has since not benefited from rigorous evaluation and hydrocarbon production studies driven heavily by rising hydrocarbon prices and modern technologies.

Preliminary academic studies have shown that the potential reservoir rocks of the Sokoto sector include all the sandstone bearing formations and the Kalambiana Formation on the carbonate side. Texturally, most of the sands are fine grained with clay intercalations. Integrating the petroleum systems studies, the potential reservoir rocks of the Sokoto sector may be the Taloka and Wurno Formations which might have effective seals in the Dukamaje and Dange shales respectively. The coarse to medium sandstones of the Gwandu Formation may be good if the ironstones are proven to be good seals and, therefore, capable of retaining hydrocarbons.

In comparison, the Niger Delta Basin was formed on top of a rift triple junction (aulacogen), which developed during the breakup of the South American and African plates in the Late Cretaceous with the sedimentary fill divided into three diachronous lithostratigraphic units namely: Akata, Agbada, and Benin Formations. The Akata Formation, at the base of this succession, is mostly marine shale. The Agbada Formation (Paralic Facies) comprises of alternating shallow marine to deltaic sandstones and shales. The Benin Formation is predominantly sandy and comprises of fluvial deposits. Extensional down-to-basin faults stretch laterally along depositional strike across nearly the entire Niger Delta, defining depobelts which have formed the basis for hydrocarbon exploration and development in the Niger Delta. The stratigraphic, structural and production frameworks have all been well studied and modelled in the Niger Delta which has become a very mature petroleum province over time.

This paper will highlight that indeed great differences exist in tectonic, structural, stratigraphic and the reservoir characteristics and environment of deposition of the producing reservoirs of the Niger Delta compared with what is known in the Sokoto sector. However, application of the knowledge gained from the Niger Delta Basin can be used to extrapolate the probable characteristics of the Sokoto sector potential reservoir rocks.

Introduction

Oil exploration activities started in Nigerian sedimentary basins (Figure 1), in the early part of the nineteenth century when the whole acreages in Nigeria was concessioned to the then Shell D'arcy and the Sokoto sector of the Iullemeden Basin was part of this. As with all exploration activities, initial efforts in the Sokoto sector included the recognisance geophysical survey which showed the poor thickness of the sedimentary cover in this sector of the Iullemmeden Basin, (Figure 2). These surveys were quickly followed with some borehole drilling which confirmed this shallow depth to basement. Thus, Shell D'Arcy moved southwards and struck gold at the Niger Delta. Efforts to have a second look at the Sokoto sector was rekindled in the 1990s during the Deep Offshore Niger Delta bid round which was tied to exploration in the inland basins. This effort failed in the Sokoto sector but benefited the Northern Benue Trough.

Figure 1: Geological Map of Nigeria with main sedimentary basins, selected growth faults in the Delta and structural trends [1].

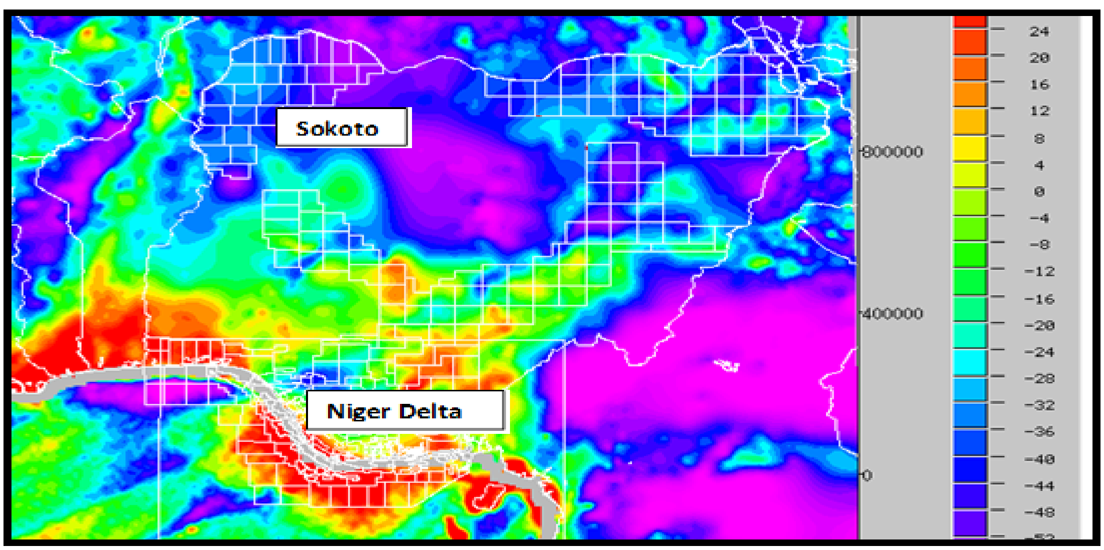

Figure 2: Bouguer gravity onshore and satellite derived free air gravity offshore Nigeria (Integrated Interpretation of Gravity & Magnetic data, Witte et al. 2000, in Geology of Nigeria by Nwajide, 2013) [2].

The Mobil Oil Company Ltd and Elf Petroleum Ltd (Total), even before this last event did some oil exploration activities in the Sokoto sector starting with carrying out some aerial survey of the basin. In the mid-1980s, following the discovery of liquid hydrocarbons in the main Iullemmeden Basin to the north in Mali, some of these companies rushed back to the Nigerian sector to re-evaluate the area in the light of the new developments. These companies finally moved out of the Sokoto sector to the Niger Delta which is by now a very well-known and prolific oil province. Following the exit of the major oil companies and their initial activities, the academic community took over essentially with field work and preliminary geochemical studies. The results of these hydrocarbon potential studies of the Sokoto sector were reported by a number of geologists including, Hamza and Garba, (2009); Obaje 2009, and Obaje et al *(*2014) etc. [3-5], and they almost unanimously concluded that the basin might harbour some hydrocarbons based purely on geochemical studies. However, identification of the exact nature, quantity and producibilty or commerciality of the hydrocarbons requires more evaluation.

Further attempt at re-evaluating this basin is on-going with the recent activity of the Petroleum Technology Development Trust Fund (PTDF) in awarding a geochemical re-evaluation of the basin to a group of researchers at the Usman Danfodiya University, Sokoto. The presence of hydrocarbon in the sector has been further strengthened by recent discoveries of apparent petroleum seepages in Kebbi State in which some preliminary chemical analyses will be carried out. In spite of the previous works, it is expected that the detailed geochemical analysis on-going will be needed to compliment the geological works, to validate speculative findings and provide verifiable data to help the Nigerian government and potential investors in making informed decisions on the Sokoto sector of the basin. A recent knowledge sharing of which this is one of the presentations showcased the interest of the Nigerian National Petroleum Cooperation (NNPC) in the area which will ultimately culminate in seismic acquisition, processing, interpretation and possible drilling that will increase both the knowledge of the subsurface and probably prove the hydrocarbon resource.

No major work has been published so far on the reservoir qualities of the Sokoto sector as reservoir studies are done when production operations start. The few existing literatures on the reservoir characteristics of this sector except for Ozumba et al, (2018) [6] using outcrop analogues can be found as petrographic studies of different formations of the basin in university students' bachelor's degree thesis in some of the northern Nigerian universities. However, the level of detail of these studies fall sharply below oil industry levels as known in the Niger Delta where modelling of reservoirs is now a common methodology. We shall rely on the environment of deposition of these reservoirs which offers the only genetic relationship that can ever exist to make some geologically reasonable comparison between them and the known reservoirs in producing basins of the Niger Delta.

Regional Geological Setting of the Sokoto Sector of the Iullemeden Basin

The Iullemmeden Basin is a major sub-Saharan inland basin in West Africa, extending about 1000 km north to south and 800 km east to west. It covers western Niger and portions of Algeria, Mali, Benin and Nigeria, Selley, (1997) [7]. The geology of Sokoto sector of the basin can be found in the works of Kogbe,1976 [8] and 1981b) [9], Petters (1978) [10], Obaje (2009) [4], Obaje (2013) [11] Obaje et al, (2014) [5], Okosun (1999) [12], Okosun et al, (2013) [13] and Nwajide 2013 as summarized in Table 1 after Ozumba et al, (2018) [2,6].

The Iullemmeden Basin is of tectono-epeirogenic origin. The basin was invaded several times by epicontinental transgressions during the Cretaceous and Paleocene. Three major subdivisions are recognized in the Nigerian section of the basin (the "Sokoto Basin"): (1) the lower, continental beds (Continental Intercalaire) of Late Jurassic to Early Cretaceous age, (2) intermediate marine and brackish water deposits and (3) "Continental T

Terminal" of upper Eocene-Miocene age, (Figure 3).

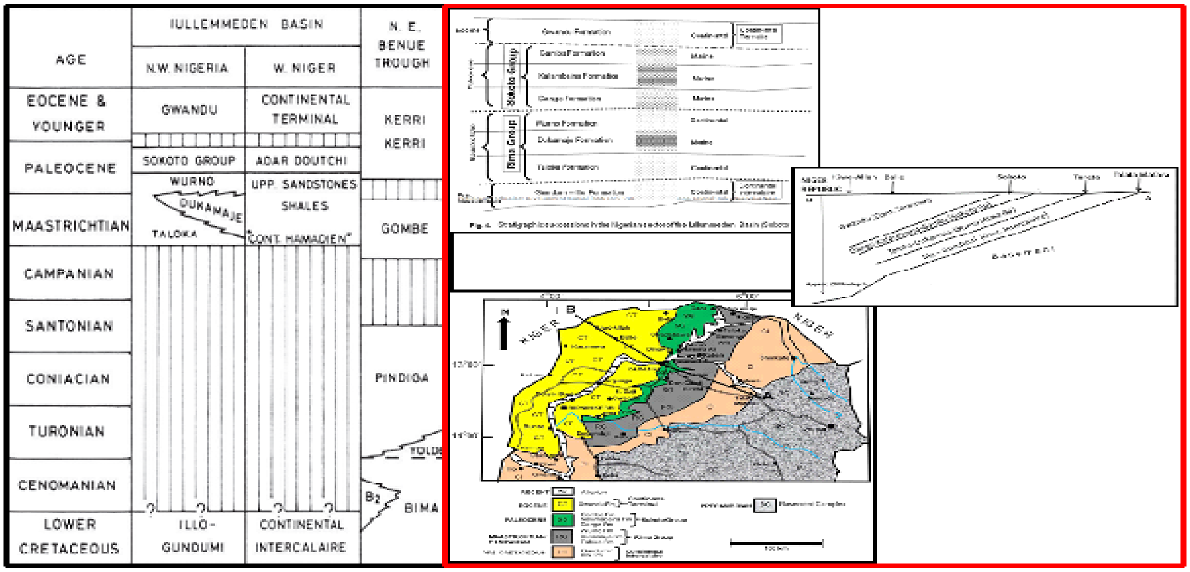

Figure 3: Stratigraphic column and Geologic map of Sokoto sector of the Iullemmeden Basin after Peters (1981) and Obaje (2013) [10,11].

The Sokoto Sector Basin Stratigraphy, Structure and Petroleum Systems: A Discussion

The overall thickness of the sedimentary succession in the Sokoto sector is only of the order of 700 to 750 m. Although there are considerable variations in the thicknesses of the various stratigraphic units in the Iullemmeden Basin as a whole, most have a restricted areal occurrence and the overall thickness of the sedimentary succession is about 1 km or less. Exceptions are the Gao Trough with 3500 to 4000 m, and areas in the proximity of the trans-Saharan lineament where the thickness may exceed 2 km or even 3 km, [14]. The greater part of these sediments, however, comprises the "continental intercalaire." Recent aeromagnetic data depicted in Obaje, (2013) confirms a maximum thickness of about 2.7 km, (Figure 4a-c)

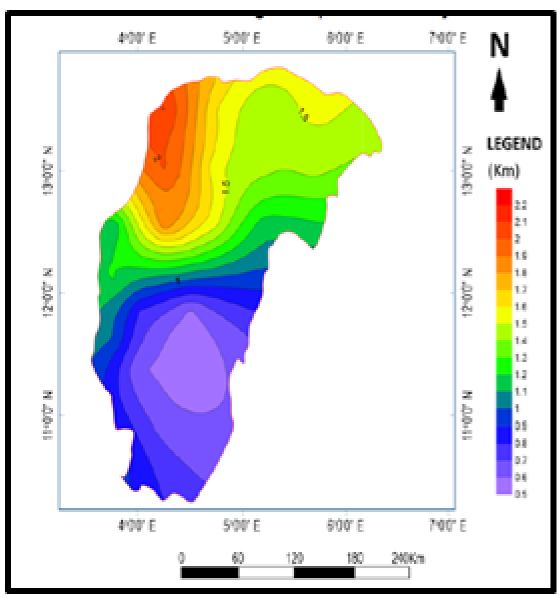

Figure 4a: Basement depth from Total Magnetic Intensity map [15].

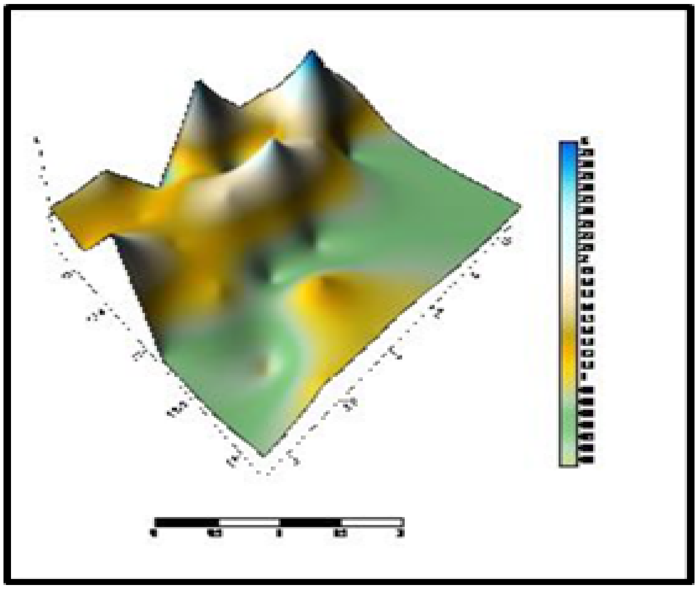

Figure 4b: Basement Depth using Spectral Depth Analysis [16].

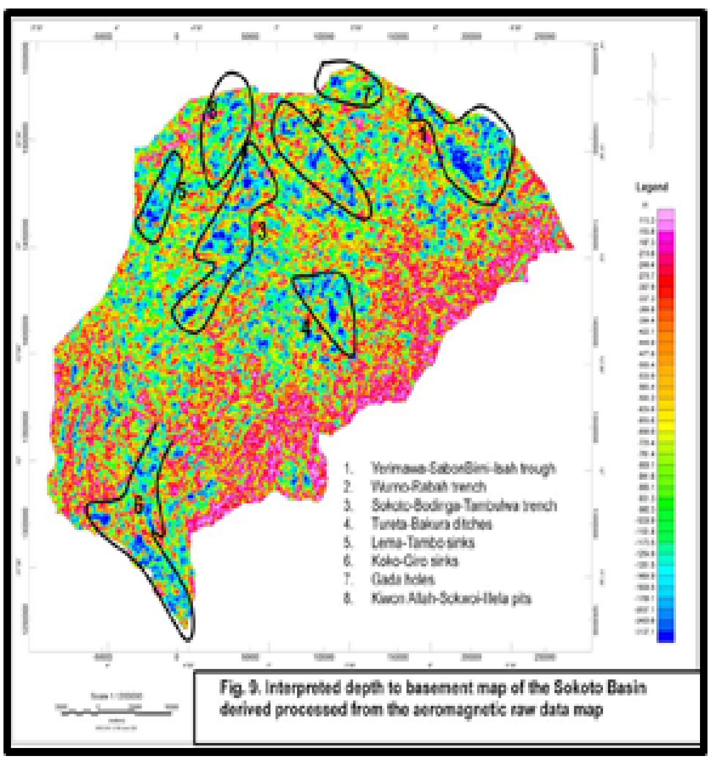

Figure 4c: Basement Depth from magnetic data analysis [5].

The Sokoto Sector is endowed with potential source rocks. The shales of the Dukamaje and Taloka Formations have recently been proven (Obaje et al, 2014) [5] while Dange Formation have marginal source rocks but challenges to commerciality anticipated include: i). poor sedimentary thicknesses, the former reaches a thickness of only 25 m, the latter only 45 m; ii). Organic geochemistry available data show dominance by Type III organic matter considering the preponderance of brackish-water foraminifera and their general palaeogeographic setting; and iii). Poor burial depths did not exceed 300 to 450m. Structurally the Sokoto sector is very simple. All lithostratigraphic units lie subhorizontally with a very gentle regional dip to the north-west. No major faulting has been reported. The only significant folding described is the result of collapse of the Gamba Formation into solution hollows developed upon the Kalambaina Formation but these folds have amplitudes of only a few meters and wavelengths hardly greater, [14]. This structural simplicity will need to be verified by seismic data when acquired

Elsewhere in the Iullemmeden Basin folding is also rare and is mainly restricted to the northern and north-easterly parts of the basin on the western flank of the Air massif but dips even here rarely exceed 5º; those that do mainly affect pre-Mesozoic beds. Faulting in this area mainly affects beds of the same age. All the major lithostratigraphic units of the Sokoto Basin are unconformity-bounded, the real prospect of stratigraphic traps for trapping of any hydrocarbons generated locally or any having migrated up dip from the deeper parts of the Iullemmeden Basin will only be ascertained through proper prospect evaluation and studies which will require extensive use of high resolution tools, such as 3D seismic and many different wireline logs. This study may then reveal evidence of angular discordances between the units and any indications of wedging out of any potential reservoir rocks.

In terms of potential reservoir rocks, the Illo and Gundumi Formations are clay-rich; the Taloka and Wurno Formations are fine-grained and can be expected to show only moderate permeability. The Kalambaina Formation exhibits solution porosity and the clean sands of the Gwandu Formation have a good porosity and permeability. Therefore, both primary and secondary porosity are present, but studies will confirm their magnitude. Two play types are also present, clastic plays and the carbonate plays. Seal or trap integrity analyses will confirm the presence or other wise of effective seals in the trapping configuration. However, literature studies point to the Taloka and Wurno Formations to have effective seals in the Dukamaje and Dange shales via shale juxtaposition.

The unconformable nature of all or most of the lithostratigraphic units and their great variation in thicknesses both along dip and strike may offer enough trapping configuration for hydrocarbons. This may also be a very good evidence for erosion in the sector. Production may pose some challenges as a result of this thickness variability. This may be mitigated by the shallow depths to objective sequences and the use of multiple wells for production purposes. In East Niger, a complex rift system, whose sedimentary fill ranges in age from Late Jurassic to Early Tertiary, has proven petroleum potential. Reservoir rocks are mainly Cretaceous to Eocene sandstones, sourced by Cretaceous marine shales and Oligocene lacustrine shales Zanguina et al, (1998) [17].

Potential Sokoto Sector Reservoir Rocks

These include the Illo and Gundumi Formations of the Continental Intercalaire Group, the Taloka and Wurno Formations of the Rima Group and the Gwandu Formation of the Continental Terminal Group on the clastic side and the Kalambiana Formation on the carbonate side. However, if we look at the lithologic descriptions of these units, we shall note as follows:

The Illo and Gundunmi are lateral equivalents. Gundunmi consists of basal conglomerates and gravels with sand and variegated clays increasing upwards, while Illo consists predominantly of cross-bedded grits with a major intercalation of pisolithic and nodular clays. Laterites and lateritic ironstones forming resistant cappings on top of the grits, (Figure 1). A close examination of this will show that both these formations have a lot of clay intercalations with some forming lateritic iron stones which will be bad for drilling bits and clays are big time barriers to fluid flow. The quality of the reservoirs will undoubtedly be variable ranging from poor to good.

The Taloka and Wurno Formations: The Tolaka Formation as described by. (Obaje et al, 2013) [11] to consists of thinly-bedded or laminated siltstones with small load casts and bioturbation structures that are indicative of low energy marine environment The presence of lenticular bedding (flaser bedding) and wavy bedding in this formation further confirmed tidal-flat marine environment of deposition. The low energy entails inherently poor sorting and, therefore, poor reservoir characteristics. Again the presence of bioturbation can either act to enhance or further degrade the reservoir characteristics [18].

The Wurno Formation consists of pale, friable, fine-grained sandstones, siltstones and interbedded mudstones. Small-scale load cast, bioturbation structures and flaser bedding are abundant. (Table 1). Again, the sandstones are fine grained, and interbedded with mud stones. These are not very good characteristics of a good reservoir rock. There will be undoubtedly some production related issues which will engender very high resolution studies of the reservoirs.

Age	Formation	Lithology	Group	Fossils	Sedimentary Structures	Environment of deposition	Analogues	Thickness (m)	Deduced Porosity	Deduced Permeability
Quaternary-Eocene	Gwandu	Mottled massive clays, with coarse-medium grained ssts.	Continental Terminal	-	Lateritic ironstones and unconformable base	Fluvio-lacustrine setting	-		Poor	Very Poor
Early Paleocene	Gamba	White clayey lst interbedded with shales, gypsum & phosphatic pellets	Sokoto	-	-	Marginal-up to marine (littoral) and sabkha environment for the lst facies.	-	-	May contain secondary porosity (vuggy)	-

Early Paleocene	Kalambaina	White clayey limestones interbedded with gypsum & phosphatic pellets	Sokoto	Richly fossiliferous (benthic foraminifera), oolitic, fish teeth, and scales & moulds of bivalves mainly echinoids, lamellibranchs & gastropods	Phosphatic pellets & coprolites, and vuggy porosity inducing slumping and folding appearance	Marginal-up to marine (littoral) and sabkha environment.	-	25	May contain secondary porosity (vuggy)	-
Early Paleocene	Dange	Indurated shales with gypsum & numerous irregular phosphatic noodles and pellets. Shales also interbedded with thin layers of yellowish-brown limestone	Sokoto	Richly fossiliferous with agglutinated benthic foraminifera & ostracods	Phosphatic nodules and pellets, small-scale load casts, bioturbation structures and flaser bedding	Marginal marine up to marine (littoral) and sabkha environment (transitional/ marginal marine, shallow marine to inner neritic environment)	-	45	-	-
Maastrichtian	Wurno	Friable fine grained sandstones, siltstones and interbedded mudstones	Rima	-	-	Marginal marine (marsh & tidal flats)	-	-	Fairly Good	Fairly Good

Maastrichtian	Dukamaje	Shales with gypsum interbeds, middle marl & limestones or mud	Rima	Miliammina, Trochammina, Textularia, Ammobaculites, Ammodiscus, Haplaphragmoides spp. & planktic forams: Guembelitria, cretacea, Orbignya inflata, and benthic forms: Nonion, Nonionella, and Gavelinella spp. Reptilian bones	Vuggy porosity, concretionary limestone	Marginal hypersaline setting with marshes, lagoons, tidal flats and estuarine	Patti Fm/ Nkporo Shale	-	-	-
Maastrichtian	Taloka	Loosely consolidated sandstones and siltstones, claystones and shales	Rima	Reptilian bones	Thinly bedded or laminated siltstones with small load casts, lenticular and flaser bedding, & wavy bedding, bioturbation (Skolithos, Ophiomorpha, Thalassinoides), faecal castings	Transgressive shallow sublittoral complex (beaches and mudflats)	Patti Formation/ Nkporo shales	-	Fairly good	Fairly good
Early Cretaceous -Jurassic	Illo	Clays & sandstones	Continental Intercalaire	Fish teeth and podocarpean fossils, wood	Cross-bedding	Alluvial Fans-Lacustrine	Bima Sandstones, Nubian sandstones	240	Good	Good

Early Cretaceous - Jurassic	Gundumi	Gravels or basal conglom-erates, pebbly sst, mudstone, clayey sst, claystone	Continen-tal Interc-alaire	-	Uncon-formable base	Fluviatile-Alluvial Fans to Lacustrine	Karoo series of S/ Africa	350	Good	Good

Table 1: Showing the textural, structural, biostratigraphy, environment of deposition, possible analogues and deduced porosity and permeability characteristics of the Sokoto Sector Formations (after Ozumba, 2018) [6].

The Gwandu Formation consists predominantly of sandy, lateritic units (red and mottled massive clays, with intercalations of coarse to medium grained sandstone) (Table 1). The top of the formation has widespread lateritic ironstones forming resistant capping's to weaker rocks. Dorminantly this is a clayey unit with sandstone intercalations. The question will be how extensive and continuous are these sandstone interactions? Also being the topmost formation, it raises the issue of sealing potentials or trap integrity. The literature provides ironstones as seals but these lithologic units have not been proven as fantastic seals in other hydrocarbon producing regions. This will, however, be a good case study in future.

The Kalambaina Formation is made up of marine deposited white clayey lime stones classified as bio clastic wacke stone interbedded shales. Being carbonates, Kalambiana Formation exhibits solution porosity which is a form of secondary porosity. Nwajide 20123, ascribes the folded appearance of this formation as caused by slumping due to solution cavities in the underlying lime stones. However, the total maximum thickness of this formation (25m) makes it unlikely as a very good potential commercial reservoir to be explored. In summary, the potential reservoir rocks of the Sokoto sector of the Iullemmeden Basin may probably only be the Taloka and Wurno Formations which might have effective seals in the Dukamaje and Dange shales respectively while the coarse to medium sandstones of the Gwandu Formation may be good if the ironstones are proven to be good seals [14].

Niger Delta Basin Regional Geological Setting

The Niger Delta Basin is an extensional rift system located in the central part of the Nigerian coastal stretch. It has been, and is still being, built out on the passive continental margin into the Gulf of Guinea. It is one of the largest basins in Africa, with a subaerial extent of about 75,000 km^2, a total area of 300,000 km^2, and a sediment fill of ca. 500,000 km^3. The sediment fill has a thickness between 9-12 km [19,20]. It is surrounded by other basins that formed from similar processes and lies atop the Benue Trough a much larger tectonic structure. The eastern bound of the basin is marked by the Cameroon Volcanic Line and the transform passive continental margin.

The delta exhibits a large arcuate shape typical of the destructive wave-dominated type on the western side, and a tide-dominated-shape on the eastern side while the central part is river-dominated, (Figure 5). The delta sediments show an overall transition from marine prodelta shales (Akata Formation) through a paralic interval (Agbada Formation) and a continental succession (Benin Formation) [21]. It is the most significant hydrocarbon province on the western African continental margin. It started to evolve in the Eocene epoch and deposition is still on-going offshore. Over 150 oil fields have been developed in it with the offshore blocks making approximately one fifth of this number (Figure 5).

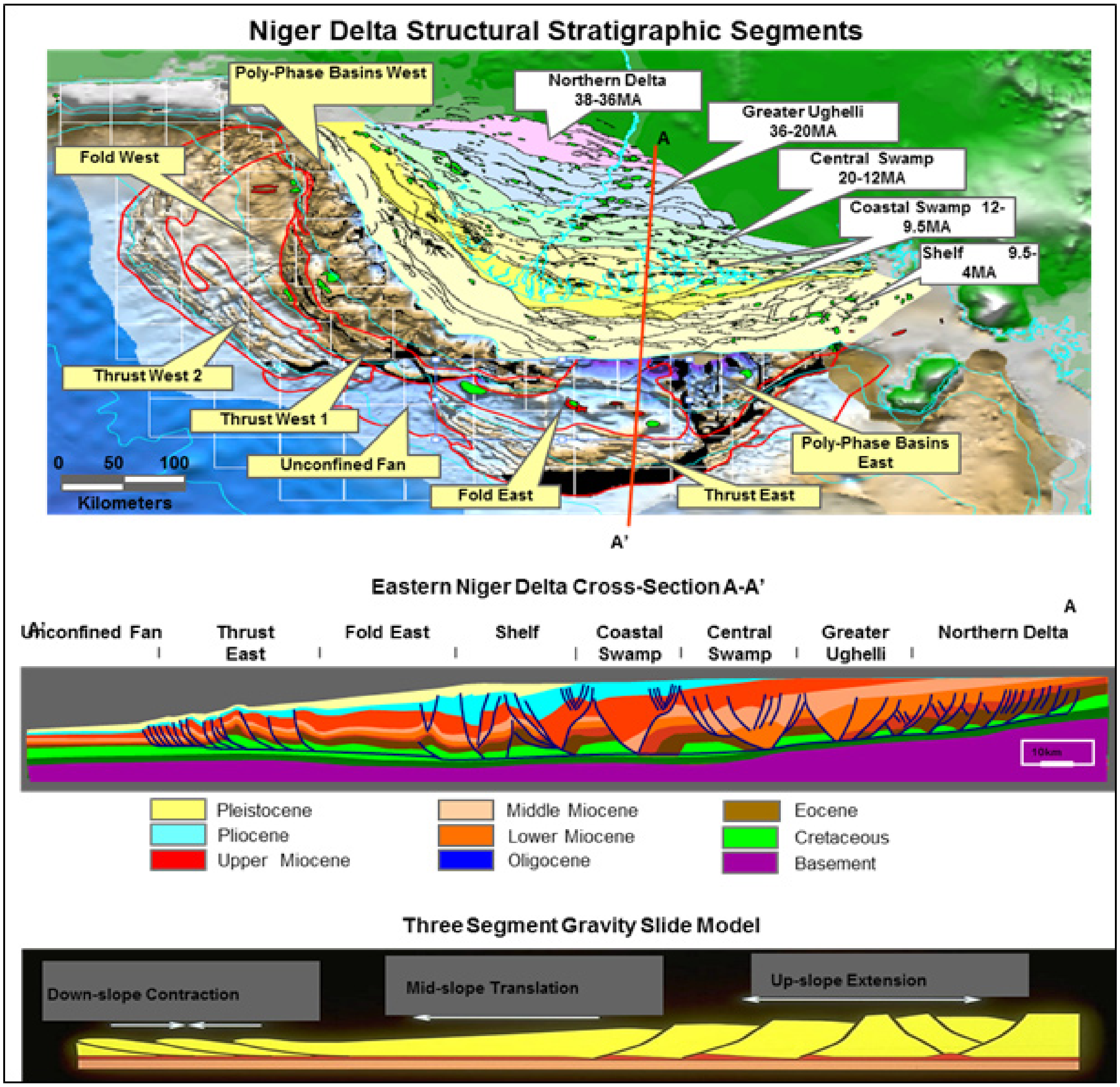

Figure 5: Showing the Structural and stratigraphic style in the Niger Delta [22,23].

Shale diapirism due to compression makes this basin different. The main impetus for deformation is however the gravitational collapse of the basin. The most striking deformational structural features are the large syn-sedimentary growth faults, rollover anticlines and shale diapirs [22]. The basin is divided into three zones based on its tectonic structure: an extensional zone lying on the continental shelf, over a thickened crust, transition zone, and a contraction zone, which lies in the deep sea part of the basin. The escalator regression model of Knox and Omatsola (1989) [24] describes the one-way stepwise outbuilding of the Niger Delta through geologic time. The units of these steps are the depobelts which represent successive phases of delta growth [25]. They are composed of bands of sediments about 30-60 km wide with lengths or up to 300 km. They contain major fault-bounded successions which contain a shore face alternating sand/shale sequence limited at the proximal end by a major boundary growth fault of a succeeding depobelt, or any combination of these. Seawards, successive depobelts contain sedimentary fills markedly younger than the adjacent ones in the landward direction. The six major depobelts generally recognized as shown in (Figure 5) are Northern Delta, Greater Ughelli, Central Swamp, Coastal Swamp, Shallow Offshore and Deep Offshore. The Deep Offshore has a unique structural style [23,26].

Niger Delta Petroleum System

Many workers have tried to study and understand the petroleum system of the Niger Delta. These include Ekweozor et al, (1979) [27], Ejedawe (1981) [28], Ejedawe et al, (1984) [29], Stacher (1995) [30], Haack et al, 1997 etc [31]. Stacher used data from the Central Swamp of the delta and the evolving concept of sequence stratigraphy to develop a hydrocarbon habitat model for the Niger Delta (Figure 6). The model relates deposition of the Akata Formation (the assumed source rock) and the sand/shale units in the Agbada Formation (the reservoirs and seals) to sea level. Pre-Miocene Akata shale deposited in deep water during lowstands is overlain by Miocene Agbada sequence system tracts. The Agbada Formation in the central portion of the delta fits a shallow ramp model with mainly highstand (hydrocarbon-bearing sands) and transgressive (sealing shale) system tracts and third order lowstand system tracts were not formed. Faulting in the Agbada Formation provided pathways for petroleum migration and formed structural traps that, together with stratigraphic traps, accumulated petroleum. The shale in the transgressive system tract provided an excellent seal above the sands as well as enhancing clay smearing within faults. These transgressive shales formed the anchor points for correlation through the entire Niger Delta.

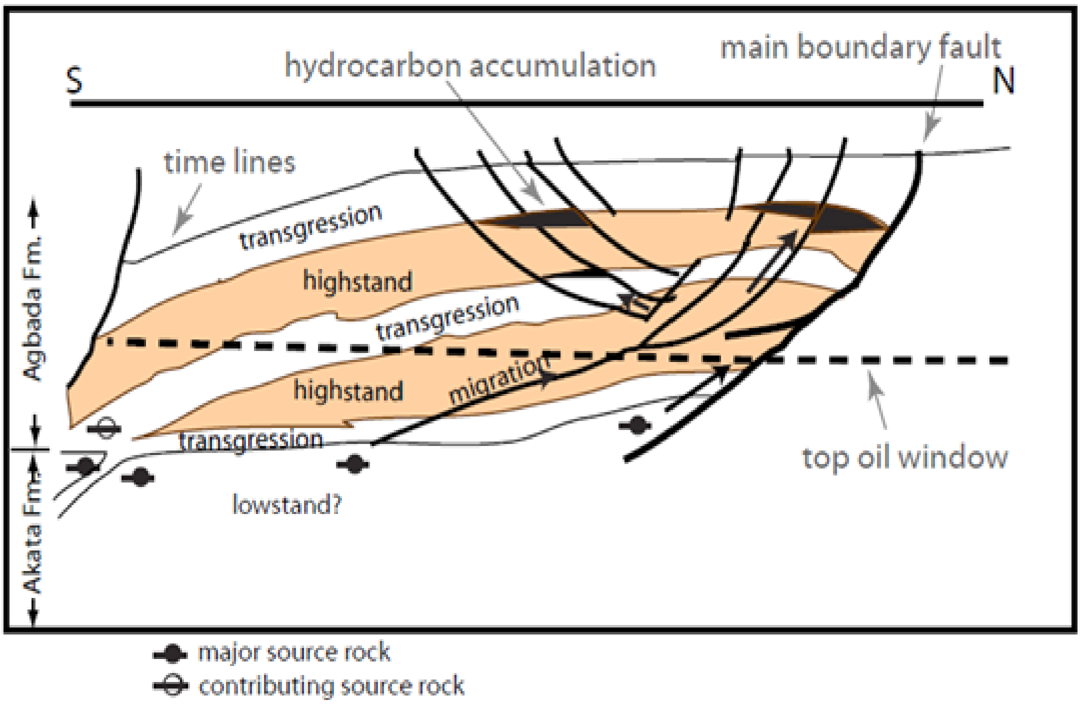

Figure 6: Sequence stratigraphic model for the central portion of the Niger Delta showing the relation of source rock, migration pathways and hydrocarbon traps related to growth faults. The main boundary fault separates megastructures which represent major breaks in the regional dip of the delta [30].

Ekweozor et al, (1979) [27] used alpha and bitter-hopanes and oleananes to fingerprint crude with respect to their source-the shale of the paralic Agbada Formation on the eastern side of the delta and the Akata marine-paralic source on the western side of the delta [32]. further constrained this hypothesis using geochemical maturity indicators, including vitrinite reflectance data that showed rocks younger than the deeply buried lower parts of the paralic sequence to be immature [33], argued that the migration efficiency from the over-pressured Akata shale would be less than 12%, indicating that little fluid would have been released from the formation. They derived a different thermal maturity profile, showing that the shale within the Agbada Formation is mature enough to generate hydrocarbons.

Combining all this evidence from studies and practical results from drilled wells incvluding many unpublished works of many geochemists, Shell Oil, developed a model for the generalized hydrocarbon systems, migration, structure and stratigraphy of the Niger Delta integrating the Deep Offshore (Figure 7). The Niger delta has unique structural and stratigraphic features that have served as traps for hydrocarbons, (Figure 8).

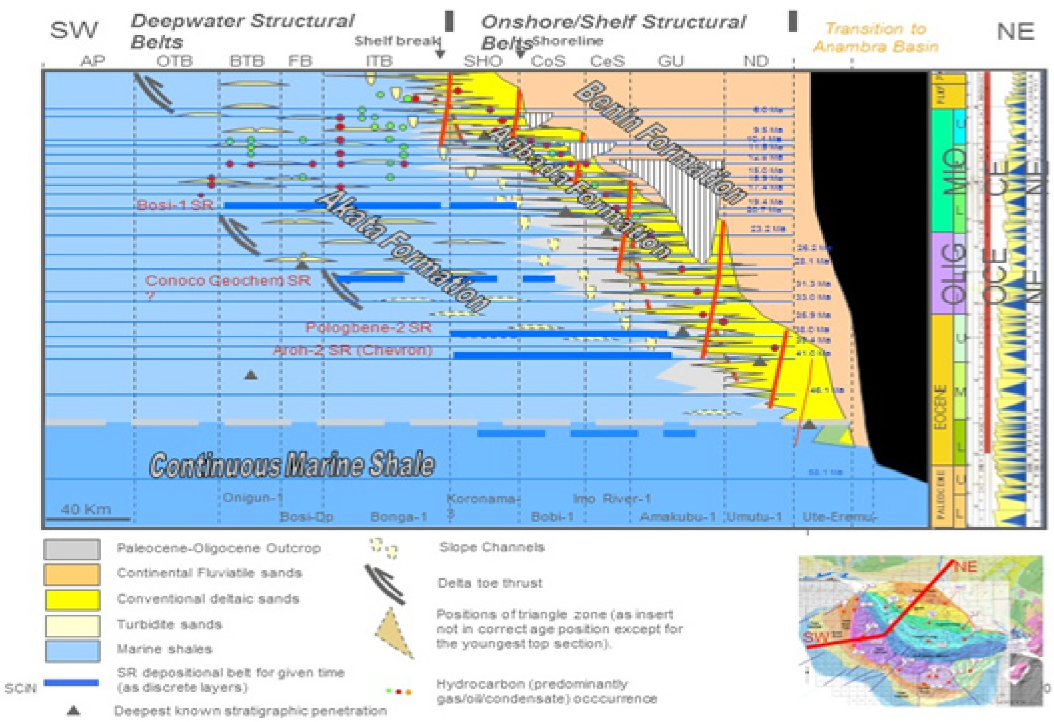

Figure 7: Generalized Niger Delta Stratigraphy, Gross Depositional Environment, and Hydrocarbon Occurrence [34].

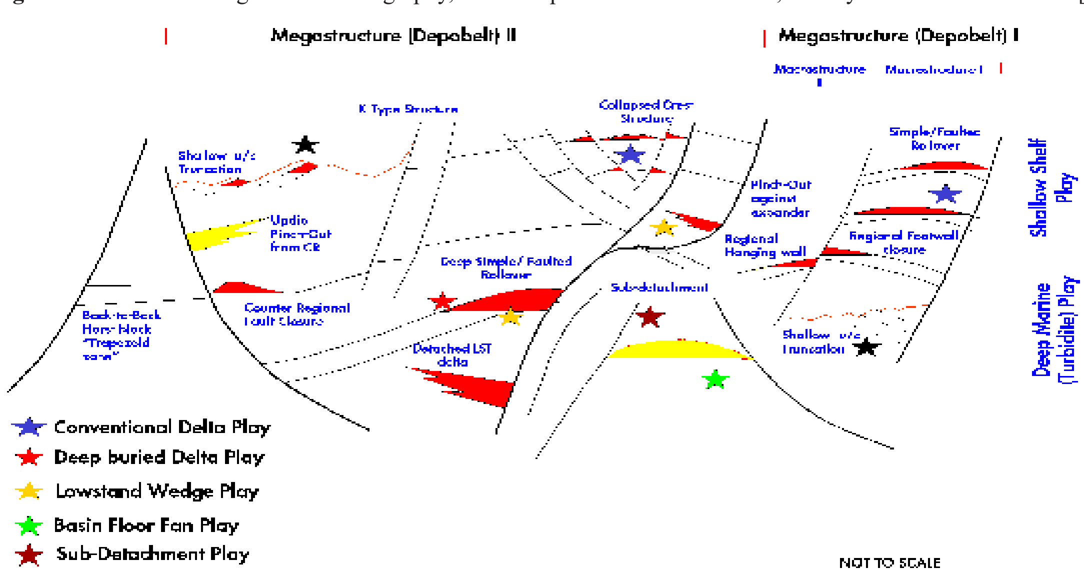

Figure 8: The generalized proven structural styles of the Niger Delta Basin modified after Evamy et al, (1978) [22].

Geological Comparison

Having written about the general tectonic evolution, stratigraphy, structures and petroleum source, reservoir, seal trap in the two basins, it is worthwhile to note that the depositional environments of the different facies of the basins vary (Figure 9).

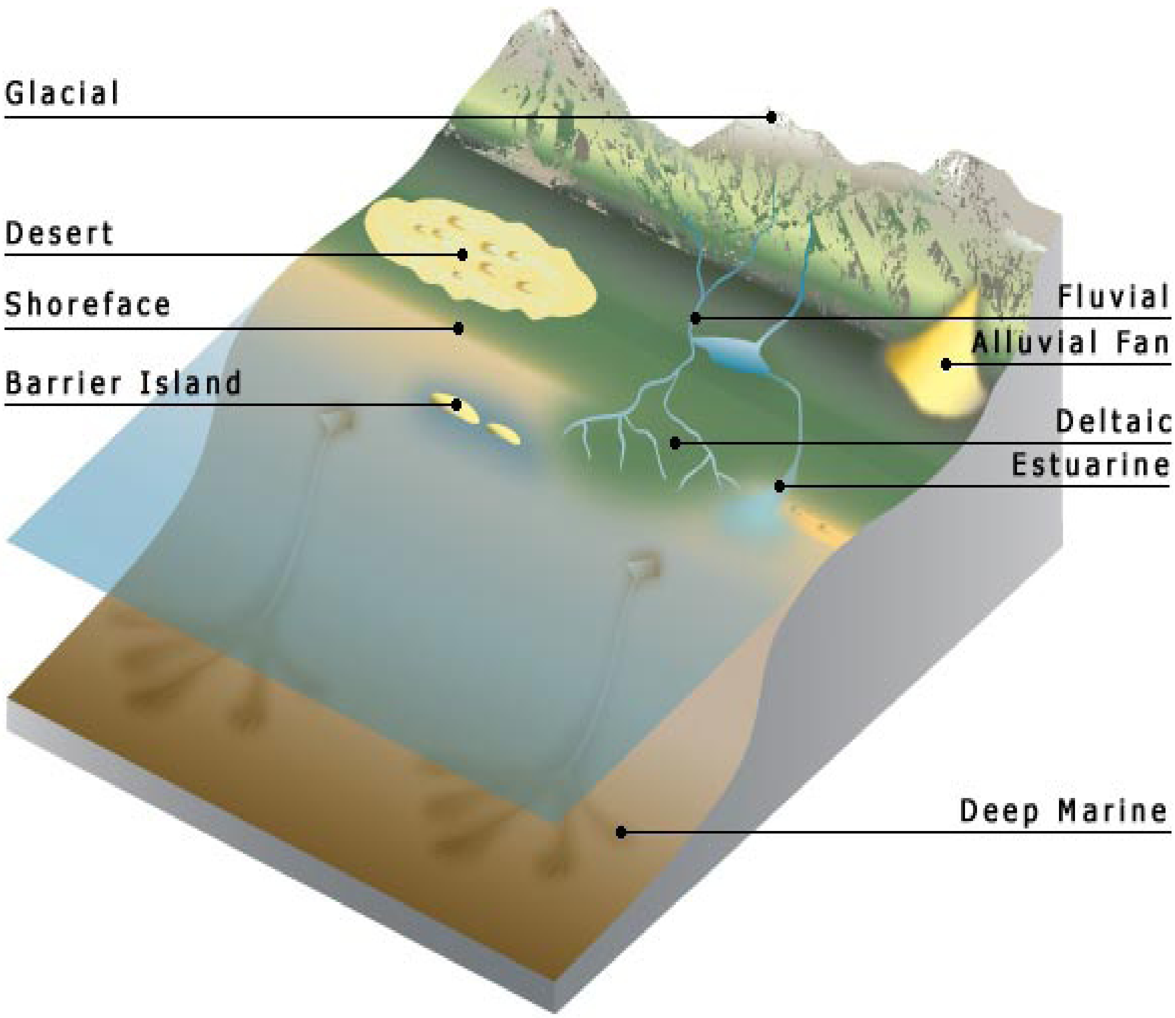

Figure 9: Gross depositional environment of the Niger Delta. Insert environments that represent some facies of the Sokoto sector'.

Conclusion

In general, little correlation exists between the Niger Delta and the Sokoto sector of the Iullemmeden Basin as shown in (Table 2) However, that does not in any way detract from the petroleum potentials and the quality of the reservoir characteristics of the Sokoto sector.

Niger Delta Basin	Sokoto Sector of Iullemeden Basin
Passive Margin	Intracratonic
Deltaic and Marine	Continental and Marginal Marine
Lithofacies entirely Clastic	Lithofacies both Clastic and Carbonate
Sediment thickness greater than 12km	Sediment thickness less than 3-4Km
Structurally Complex	Structurally Simple
Whole Basin	Eastern Margin of Iullemeden Basin
Stacked Reservoirs	Reservoir Stacking Unknown
Proven Petroleum System	Petroleum System Under Study
Diachronous Lithostratigaphy	Unconformity Bounded
Age is Eocene -Recent	Jurassic - Recent
Underlying Older -Anambra Basin	Underlying Basement
Lower Geothermal Gradient	Higher Geothermal Gradient
Mature Basin	Immature - almost Pristane

Table 2: Geological comparison between the Niger Delta Basin and the Sokoto Sector of the Iullemmeden Basin.

Potential reservoirs no doubt exist in the Sokoto sector as is the case with the Niger Delta but further studies especially after the preliminary seismic acquisition and processing will highlight the more intrinsic features and qualities of these Sokoto potential reservoir rocks.

Similar environment of deposition exists in both basins especially in the shallow marine realm and these equivalent reservoirs in the Niger Delta have proven excellent reservoir rocks not just in quality but producibilty of the fluids contained in the reservoirs.

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