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OSTRACOD BIOSTRATIGRAPHY AND PALEOECOLOGY OF THE DUKULFORMATION IN THE YOLA ARM OF THE UPPER BENUE TROUGH, NORTHEASTERN NIGERIA

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ABSTRACT

Lithology, ostracod biostratigraphy, and paleoecology of the Dukul Formation have been carried out from outcrop sections at Lakun within the Dadiya Syncline,Yola Arm of the Upper Benue Trough. Lithologcal studies showed that the formation consists of fissile black shales interbedded with bioturbated grey marlstone, grey to brown mudstone, and biomicritic limestone. The ostracod assemblages comprise *Brachycythere sapucariensis, Ovocytheredea apiformis, Ovocytheredea symmetrica, Cytherella comanchensis, Clithrocytheridea senegali, Krithes sp.*and *Cythereisis gabonensis* with predominance of *Cytherella* and *Ovocytheredea* genera. The associated foraminiferal assemblages are mostly the agglutinated forms (*Haplophragmoides, Trochammina, Ammobaculities, Reophax*, and *Ammotium*) with few planktonic forms (*Heterohelix globulosa, H. moremani* and *Hedbergella sp.*). The lithofacies characteristics and microfaunal assemblages indicate a shoreline to shelf (inner to middle) environment of deposition. Ostracod assemblages and associated foraminifera give late Cenomanian-lower Turonian age for the Dukul Formation .The presence of pyritised black ostracods in pyritised black shale suggests anoxic depositional paleoenvironments.

KEYWORDS: Upper Benue Trough, Yola Arm, Dukul Formation,Ostracods, Biostratigraphy

INTRODUCTION

The Dukul Formation represents the base of the marine sequences in the Yola Arm of the Upper Benue Trough deposited during the late Cenomanian to early Turonian maximum transgressions which affected the Benue Trough and indeed world wide. The formation consists of very thick beds of fissile black shales intercalated with medium beds of fossiliferous and non fossiliferous brown to grey limestone, marlstone and mudstone (Carter et al.,1963; Ibrahim,1992; Mamman,1998; Ojo and Akande, 2000).

The Upper Benue Trough is the northern most part of the Benue Trough aulacogen which developed during the Early Cretaceous separation of the South American from the African plate (Benkheil, 1989) (Figure 1).

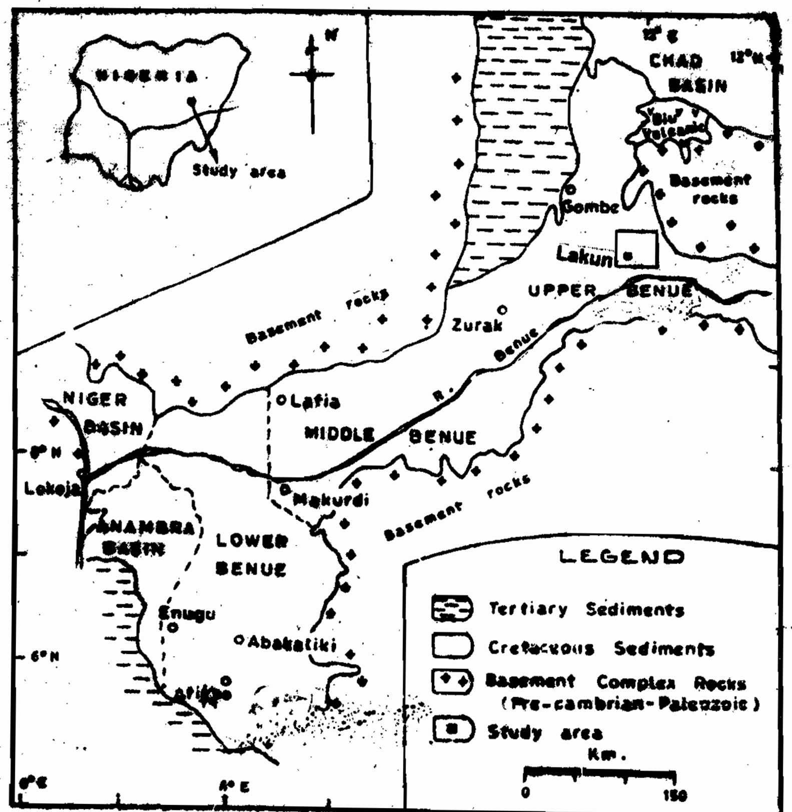

Fig. 1 The Benue Trough showing the study area (modified after Mede, 1993).

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Several workers have studied the sedimentology and stratigraphy of the formation mostly on a regional scale (Carter et al.,1963; Allix,1983; Mode,1993; Obaje, 2000). Also foraminiferal microfauna have been reported from the formation (Petters, 1980; Petters and Ekweozor,1982; Mamman,1998). The present study is aimed at the documentation of the ostracods from the formation and detailed lithologic studies from two outcrop sections exposed along stream channels at Lakun village within the Dadiya Syncline (Figure 2). The Ostracod assemblages allow the biostratigraphy and paleoecology of the formation to be assessed. Also the petroleum source rock potential of the formation is presented from the ostracod assemblages and the lithofacies characteristics. Taxanomic descriptions of the ostracods in this study are not presented here as our emphasis is more on lithostratigraphy, biostratigraphy and paleoecology rather than taxanomy.The taxanomic description will be published in another work in preparation.

Stratigraphy

The Yola Arm is covered by continental and marine Cretaceous Aptian-Early Santonian deposits with total thickness of 3-4 km (Carter et al.,1963; Benkheil, 1989; Allix, 1983;Odebode,1987; Mamman, 1998; Zaborski, 2000 and 2003) The stratigraphy is summarized in table 1.

The Bima sandstone is the oldest sedimentary sequence in the entire Upper Benue Trough and overlies the undulating Precambrian Basement Complex uncomformably. It has an overall thickness of close to 2000m and is Aptian to Albian in age (Carter et al., 1963 and Guiraud, 1990). The Bima Sandstone was deposited under continental conditions (fluvial, deltaic,lacustrine).and is made up of coarse to medium grain sandstones intercalated with carbonaceous clays, shales and mudstones.

The Cenomanian Yolde Formation lies conformably on the Bima Sandstone. This formation represents the beginning of a marine incursion into this part of the Benue Trough, and was deposited in a transitional/coastal marine environment. It is composed of sandstones, limestones, shales, clays and mudstones. The lower Turonian Dukul Formation represents the basal part of the full marine sedimentary sequences and overlies the Yolde Formation directly. It comprises of limestone, marlstone, mudstone and shale. The Jessu Formation overlies the Dukul Formation, and was deposited during the upper Turonian regression in the basin. The formation compose of shale, siltstone, mudstone and fine to medium grain sandstones.

The Senonian sequence (Sukuliye, Numanha and Lamja Formations) in the Yola Arm were deposited during the Coniacian in coastal to shelf marine environment (Carter et al., 1963 and Odebode, 1987). They composed of limestone, shale, mudstone and sandstone.

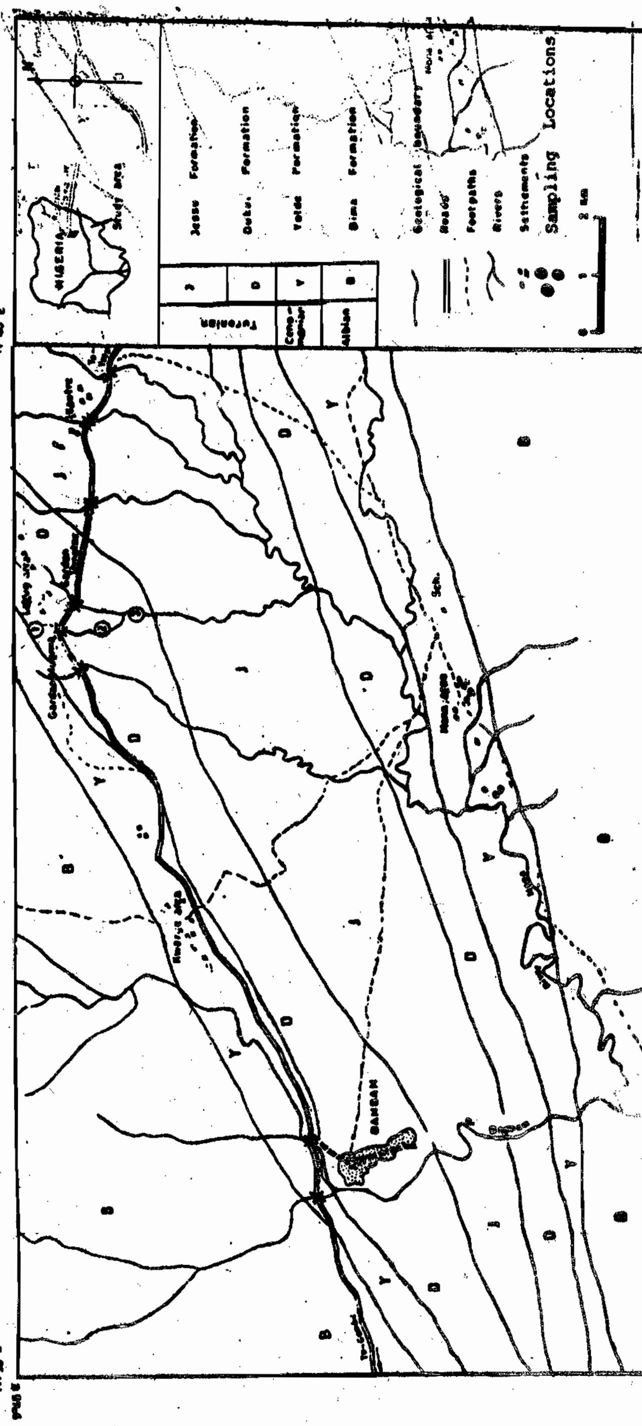

Fig. 2 GEOLOGICAL MAP OF THE STUDY AREA SHOWING SAMPLING LOCATION (modified after Benkheil J., 1985).

METHODS

Rock identification, bed by bed thickness measurements and collection of shale samples at interval of 0.5m for microfossil analysis were made from two outcrop sections of the Dukul Formation at Lakun village (Figure 2). The shale samples were disintegrated into small pieces using pestle and mortar and then treated with hydrogen perioxide (15%) and sodium bicarbonate ($NaHCO_3$) in order to free the microfossils from the rocks. The mixture is boiled, washed over 63µm(0.63mm) sieve mesh and finally oven dried. Both ostracod and foraminifera were picked from the residue. The microfossils picked were studied using reflected light microscope. The identification and classification of the ostracods have mainly been done according to the descriptions and figures of the following authors: Krommelbein (1964), Neufville (1973), Okosun (1992), and Swain et al., (1995).

The Dukul Formation

The type locality of the Dukul Formation is situated in a stream section south west of the Dukul village (Carter et al.,1963).The stratigraphic position of the Dukul Formation with respect to other formations in the Benue Trough is shown on Table 1. It is the lateral equivalent of the lower part of the Pindiga Formation and Gongila Formation in the Gongola Arm of the Upper Benue Trough and the Chad Basin respectively (Carter et al.,1963; Popoff et al.,1986; Gebhardt,1997). The two outcrop sections of the Dukul Formation studied are located 600m (section 1) and 1250m (section 2) north and south of Lakun village respectively along stream channels (Figure 2).

Table 1 Correlation of the stratigraphic Succession of the Lower, Middle and Upper Benue Trough (modified after Offodile, 1976; Petters, 1978; Lawal, 1979 and Petters and Ekweozor, 1982).

AGE	UPPER BENUE TROUGH. DADIYALAU (Petters, 1978)	UPPER BENUE TROUGH. PINDIGA – GOMBE (Lawal, 1979).	MID - BENUE TROUGH (Offodile, 1976.)	LOWER BENUE TROUGH (Petters & Ekweozor 1982.
Holocene			Volcanics	Benin Fm
Pleistocene				
Pliocene		Biu Basalts		
Miocene				
Oligocene				
Eocene				Ameke Fm. / Nanka Fm. / Ogwashi-Asaba
Palaeocene	Longuda Basalts	Kerri-Kerri Fm		Imo Shale Fm.
Maastrichtian		Gombe Sst.	Lafia Fm	Nsukka Shale / Ajali Sandstone / Mamu Fm.
Campanian		Pindiga Formation		Enugu & Nkporo Fm. / Owelli Fm. / Afikpo Fm.
Santonian			Hiatus	Hiatus
Coniacian	Numanha Fm / Sukuliye Fm / Lamja Sst		Agwu Fm	Cross River Group: Agbani / Nkalagu Formation
Turonian	Jessu Fm / Dukul Fm		Eze-Aku Fm	Cross River Group: Aga-ila / Nkalagu Formation / Makurdi
Cenomanian	Yolde Fm		Keana Fm / Awe Fm	Cross River Group: Nkalagu Formation / Amasiri
Albian	Bima Sandstone		Arufu - Uomba - Gboko	Asu River Group: Awe Fm. / Abakaliki Fm. / Awi Fm.
Pre-Albian	Basement Complex			

Section 1

Section 1 has a total thickness of 10m and the beds dip at an angle of 18°SE towards the main axis of the Dadiya Syncline (Figure 3). From the floor of the stream channel, section 1 starts with 0.5m thick hard massive fossiliferous grey limestone, visible fossils seen from hand specimen are the bivalves and ammonites, while petrograhic studies show whole ostracod carapaces, bivalves and bryozoans. These macrofossils form the allochems (10%) in the limestone, fine to medium grained angular to subangular quartz fragments constitute 15% and micrite 75%. The limestone has beer classified as sandy biomicrite (Folk, 1962). The limestone is overlain by thickly bedded fissile dark grey to black shales with interbeds of marlstone whose thicknesses range from 5 to 25 cm. The upper part of the section is characterized by thick fissile shales which change from dark grey to light brown in colour.

The dark grey marlstone beds are replaced by hard massive mudtsone units which range in thickness from 4 to 50cm.The shales contain detrital gypsum and glauconite. No macrofossils have been observed from the shales.

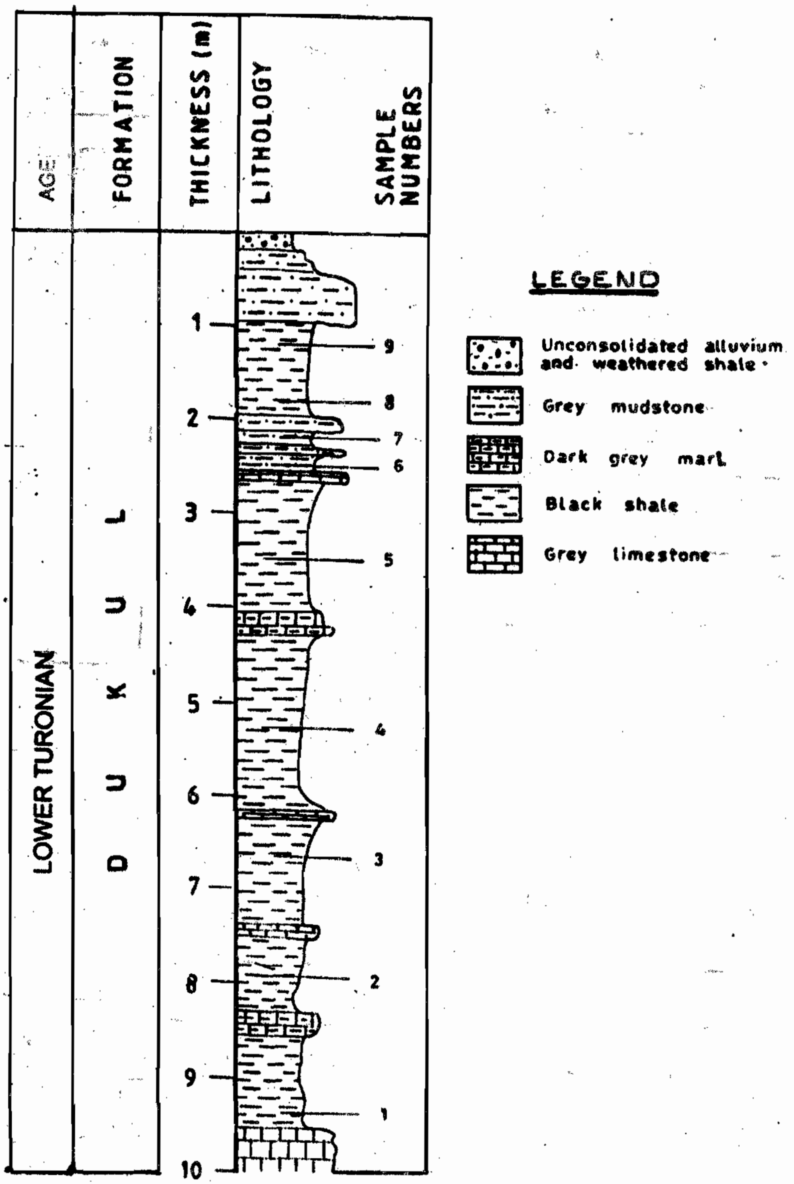

Fig. 3 Lithologic units of the Dukul Formation in section 1 Lakun village.

Section 2

Section 2 (Figure 4) has a total thickness of about 11m. From the bottom of the stream channel, the section consists of grey to black thinly and parallel laminated fissile shales with detrital gypsum intercalated with massive grey to brown limestone, mudstone and thin beds of gypsum (2cm thick). The limestone units in the lower part of the section are grey, massive and nonfossiliferous while those in the upper part are grey to brownish but fossiliferous (bivalves, ostracods carapaces etc). Petrographic studies classify the limestone as shelly biomicrite. The occurrence of some ammonites, bivalves and bryozoans in the limestone units indicate true marine conditions (Ehinola et al., 2003). Also the high lamination exhibited by the black shales with absence of bioturbation and scanty benthic foraminifera but plenty planktonics (Mamman work in progress) indicate deposition out of suspention in a low energy, oxygen deficient paleoanoxic environment (Demaison and Moore, 1980)

The lithologic units described from the two sections of the Dukul Formation are lithological equivalent of the lower Pindiga and Gongila Formations in the contiguous Gongola Arm and Borno Basin respectively (Carter et al., 1963; Popoff et al.,1986 ; Gebhardt,1997; Ojo and Akande 2001), lower Awgu and Nkalagu Formations in the middle and lower Benue Trough respectively (Obaje , 2000; Abubakar et al., 2001; Petters, 1980). These lithofacies are believed to have been deposited during the Late Cenomanian-Early Turonian peak period of the epicontinental transgression which have affected the whole of the Benue Trough and indeed the whole globe (Reyment 1980; Reyment and Dingle, 1987; Petters, 1980; Gebhardt, 1997; Demaison and Moore, 1980; Okosun, 1992). The lithofacies characteristics of the Dukul Formation from the two sections which correlate with similar reports by some earlier workers (Carter et al., 1963; Allix , 1983; Mode 1993 ; Petters, 1980), we suggest that the formation have been deposited in open marine (inner to middle shelf)

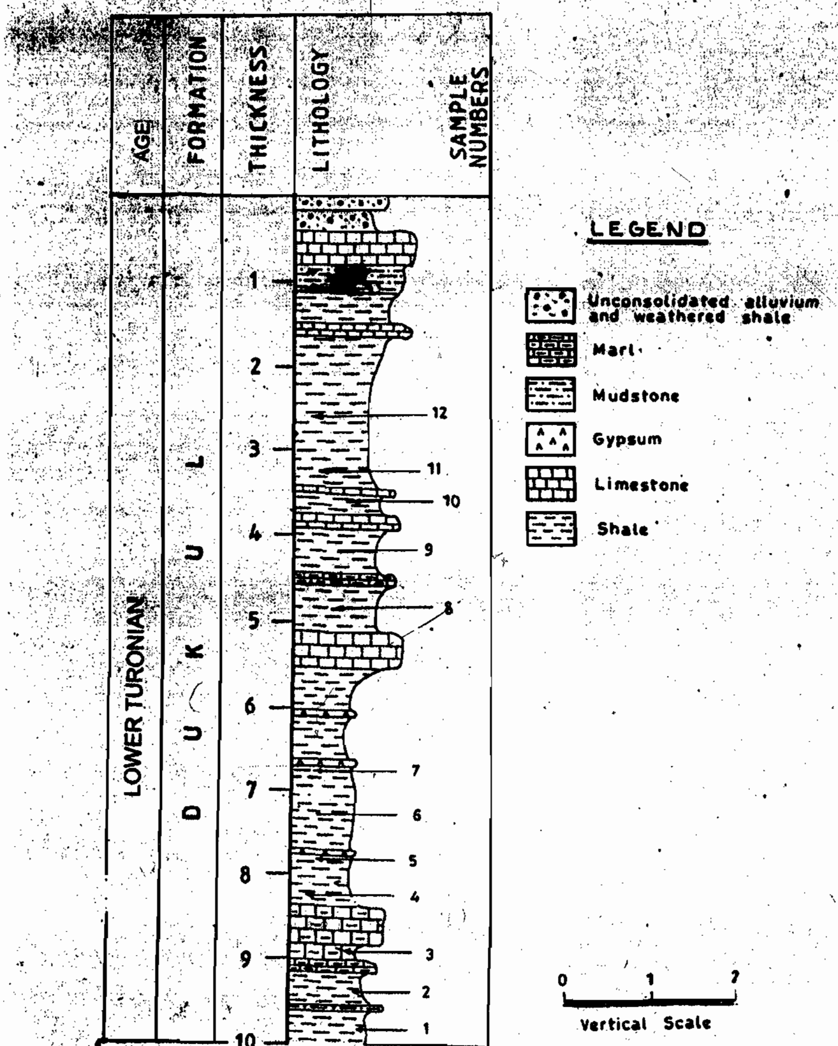

Fig.4 Lithologic units of Dukul Formation in section 2 Lakun village.

Ostracod Biostratigraphy

Ammonites, pelecypods, foraminifera and to lesser extent ostracods have been used to establish faunal similarities and correlations between Cretaceous sediments within and out side Nigeria (Cater et al.,1963; Reyment,1980; Petters, 1980; Popoff et al.,1986;). Ostracod reports from Nigeria came mostly from sediments of lower Benue Trough, Sokoto Basin,Chad Basin and Gongola Arm of the Upper Benue Trough
(Fayose and De Klasze, 1976 ;Okosun, 1992; Swain et al., 1995).

In this study, a total of 6 genera and 7 species of ostracods have been recorded from outcrop sections of the Dukul Formation (Figure 5 and Table 2). They are *Brachycythere sapucariensis, Ovocytheredea apiformis, Ovocytheredea symmetrica, Cytherella comanchensis, Clithrocytheridea senegali, Krithes sp.and Cythereisis gabonensis*. The associated foraminiferas are *Heterhelix globulosa, H. moremani, H. reussi*, and *Hedbergella sp.* (planktonics) which are Late Cenomanian-lower Turonian species (Petters 1980;Swain et al., 1995 ; Ehninola et al., 2003). *Brachycythere sapucariensis* was first described from the Sapucari Formation of lower Turonian age in eastern Brazil (Krommelbein, 1964).It has also been recorded from Turonian Eze- Aku Formation, lower Benue Trough (Swain et al.,1995), lower part of the Fika Shales(Turonian) and Gongila Formation (Okosun,1985 and 1992). Six of these species (*Brachycythere sapucariensis, Ovocytheredea apiformis, Ovocytheredea symmetrica, Cytherella comanchensis, Clithrocytheridea senegali, Krithes sp*) have been reported from Late Cenomanian to early Turonian marine sediments from Benue Trough and the Chad Basin in Nigeria (Reyment,1980; Okosun,1992;Swain et al., 1995), North and West Africa, Middle East and the US (Neufville, 1973;Reyment, 1980;Honigstein et al., 1985). From the ostracod assemblages and associated age significant foraminiferas, the age of the Dukul Formation is said to be lower Turonian.

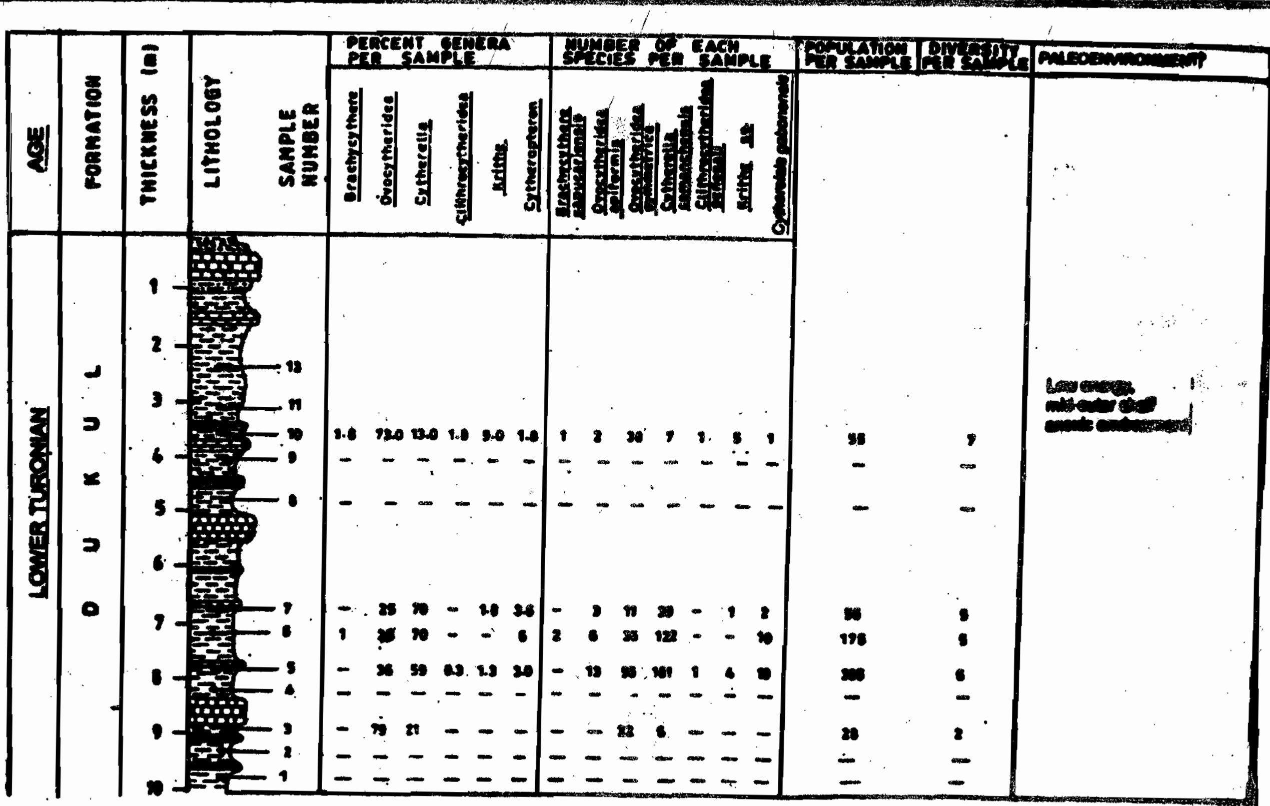

Fig. 5 Ostracods distribution chart for Dukul Formation in section 2 Lakun village.

Table 2. Percent Distribution of Ostracods Genera from Dukul Formation in Lakun Village

GENERA	TOTAL NUMBER OF GENERA IN SECTION 2	PERCENT ABUNDANCE
Brachycythere	39	5.89
Ovocytheridea	233	35.20
Cytherella	355	53.63
Clithrocytheridea	2	0.30
Krithe	10	1.51
Cythereidea	23	3.47
Total	662	100.00

Ostracod Paleoecology

Ostracods have been used in paleoecological and paleogeographical analysis because of their benthic nature and restricted mode of dispersal (Okosun,1992). The ostracod microfauna recorded from the two sections comprises of 6 genera and 7 species (Table 2). These are *Brachucythere sapucariensis, Ovocytheridea apiformis, Ovocytheridea symmetrica, Cytherella comanchensis, Clithrocytheridea senegali, Krithe sp.*and *Cythereisis gabonensis*.(Figure 5 and Plate 1). It is well known that for the Cretaceous and Cenozoic periods, the shoreline was characterized by an ostracod taxa that belonged to the *Cytheridea* genera (Howe,1971) which include species such as *Ovocytheridea apiformis ,Cyprides jones, Haplocytheridea stepenson*,etc. Also assemblages rich in *Bythocytherids, Cythereisis gabonensis* and *Macrocypridids* are characteristics of deep water marine shelf (Okosun,1998).The ostracods and foraminifera recovered from the black shale (sample 1) of section 1 are black to dark grey in colour and are dwarf forms .This is an indication of pyritization of the tests/shells and shows the reducing nature of the environment of deposition(Oertli,1971). The presence of the pyritised black shale ,dark brown to black ostracods provide proof of reducing micro or macro environment in the

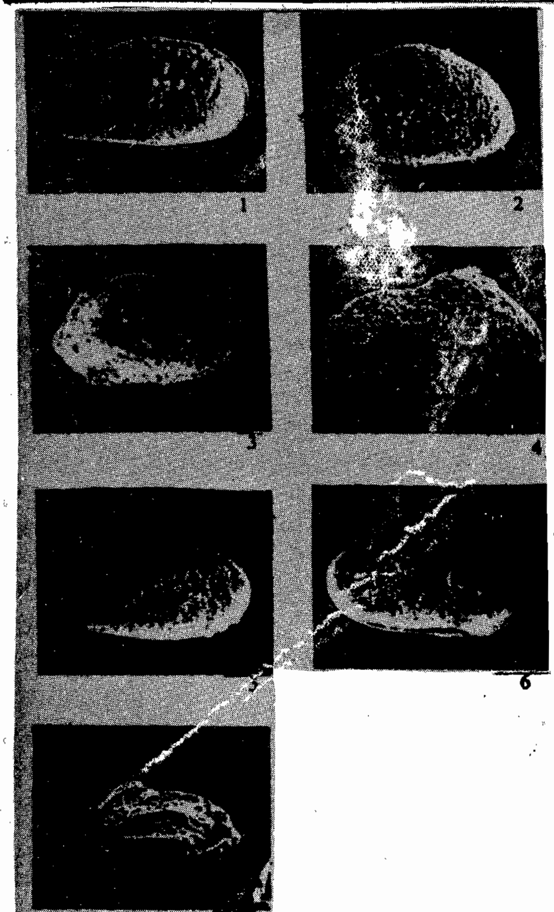

Plate 1: Ostracods recovered from the Dukul Formation at Lakun Village

1. *Brachycytheridea sapucariences* Krommelbein, 1964
   Right side of the carapace X 60
2. *Krithe sp.* Brandy Crosskey and Robertson, 1874
   Left side of the carapace X 60
3. *Clithropcytheridea senegali* Apostolescu, 1961
   Left side of the carapace X 60
4. *Cytherella comanchensis* Alexander, 1929
   Right side of the carapace X 60
5. *Ovocytheridea symmetrica* Reyment, 1960
   Right side of the carapace X 60
6. *Ovocytheridea apiformis* Reyment, 1960
   Right side of the carapace X 60
7. *Cythereisis gabonensis* X 60

sediment which from the petroleum geologist's point of view is a positive indication of good correlation between highly pyritised and dark brown or black ostracods and well intervals with oil or gas shows in Mozambique, Paris and Aquitaine Basins(Howe ,1971). The occurrence of the ostracods Krithe sp.,Cythereisis gabonensis in association with the foraminiferal species *Hetrohelix globulosa, Hedbergella sp., Haplophragmoides sp.* and *Trochamina sp* are indication of inner to middle epicontinental shelf environment of deposition (Brasier,1980 and Okosun ,1998).

Ostracod assemblages : their implication in hydrocarbon exploration Apart from their values in paleoenvironmental reconstructions and dating, ostracods have potentials in petroleum exploration.These includes the delimitation of ancient shorelines, indications of potential source rocks and its maturity based on the colour of the ostracod carapace. The determination of ancient shoreline in hydrocarbon exploration can lead to cost saving in an era of high cost of drilling wells. Major oil fields are many times associated with shallow marine continental shelves and shoreline facies. In the United States Gulf Coast and the Nigerian Niger Delta petroleum province, hydrocarbon reservoirs are found to be located in sands close to ancient shoreline (Howe, 1971 and Whiteman, 1982).The shoreline environment is characterized by many ostracod taxa (Howe,1971).The genera *Cytheridea* of which the species *Ovocytheridea apiformis* from the studied sections belong to this group, suggest that the upper part of the sections was deposited in shoreline environment(lagoon to estuarine), while the lower parts in epicontinental marine (shelf). The ostracods recovered from sediments usually vary from white to light brown or grey in colour. Such colour variations could be due to diagenesis (black colours from pyritization), thermal maturation of the contained sediments etc. Black shale usually contain pyrite and dark brown to black ostracod fauna. The dark brown and black colouration of the tests is due to pyritization of the ostracods shells which probably occurred immediately after death under anoxic conditions. The anoxic conditions will allow preservation of organic matter in the sediments which eventually form the source rock for the hydrocarbons. Black ostracods in the pyritised black shales have been observed from sample 1 section 1 of the study, which suggest that the black shales from these sections with black ostracods may have good organic matter content which can give rise to good petroleum source rock in the area. This findings correlate with that of Obaje (2000) which shows a total organic carbon (TOC) of 1.71 wt % for shales from the Dukul Formation at Lakun and environs. This is far above the minimum TOC of 0.5 wt % required for any good petroleum source rock (Demaison and Moore. 1980).

CONCLUSION

The Dukul Formation from the 2 sections studied consists of grey to brown fossiliferous and nonfossiliferous limestone, dark grey to black thinly laminated soft and hard shales with intercalations of marlstone and mudstone beds. The shale do not contain any macrofossils or tracefossils, while some of the limestone and marlstone contain both micro and macrofossils such as foraminifera (*Heterohelix, Hedbergella, Ammobaculities, Haplaphragmoides, Trochammina* and *Ammotium*), ostracod, ammonites, bivalves etc. The lithofacies and biofacies characteristics suggest that the formation was deposited in an open marine (inner to middle shelf) with high anoxicity.

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