A Modified Structural Setting And Subsurface Distribution of Cretaceous Facies from Southwest to Northeast in the Calabar Flank of the Lower Benue Trough

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ABSTRACT

This research is focused on the structural setting and subsurface distribution of cretaceous facies in the Calabar Flank, Lower Benue Trough. The aim of this research is to compare the works of Nyong (1995), Reigers and Petters, (1997) in light of new available subsurface data. Materials used are data sets from three wells drilled at different periods within the same acreage (Wells A, B and C). Seismic data, well logs and mud log data have been used to analyze and study the subsurface geology of the study area. Well data from the three wells were viewed and matched with processed seismic data. A composite stratigraphic section produced show correlatable facies, their lateral extents and the subsurface facies distribution in the study area. Well A drilled, south central Calabar Flank encountered shale and sandstone, very thick shale unit with limestone overlying sandstone at the base. Well B also drilled south central Calabar Flank about 0.8km from Well A encountered the same sequence. Whereas Well C drilled about 4.7km from Well B encountered sandstone, shale, marlstone and limestone. This research shows that only well C encountered marlstone. Observations from the well sections, show the penetrated limestone unit appears disconnected, with very high resistive anomaly suggesting that the limestone reservoir penetrated by the three wells are not laterally continuous. These findings tend to modify the earlier published articles on the structural setting and subsurface distribution of Cretaceous sediments SW to NE of the Calabar Flank South Eastern Nigeria in terms of facies distribution, facies lateral extent and structural variability or changes.

Keywords: Correlatable facies, facies distribution, composite stratigraphic section, processed seismic.

INTRODUCTION

This research takes into consideration previous works carried out in the Calabar Flank with a view to modifying them in light of new sub surface data sets (well and seismic). Previous works by Nyong (1995), Reigers and Petters (1997) on the structural setting and subsurface distribution of sediments in the Calabar Flank were concepts drawn basically from surface outcrop studies which could be limited. This research seeks to support and validate most of their subsurface analysis and understanding especially in the identification of major lithostratigraphic sequences but however differ in few instances like facies distribution, stratigraphy, facies extent and structural variability. In addition, this research findings may however modify the previous works carried out in this area by making few inputs which were not adequately considered perhaps due to limited data as at the time of their research. The research area is located in the southern segment of the sedimentary domain of the Benue Trough (see Fig.1A). This domain is one of the most folded and mineralized sediments in Nigeria. The area is low lying and appears physiographically well defined, relating perfectly with the Cross-river drainage area. Its eastern boundaries are the basement complex topographic provinces as the Obudu plateau and the Oban hills both of which are extensions of the Cameroonian mountains known to be some 1800m above sea level (Fig:1B).

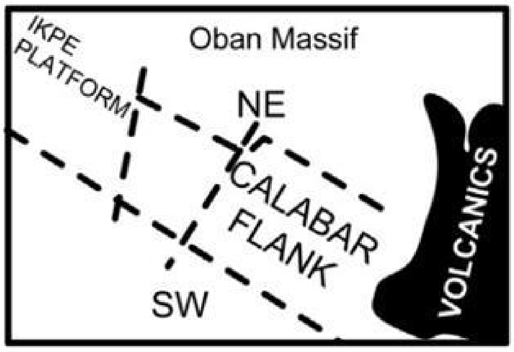

Figure 1A: Structural map of Study Area.

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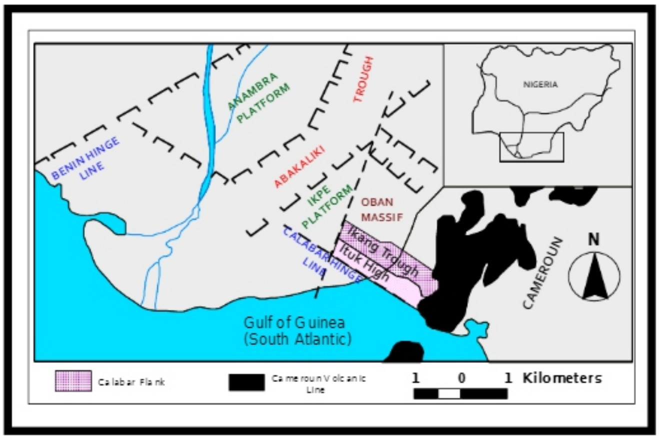

Figure 1B: Map showing the structural elements of the Calabar Flank and adjacent areas (Redrawn from Nyong and Ramanathan, 1985).

STRATIGRAPHY

The southern Benue Trough has four stratigraphic packages which are delineated by unconformities. The most prominent are the nonconformity between the crystalline basement complex and the basal units, and the angular unconformity forming the base of the Anambra basin. These two also have intervals between them that shows other unconformities which delineate stratigraphic units.

The associated transgressive and regressive cycles this region experienced made sediment of varying composition to be deposited (Nyong and Ramanathan, 1985). Sedimentary succession in this region is predominantly cretaceous comprising of the River-borne sandstone, Awi formation and the overlying marine Odukpani group (see Fig: 2A). The main geologic and stratigraphic units that underlie this region includes the arkosic sandstones of the Awi formation, Mfamosing limestone, the Ekenkpon shale (organic shale, calcareous mudstones and oyster beds), New Netim marlstones, Nkporo shales (carbonaceous shales, mudstones and gypsum) and the coastal sands otherwise called the Benin formation. The formation ranges in age from cretaceous to tertiary (Offiong and Edet, 1998).

The ages of the cretaceous sedimentary rocks range from the Aptian to Campo-Maastrichtian. Sedimentation began with the deposition of the Awi formation Sandstones interbedded with shales which is then uncomformably overlain by fossiliferous carbonates of the Mfamosing limestone. Sedimentation continued with the deposition of the Ekenkpon shale and New Netim Marlstone. There was a period of non-deposition recorded during the Late Coniacian Early Campanian. Sedimentation in for the cretaceous sediments ended with the deposition of the Nkporo Shale in the Late Campano-Mastrichtian age (see Fig. 2B)

Structural setting

The Calabar Flank is that part of southern Nigeria sedimentary basins characterized by crustal block faulting trending in the NW-SE direction. The sedimentary basin

AGE	LITHOLOGY		DESCRIPTION
Recent Eocene -	Benin Formation		Loose sands, pebbly and arkosic
Maastrichtian L. Campanian -	Nkporo Shale		Dark grey, very fissile carbonaceous shale with gypsum bands and some calcareous nodules
Santonian	Santonian Deformation		Santonian deformational episode characterized by period of folding of pre-existing rocks and erosion and/or non deposition.
Coniacian	ODUKPANI GROUP	New Netim Marl	Dark grey massive marls intercalating with flaggy, calcareous grey shale with thalassinoides structures
Turonian	ODUKPANI GROUP	Ekenkpon Shale	Grey fissile shale with thin bands of calcareous nodules, limestone and mudstone units. Abundant shell fragments, keeled ammonite, juvenile
Cenomanian	ODUKPANI GROUP	Un-named Shale	Dark gray shale, highly fissile and separated by the upper shale unit by a regressive mudstone
Mid - Albian	ODUKPANI GROUP	Mfamosing Limestone	White to light grey limestone, stromatolitic at the base, with abundant fossils (gastropods, corals, shell fragments)
Neocomian - Aptian	Awi Formation		Reddish brown, coarse to medium grained arkosic sandstone. Pebbly at the base and exhibit fining upward succession in cycles, graded bedding.
Precambrian	Precambrian Basement Complex		Southeastern Basement Complex – Oban Massif composed predominantly of granite gneisses, granites and granodiorites.

Figure 2A: Stratigraphic chart of the Calabar Flank (Modified after Petters *et al.,* 2010).

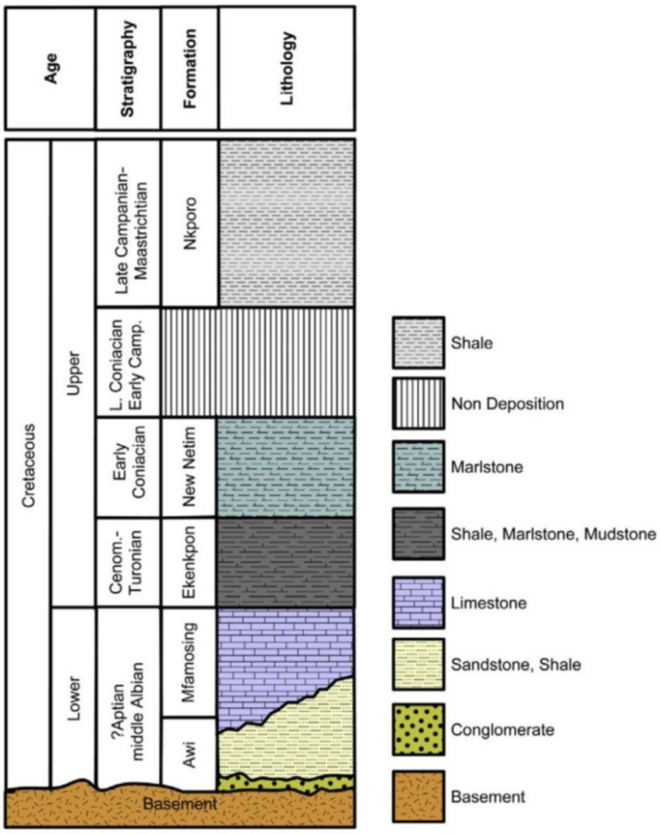

Figure 2B: Lithostratigraphic section of cretaceous sediment in the Calabar Flank.

was controlled by vertical movements of faulted blocks notably the Ituk High and the Ikang Trough and by associated transgressions and regressions (Murat, 1972; Nyong, 1995). This sedimentary basin is made up of about 4000mm of Albian to Maastrichtian marine deposits in outcrop section (Ehinola *et al.,* 2008) sitting on continental (fluvio-deltaic) Awi Formation (see Fig:3). Essien *et al.* (2005) pointed out the uniqueness of the basin such that within a stretch of about 8 km from the basement complex down-dip, the whole sections can be studied.

MATERIALS AND METHODS

Materials used for this research includes: seismic, amplitude data, well logs, location map and mud log data. These data were collected from three wells (A, B, C) that were drilled at different periods within the study area. This research was carried out in the workstation at the Department of Geology, University of Port Harcourt, using petrel and surfer softwares. The procedure adopted in carrying out this research involves lithology identification and description using well logs, processed seismic and mud log data. The result from this research was used to compare previous works in view to justifying the modification of their works.

RESULTS AND DISCUSSIONS

A composite stratigraphic section produced by matching Seismic attributes with well and mud logs were used to establish facie types, facie distribution and the lateral facie extent in the study area (see Fig. 4 and Fig. 5 and Fig. 6). The structural and subsurface schematic representation of facies types, their distribution and lateral extent (see Fig. 8) of the study area has been used to compare with previously published works in view to modifying the subsurface geology of the area (Calabar Flank) earlier established (Nyong and Ramanathan (1985), Reigers and Petters (1997)).

Fig. 7a and Fig.3 shows previously published work by

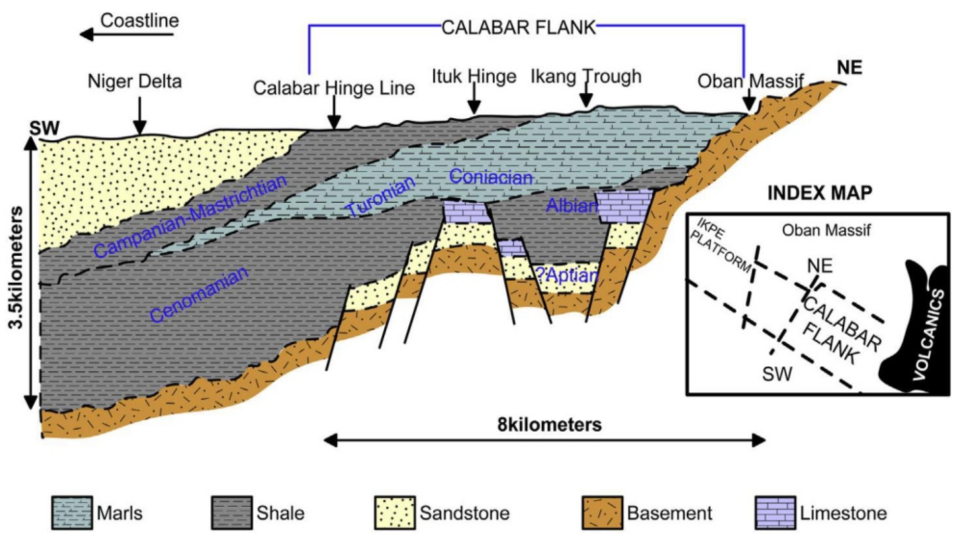

Figure 3: Structural setting and subsurface distribution of cretaceous sediment from SW to NE of the Calabar Flank (after Nyong and Ramanathan 1985).

Nyong and Ramanathan, 1985, Reigers and Petters, 1997 on the structural setting and subsurface distribution of cretaceous sediments in the Calabar Flank. This work is being compared with the findings of this research in light of new available subsurface data sets.

Well A drilled at the south central of the Calabar Flank which shows an intercalation of shale and sandstone, very thick shale units with limestone overlying sandstone at the base. Well B drilled also at the south central of the Calabar Flank about 0.8km away from Well A encountered the

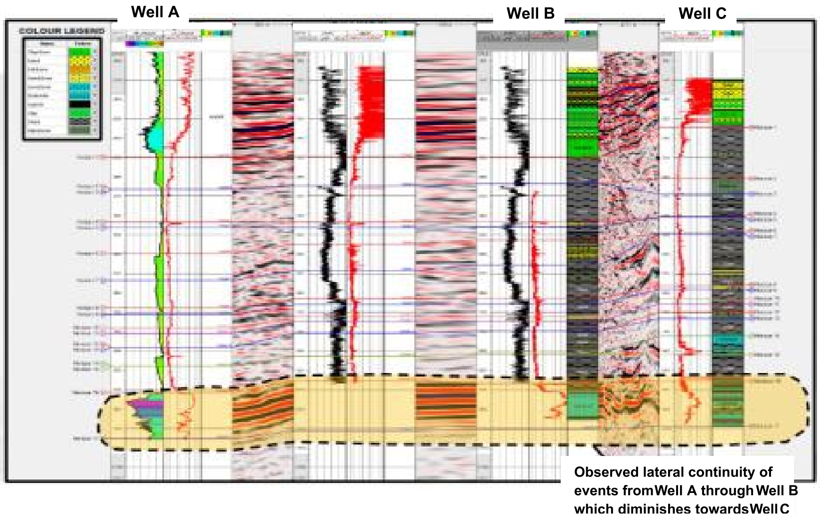

Figure 4: Composite Well Sectional View Of Wells A, B, C With Seismic Backdrops.

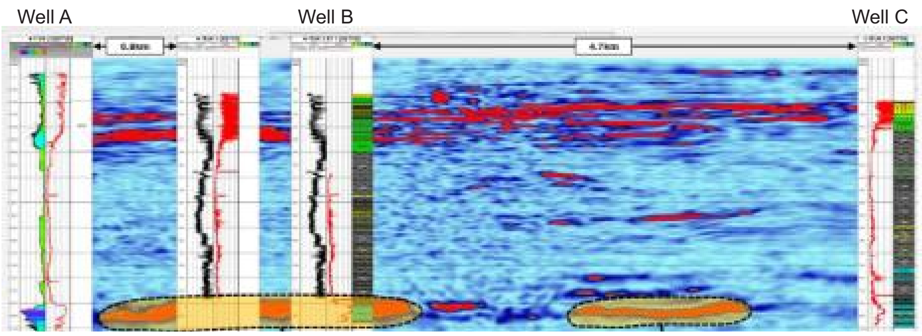

Figure 5: Well Sectional view of Well A, B, C.

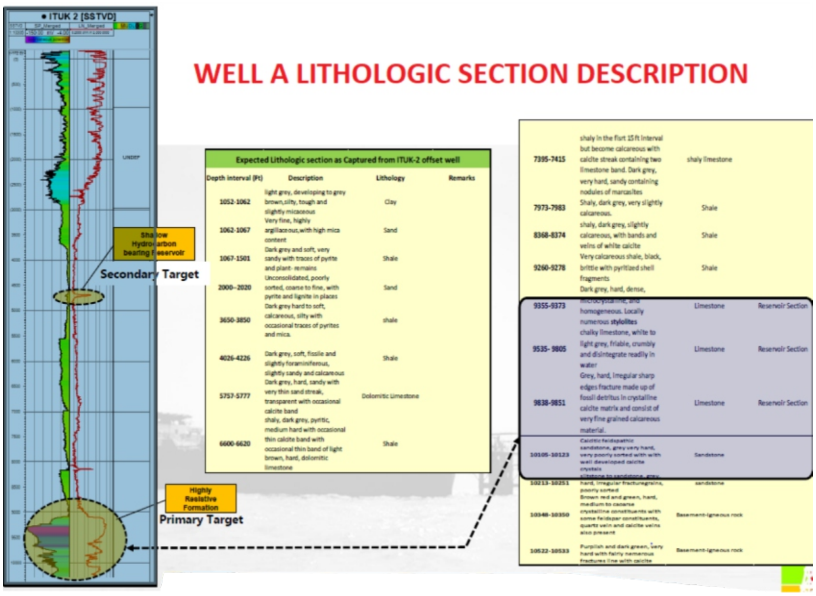

Figure 5: Well a lithologic section description.

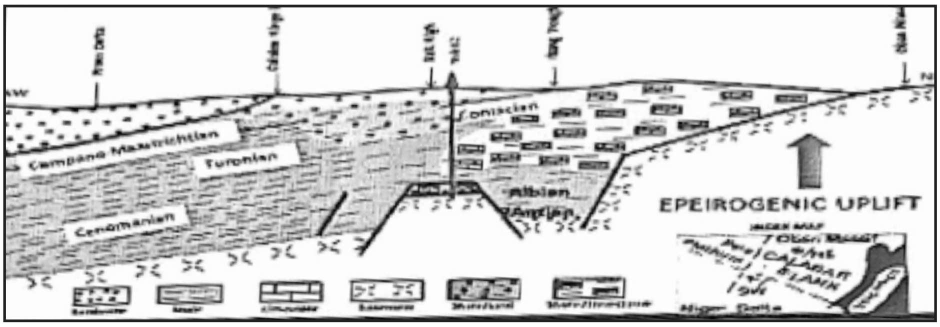

Figure7a: A schematic of the structural setting and conceptual subsurface distribution of Cretaceous sediments from SW to NE in the Calabar flank (Modified after Nyong, 1995, Reijers and Petters, 1997).

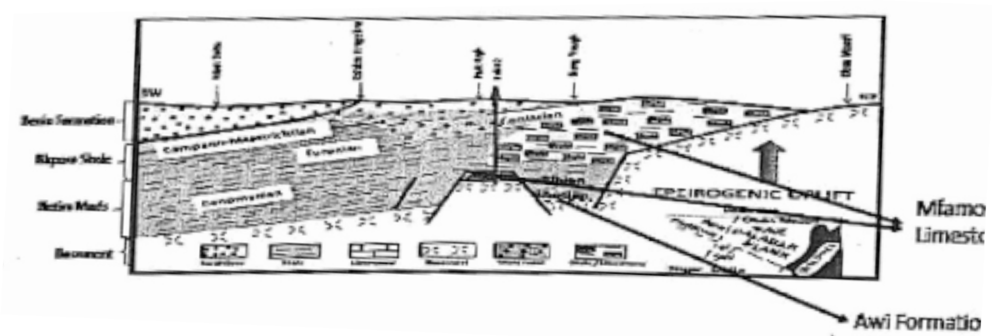

Figure7b: A labelled cross section of the area showing the various formations, including Mfamosing Limestone carbonate (Modified after Nyong, 1995, Reijers and Petters, 1997).

same sequence. Well C drilled about 4.7km away from Well B encountered sandstone, shale, marlstone and limestone. This research shows that only Well C encountered marlstone (see Table 1). This suggests that the New Netim marlstone which outcropped around Odukpani area of Calabar terminated early subsurface and did not extend to the south eastern part of the Calabar Flank. This is fundamental as it gives a new subsurface lithostratigraphic understanding of the Calabar Flank (see Fig. 8).

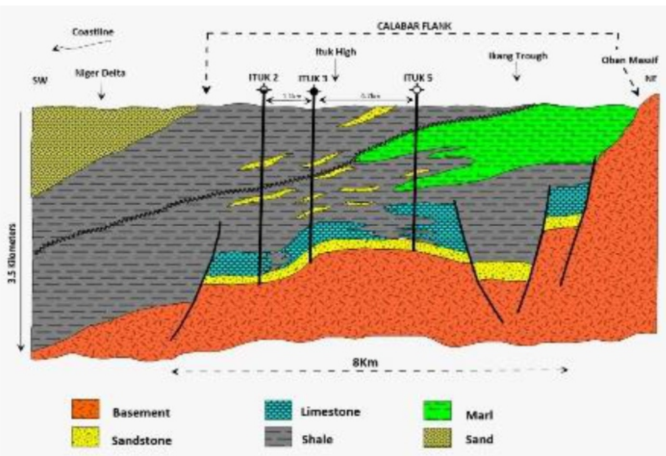

Figure 8: Modified structural and subsurface distribution of cretaceous sediments from SW to NE in the Calabar Flank.

The well's sectional view in Fig. 5 shows that the limestone penetrated by wells B and C appears disconnected, highly resistive anomaly which implies that the limestone reservoir as seen by well B is not laterally continuous to well C. Consequently, the limestone as tested by well B also pinches out before getting to well A. Lateral continuity of events is observed from well A through well B which diminishes towards well C as seen in Fig:4. This therefore implies that the limestone otherwise referred to as the Mfamosing limestone pinches out subsurface towards the Northeastern part of the Calabar Flank while there is an observed lateral disconnection of the same limestone along the subsurface southwestern part of the Calabar Flank. This subsurface geologic setting and sediment distribution discovered in this research is further represented as shown in Fig. 8. The previous works on Calabar Flank subsurface geology as represented in Fig. 7a & 7b and Fig: 3 shows that wells A, B, C would have penetrated same lithologic sequences which differ from what is observed in Fig. 8 and Table 1.

The stratigraphic correlation of lithologic units across the three wells drilled in the Calabar Flank shows the same correlatable sequence for well A and B while well C has a slightly different sequence (see Fig:9). Well C has

Table 1: Stratigraphic and lithologic sequence of lower Benue trough with wells that penetrated each section.

AGE	FORMATION	DEPOSITIONAL ENVIRONMENT	Wells that penetrat formations
Campanian Maastrichtian	Nkporo shale	Shallow- Marine	Wells A, B, C penetrated thi formation
Santonian	Santonian Episode	No Deposition	
Coniacian	New Netim marl	Marine	Only Well C penetrated
Cenomanian - Turonian	Ekenkpon shale	Marine	Wells A, B. C penetrated thi formation
Albian	Mfamosing	Marine	A,B,C penetrated Fm
Aptian	Awi Fm	Fluvio-Deltaic	A,B,C penetrated Fm
Precambrian	Oban basement		

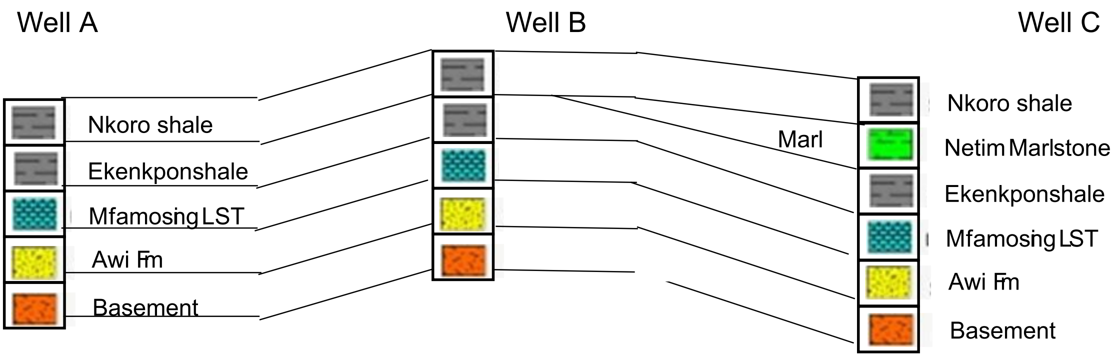

Figure 9: Correlation of stratigraphic units in This work (Calabar Flank).

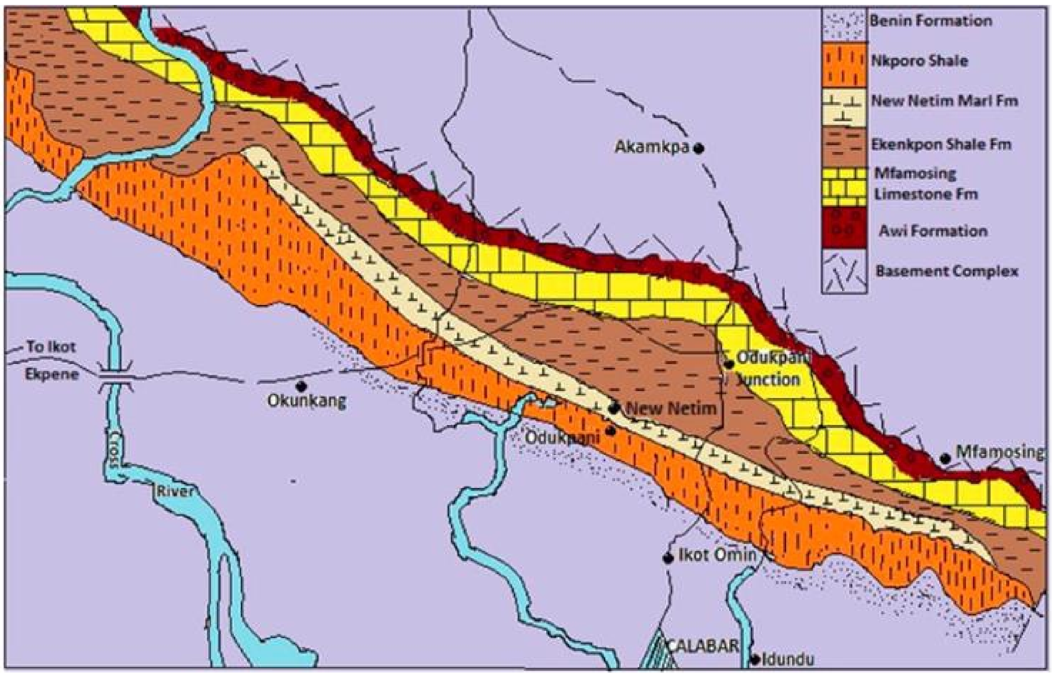

Figure10: Geologic outline and stratigraphic units of the Calabar Flank (after Shehu *et al* 2016).

marlstone overlying the Ekenkpon shale which pinched out before getting to well B as shown in Fig. 9. The stratigraphy in previous articles establishes a correlatable sequence from the Southwest to the Northeast of the Calabar Flank as shown in Fig. 10 which differ with the findings in this research.
This research finding therefore opens up reasons for comparison and modification to be made in the different versions as shown in Fig.3, Fig. 7a and Fig.8.

SUMMARY AND CONCLUSION

Previous works in the Calabar Flank have tried to conceptualize illustrations of the subsurface from surface outcrop studies. This subsurface research that is data driven (well and seismic) contradicts what has been done in the past. Juxtaposing the structural and subsurface geological setting from the findings of this research (Fig.8) against that shown in Fig. 3, Fig.7a and Fig. 7b representing the previous versions, it is evident that the lithostratigraphic sequences are not correlatable and different especially in the distribution of facies, their lateral extents and their structural settings. The Netim marlstone as previously established as a lithostratigraphic unit that stretches along the Northeast to Southwest of the Calabar Flank (Fig:10) is now modified as it is evident that it rather pinches out towards the south central Calabar Flank and did not extend (see Fig:8). The Mfamosing limestone was also previously established as a blocky connected lithostratigraphic unit that stretches along the Calabar Flank (Fig:10) is modified by this research as it appears disconnected subsurface and pinches out towards southwestern part of the Calabar Flank (Fig:5 and Fig:8). In view of this research findings a modified schematic of the structural setting and subsurface distribution of cretaceous facies from SW to NE of the Calabar Flank is produced in Fig. 8.

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