INTERNATIONAL JOURNAL OF NATURAL AND APPLIED SCIENCES (IJNAS), VOL. 4, NOS.1& 2 (2009); P. 65– 76, 2 TABLES, 2 PLATES, 8 FIGS.

Paleoenvironment of the Mfamosing Limestone, Calabar flank, southeastern Nigeria.

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ABSTRACT

Microfacies analyses of outcrops samples and cores from two (2) wells were used in the determination of the paleoenvironment of the Mfamosing Limestone. Pelbiomicritic mudstone - wackestone, algal stromatolitic boundstone, oobiosparitic packstone - grainstone, intrabiosparitic packstone and biosparitic grainstone - packstone microfacies types were identified. These were used to infer lagoonal complex, tidal flats and channels, carbonate shoals and shelf margins with open circulation paleoenvironments respectively for the Mfamosing limestone.

INTRODUCTION

The paleoenvironment of the Mfamosing Limestone has been a subject of discussion over the years by various workers .This research is a contribution to this on-going debate which involves the use of petrography and microfacies analyses. The approaches used to achieve the objectives of this research includes: detailed field mapping, sampling of outcrops and cores and laboratory analyses etc. of these samples for the purpose of achieving the following.

(1) Determination of the paleoenvironmental condition during deposition of these carbonate sediments (2) Determination of other related attributes i.e. allochemical constituents, diagenetic imprints, depositional fabric and porosity. etc.

Samples used for this research where obtained from limestone outcrops from the field exercise, and from two (2) cored wells ODBH4/2 and ETBH3/2 located at Odukpani and Etankpini villages in the study area.

The limestone samples were used for petrographic and microfacies analyses which aided in the determination of the various paleoenvironments during the deposition of this carbonate sediments.

The formation of interest is the Mfamosing limestone (Petters, 1982) near Calabar, South Eastern Nigeria. This carbonate platform is located within the Calabar Flank (Murat 1972) and represents the thickest carbonate body in Nigeria (Reijers and Petters, 1987),(Figs. 1 and 2). It is about 50m thick in outcrop section (type section) and 450m thick in the subsurface on the Ituk high (Reijers and Petters,1987).

Geologic setting

Geologically, Calabar Flank is unique in many respect, it is that part of the southern Nigerian sedimentary basin that is bounded by the Oban massif to the north and the Calabar hinge line delineating the Niger Delta basin in the south, Fig.2 (Nyong 1995). It is also separated from the Ikpe platform to the west by a NE-SW trending fault. In the east, it extends up to the Cameroun volcanic ridge. It served as the gateway to all marine transgression into the Benue Trough and is located between two hydrocarbon provinces, the Tertiary Niger Delta and the Cretaceous Douala basin in Cameroun (Reijers and Petters, 1987). The origin of the Calabar Flank is intimately associated with the development of the Benue rift system, both events being related to the opening of the South Atlantic and the existence of a RRR triple junction which was active in Early Cretaceous times under the Niger delta miogeocline. (Burke et al, 1972, Nwachukwu 1972).

Structurally, the Calabar Flank consists of basement horsts and grabens that are aligned in a NW – SE direction like other South Atlantic marginal basins in West Africa (Reijers and Petters, 1987). The Calabar Flank shows striking stratigraphic similarities with coeval marginal basins of the South Atlantic. They all were produced during the opening of the South Atlantic ocean and the first marine incursion in Middle Albian resulted in Mfamosing limestone deposition particularly on the horst and relatively stable platform areas and their Flanks (Fig.2).

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Manuscript received by the Editor February 15, 2007; revised manuscript accepted August 11, 2008.
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METHOD OF STUDY

Extensive field mapping of this Limestone body was carried out along its depositional strike. A total of sixty (60) samples were collected from outcrops and from two (2) cored wells ODBH42 (Odukpani village) and ETBH32 (Etankpini village) located in the study area.

Standard thin sections of rock of standard thickness of 0.03m were prepared from the samples using thin section preparation techniques. From this methodology, forty (40) thin sections of different limestone rocks from outcrops and cores where produced for microfacies, diagenetic imprint, allochemical compositions and textural studies. Different microfacies where studied under plane polarized light (PPL) and cross polarized light (XPL) at various magnifications. Photomicrographs were also made from the thin sections.

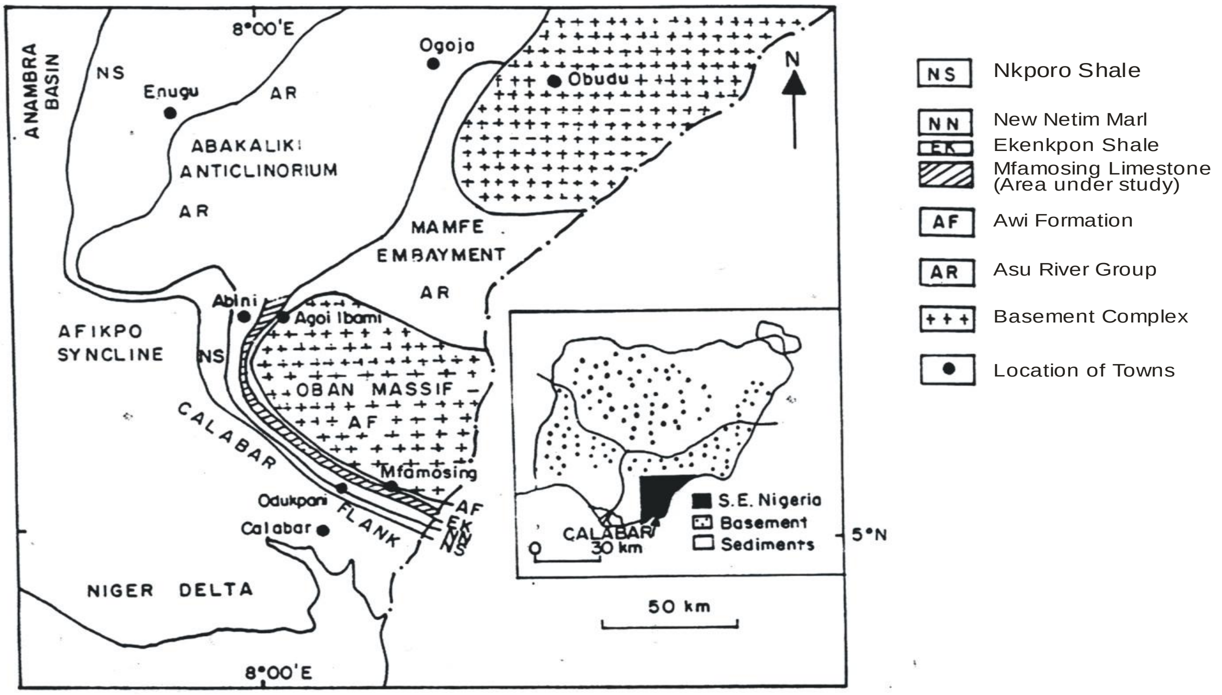


Fig.1 Geologic sketch map of south – eastern Nigeria Showing Mfamosing Limestone of the Calabar Flank. (Modified after Petters et al., 1995).

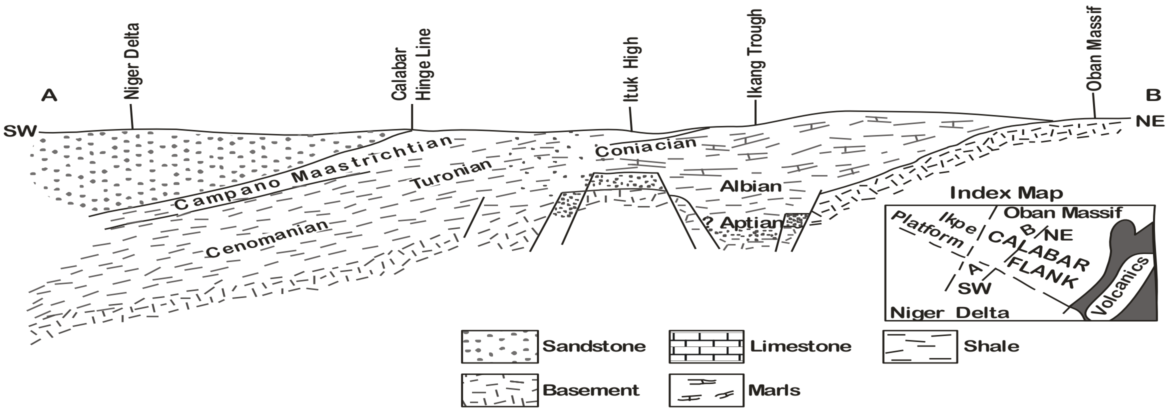


Fig. 2. Structural elements and conceptual subsurface distribution of Cretaceous sediments in the Calabar Flank (After Nyong,1995).

RESULTS

Microfacies and paleoenvironment

The petrographic description of the limestone thin section slides afforded the opportunity for the identification of the different microfacies types revealed from both outcrop samples and from the cores recovered from the wells.

The petrographic description of the two wells is given in Fig.3 and Fig.4, which shows the various microfacies obtained.

Well ODBH4/2 located in Odukpani village comprises of about 30m thickness of overlying greyish – dark grey fissile shales. The limestone unit is light grey – greyish in color, with a continuous sequence without any intervening sand or shale units to a depth of 42.75m. This implies that the Mid-Albian transgression here was continuous without any regressive episode. The basal unit is made up of arkosic sandstone of the Awi sandstone Formation. The sands are grey with a coarse grained texture (Fig.3).

From well ODBH4/2, four (4) microfacies were identified which gives a clue to the depositional environments in the well. The pelmicritic mudstone facies indicates deposition in a low energy lagoonal environment, while the biopelsparitic and pelbiosparitic grainstone facies where deposited in a high energy tidal channel environment. The pelbiomicritic wackstone also indicates deposition in a lagoonal environment. The overlying shales indicate a deep marine condition and the basal sandstones are of the continental environments. The limestone allochemical components comprises of pelloids, ooids, echinoid fragments, brachiopod fragments and other skeletal fragments in a micritic or a sparitic matrix. (Plate 1-4). The variation in petrographic attributes is with increasing depth of the well. The texture ranges from Calcilutite – Calcirudite.

The microfacies types encountered in the well are as shown in (Fig. 3). The important diagenetic features observed includes leaching, isopachous rim and cementation which is restricted to cracks and so represent post depositional processes in the limestone.

Depositional textures show that the limestone sequence in the well varies from mudstone – wackstone - grainstone.

For well ETBH3/2, there is a marked variation in texture ranging from medium – fine grain, and calcilutite – calcirudite with increasing depth of burial. The allochems are made up of intraclasts, pelloids, molluscan fragments, Algal micritic coatings, and gastropod fragments, with other bioclasts embedded in a micritic and a sparitic cement. Diagenentic processes encountered in the well include cementation and recrystallization with a mudstone – wackstone – grainstone depositional fabric.

The different depositional environments encountered in this well were obtained from the various microfacies types in the well.

The major microfacies are displayed in Fig. 4.

These microfacies represent different environmrents of deposition. The biopelsparitic grainstone, intrasparitic wackstone, represents deposition in a high energy environment such as a tidal channel, while the biomicritic mudstones, biomicritic wackstone and pelmicritic grainstone represents deposition in a low energy lagoonal complex.The variation in the different depositional environments is with increasing depth of burial in the well.

Apart from cores from the two (2) studied wells, outcrop samples from various localities in the study area (Mfamosing, Oberakai, Abgung, Etankpini, Odukpani and Okoyong Usanga Abasi) were also subjected to petrographic analyses with the sole aim of determining the different microfacies types from various petrographic attributes which helps in the determination of depositional environments in these various localities. Fig.5 shows different outcrops sections sampled with their respective petrographic attributes. The different microfacies types discovered includes oolitic pelloidal packstone, intrabioclastic grainstone – packstone, gastropod bioclastic grainstone, algal stromatolitic boundstone and microbioclastic lime wackstone. (Table 1, Plate 1-2).

The various allochems displayed consists of oolites, algal coated grains, intraclasts, pellets and bioclasts such as molluscan fragments, pelycepods, gastropods and echinoid fragments and foraminiferal test depositied in a sparitic or micritic matrix (Table 1). These microfacies types and its allochemical constituents have a spatial distribution in the studied area.

Diagenetic imprints reveals leaching, recrystallization, cementation and dolomitization. Plate 1-4 shows these various attributes with their respective microfacies types. The inferred depositional environment for this microfacies types which varies from different locatons includes Oolitic shoal, Tidal bar / channel for the oolitic pelloidal packstone, open shelf environment for the intrabioclastic grainstone – packstone facies, Lagoon for the gastropod bioclastic grainstone and intertidal bank for the algal mat stromatolitic b oundstone (Table 2). Detailed investigation of the outcrop samples and c ores from wells from the Mfamosing limestone reveals that, lit hologically and paleontologically, the Mfamosing limestone is not homogenous and shows variation to a greater extent. It displays rapid facfacies changes. Petrographic analyses shows that the microfacies types encountered in this limestone unit were continuously reoccurring at different localities both in the subsurface cores and outcrops (Fig.3 and Fig.4 and Table 1). Analyses of a variety of rock attributes including grain composition, texture, fossil occurrence and primary structures allows for the identification of the different microfacies types in this study. (Plate 1-2).

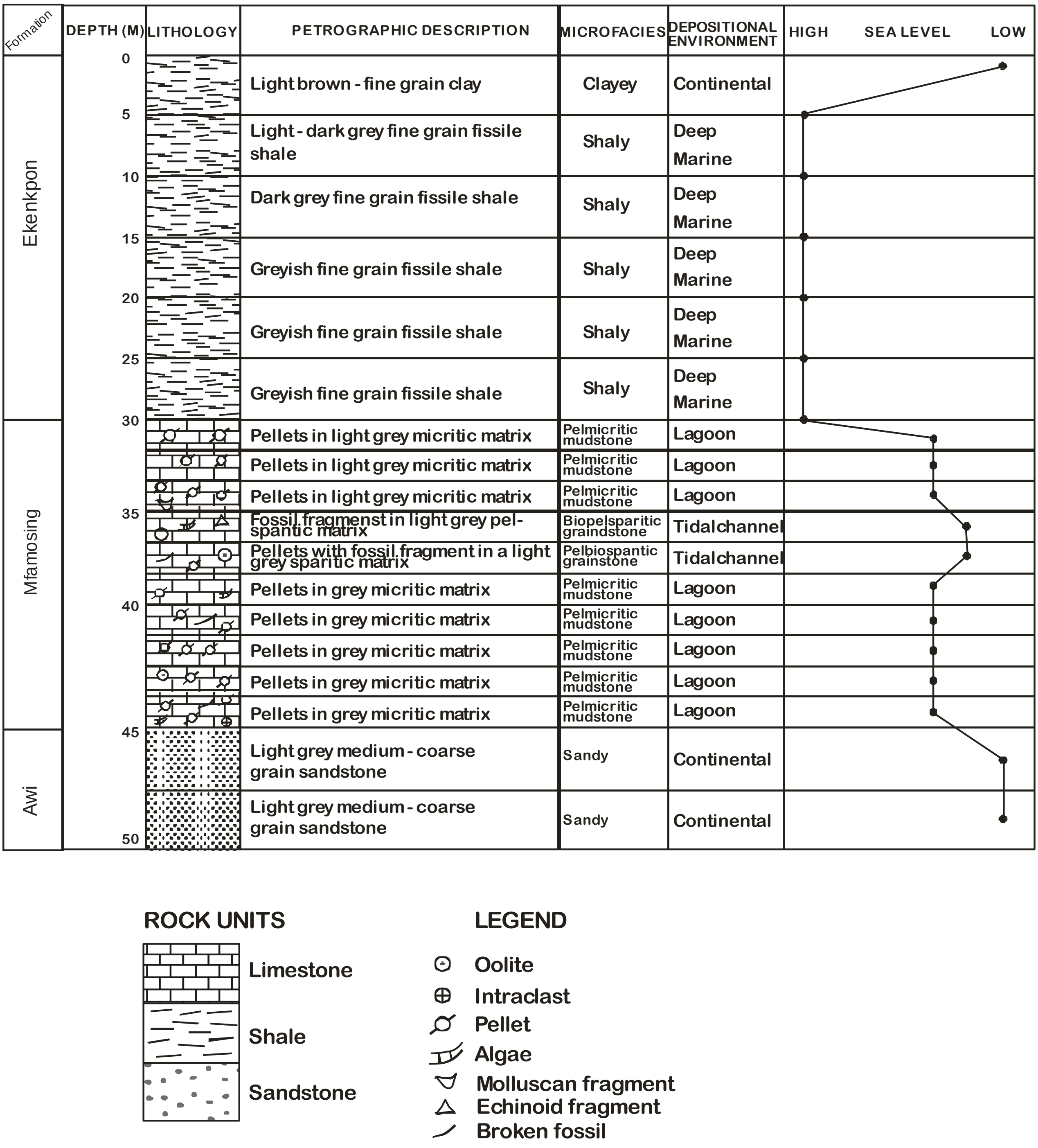


Fig. 3. **Lithostratigraphy, Petrography and sea level fluctuation for Well (ODBH 4/2) in Odukpani Village in the study area.**

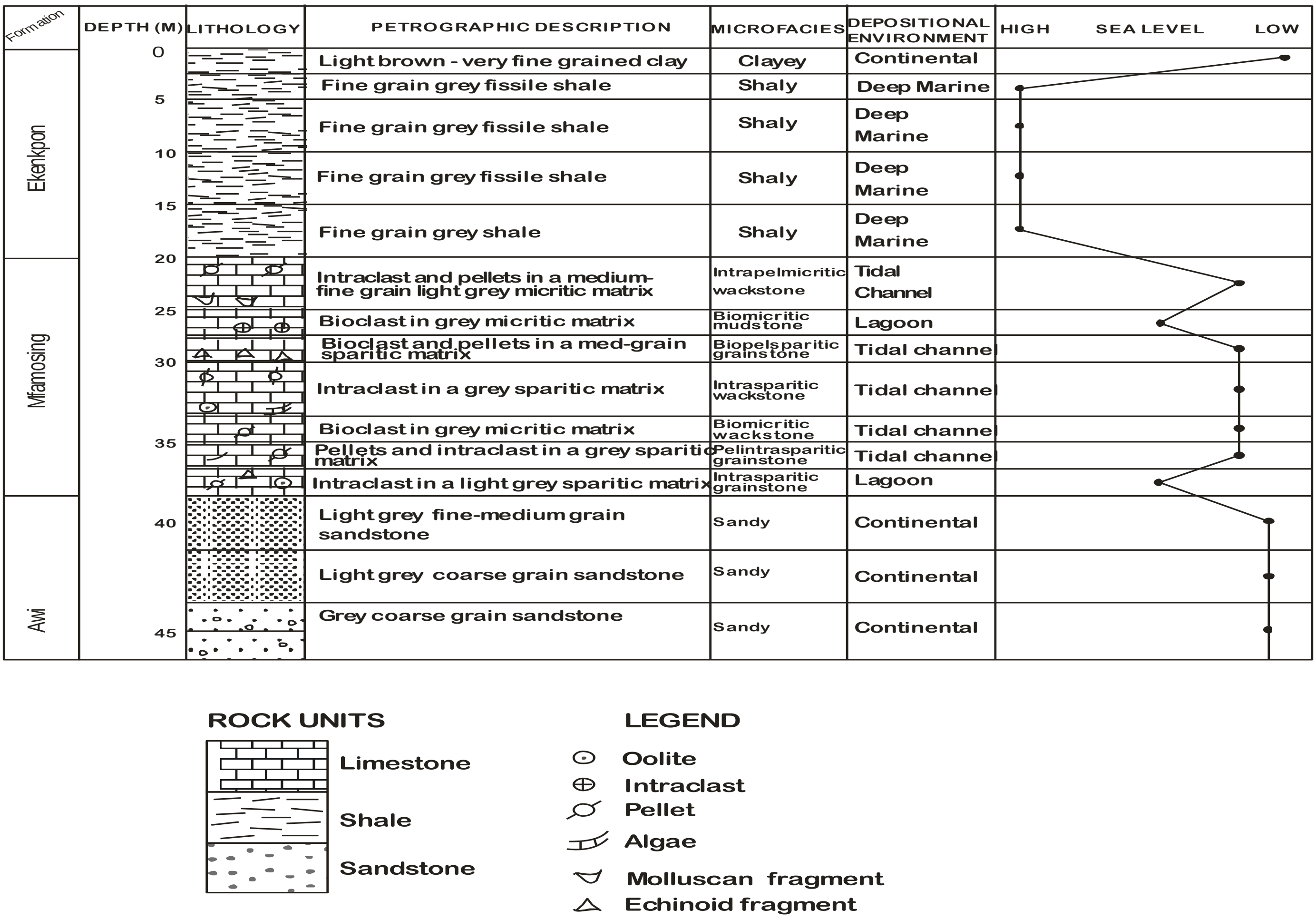
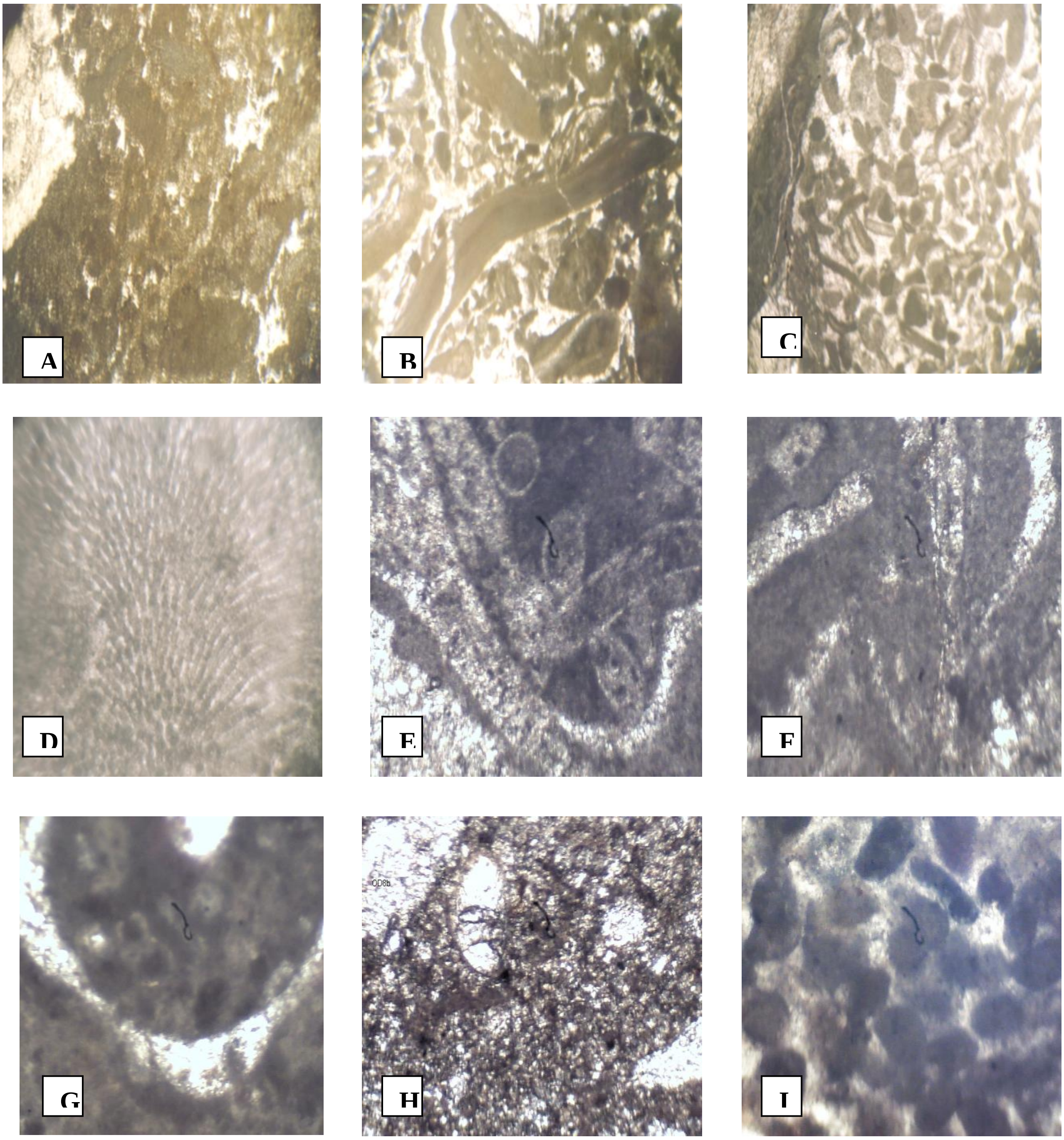


Fig.4. **Lithostratigraphy, Petrography and sea level fluctuation for Well (ETBH3/2)in Etankpini village in the study area.**

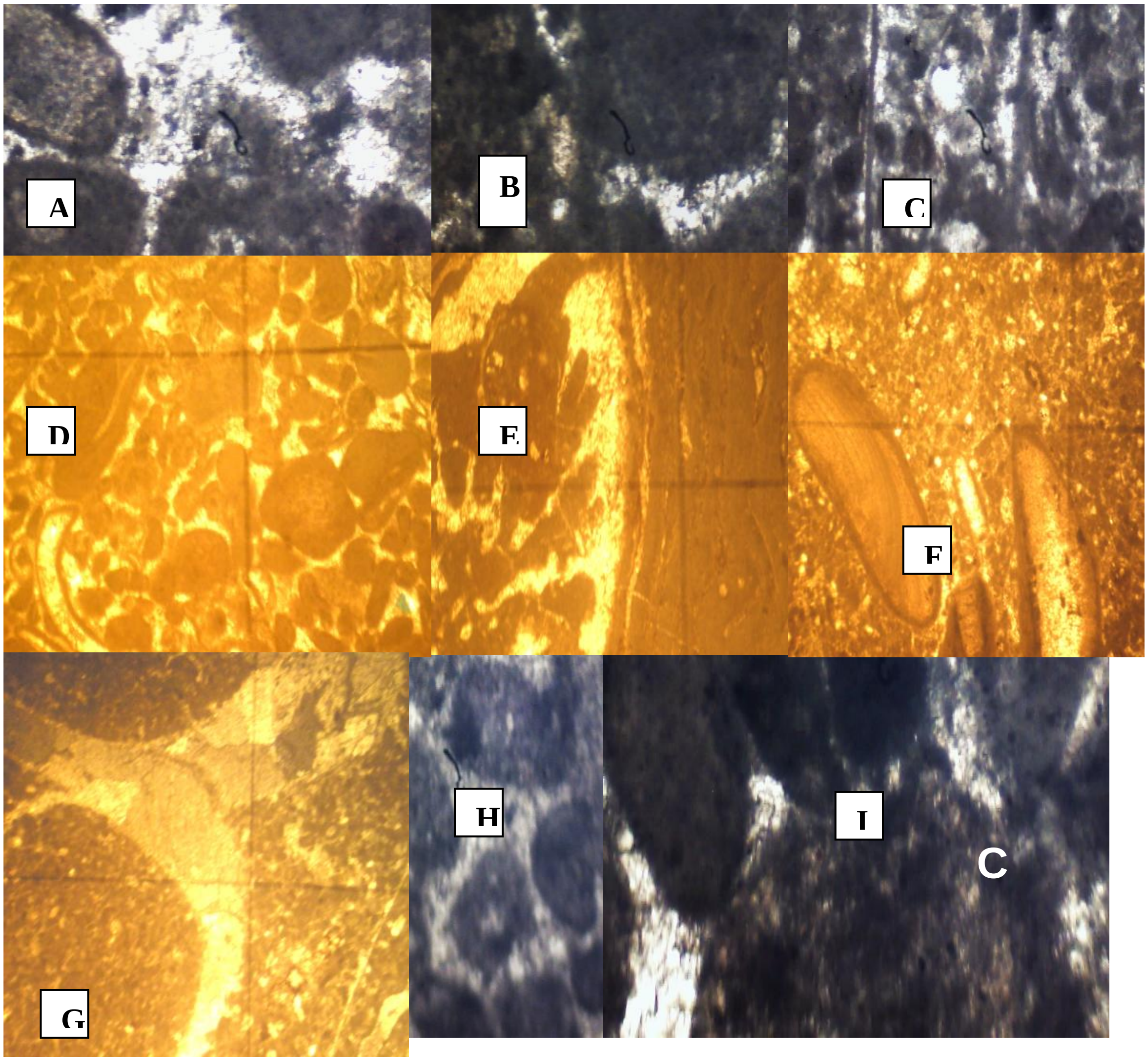
The mud supported micrites are characteristic of low energy open shelf or lagoonal environment, while the grain supported sparite are characteristic of a high energy environment such as carbonate shoal and tidal channels. The different microfacies types revealed from both wells and outcrop samples can be classified into the following categories:

PLATE 1



Photomicrograph of Mfamosing Limestone showing (A) Micritic mudstone microfacies from Oberakai,ML10.(B) Biosparitic granstone-packstone microfacies,from Etankpini, ML25.(C) Intrabiosparitic packstone microfacies from ODBH4/2,29.02m-31.80m.(D) A coralline algal shaped calcitic sporangia from Agbung,ML7.(E) Biopelsparitic grainstone,note the algae coated with calcite grains with a Molluscan fragment,from ETBH3/2, 23.35m-24.35m. (F) Intrasparitic wackstone microfaciess showing calcite mosaic cement, from ETBH3/2, 24,35m-25.35m,(G) Biomicritic wackstone showing Gastropod fragment, from ETBH3/2,26.35m-27.35m.(H) Pelmicritic grainstone, from ETBH3/2,27.35m-28.45m,(I) Pelloidal micritic wackstone

PLATE 2



Photomicrograph of Mfamosing limestone showing: (A) Micritic grainstone,from Mfamosing,ML29(B) Biopelmicritic grainstone from Agbung ML15,(C)Oobiosparitic wackstone from Odukpani ML 21(D) Intrabiosparitc packstone, note the presence of molluscan fragment from Oberakai ML39(E) Biomicritic mudstone, note the presence of echinoid, from Etankpini, ML25,(F) Biopelsparitic grainstone from Mfamosing ML5,(G) Coralline algae in a sparite matrix,note the coarse mosaic cement,(H)Pelsparitic packstone,ML 32, (I) Pelelmicritic mudstone from ODBH4/2 33.80m-35.46m .(UnderPPLX60).

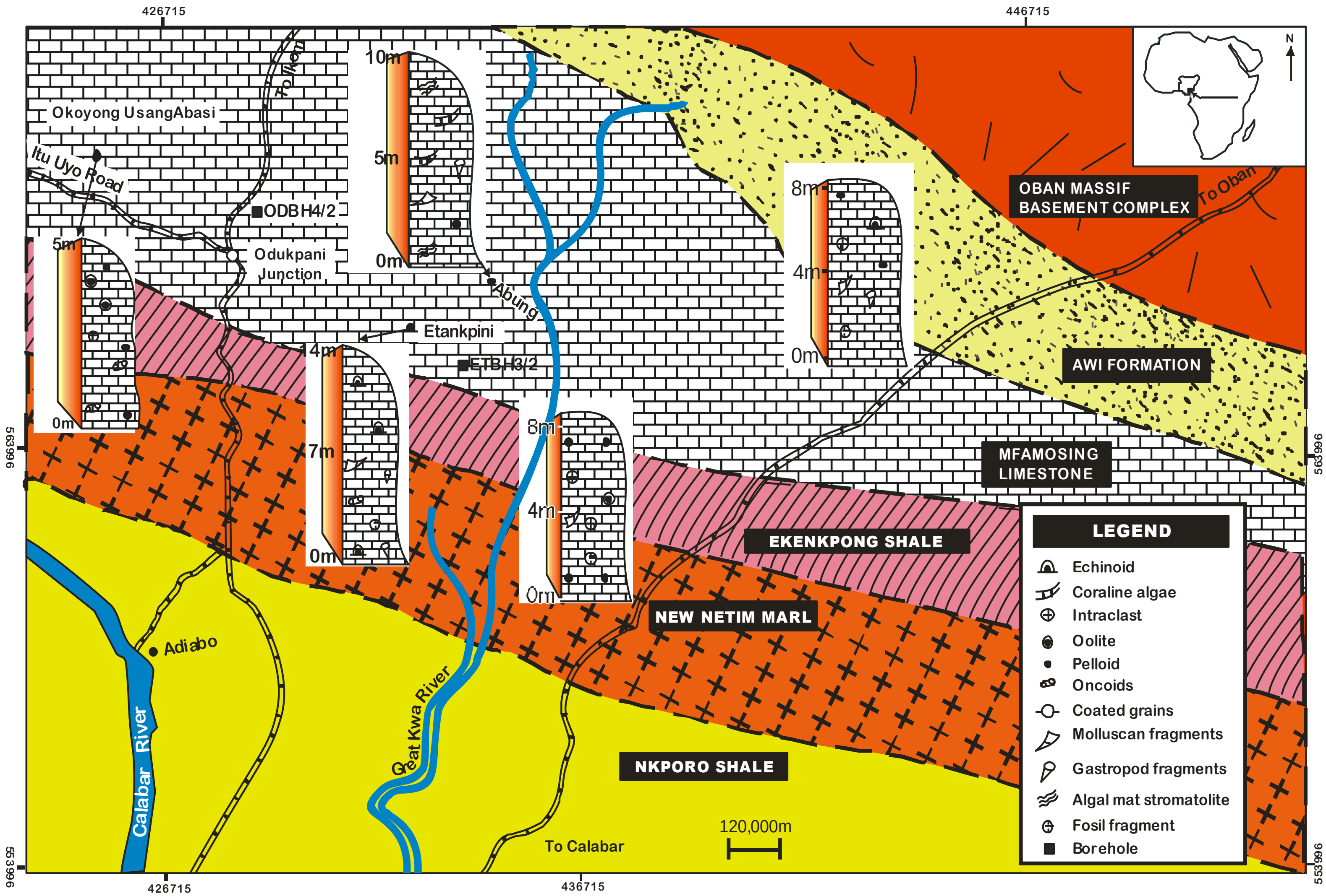


Fig. .5 Sketch sections showing limestone outcrops, stratigraphic sections and lithofacies in the study area, Calabar Flank.

TABLE.1. Spatial distribution of microfacies types in the Mfamosing Limestone at different localities.

		DISTRIBUTION PATTERN/ LOCALITIES					
S/N	MICROFACIES TYPES	MFAMOSING	OBERAKAI	AGBUNG	ETANKPINI	ODUKPANI	OKONYONG USANG ABASI
1	OOLITIC – PELLOIDALPACKSTONE	X	X	X	X		X
2	INTRA – BIOCLASTIC GRAINSTONE – PACKSTONE	X	X	X	X	X	
3	GASTROPOD BIOCLASTIC GRAINSTONE	X	X	X	X	X	X
4	ALGAL MAT SROMATOLITC ONCOLITIC BOUNDSTONE	X	X	X	X		
5	MICROBIOCLASTIC LIME WACKSTONE/LIME MUD CALCILUTITE	X	X	X	X	X	X

TABLE.2. Description of microfacies types, petrographic attributes, skeletal particles and environmental settings in the Mfamosing limestone.

S/N	MICROFACIES TYPES	TEXTURE AND GRAIN TYPE	FOSSIL	ENVIRONMENTAL SETTING
1	OOLITIC PELLOIDAL PACKSTONE	OOLITE, COATED GRAINS AND GRAPESTONE IN A SPARRY CEMENT		OOLITICSHOAL, TIDAL BAR/ CHANNEL
2	INTRABIOCLASTIC GRAINSTONE PACKSTONE	ROUNDED INTRA/BIOCLAST,COATED GRAINS IN A SPARRY CEMENT	MOLLUSK,PELYCEPOD,GASTROPODS,CORALLINE ALGAE	OPEN SHELF
3	GASTROPOD BIOCLASTIC GRAINSTONE	WHOLE GASTROPOD/PELYCEPOD AND MOLLUSCAN FRAGMENTS IN LIME MUD	HIGHLY SPHIRE GASTROPOD, MOLLUSCAN FRAGMENTS.	SHALLOW, PROTECTED BAY/ LAGOON/ POND
4	ALGAL MAT STROMATOLITIC BOUNDSTNE	ALGAL MAT, ONCOLITES	BLUE GREEN ALGAE	INTERTIDAL (ALGAL BANK)
5	MICROBIOCLASTIC LIME WACKSTONE/ LIME AND CALCILUTITE	MICROBIOCLASTIC DEBRIS IN LIME MUD WITH DISSEMINATED AMOUNT OF QUARTZSILT	FORAMINIFERA, ECHINOIDS, MOLLUSCAN AND FOSSIL FRAGMENTS.	LAGOON

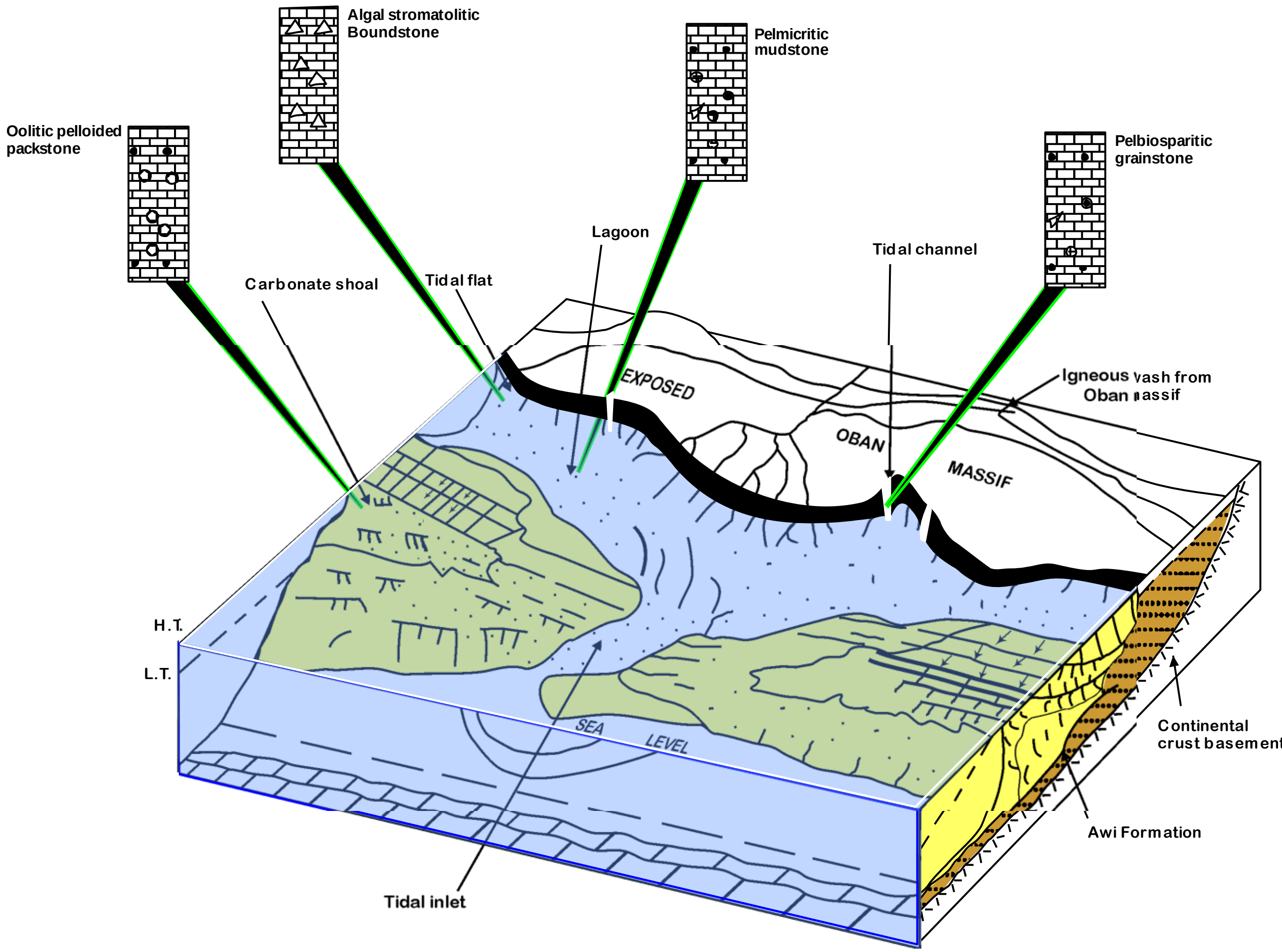


Fig.6. **A conceptual block diagram of the Mfamosing Limestone in the area under investigation, where the Carbonate Platform seems to have been fully developed with diverse depositional settings.**

(i) Pelbiomicritc mudstone - wackestone
(ii) Intra-bioclastic packtone
(iii) Biosparitic grainstone - packstone
(iv) Algal stromatolitic boundstone
(v) Oobiosparitic packstone - grainstone.

Depositional model

From the different microfacies types and the general geology of the study area, an attempt is made on modeling the depositional setting in the study area. Table 2 shows the various microfacies types and their environment from different `outcrops samples in different localities, while Fig. 3 and Fig. 4 shows the different microfacies and environments from the two studied wells. Based on the microfacies present, the conceived depositional scenario in this area is simply that of skeletal intra – bioclastic barrier/shoal bar which separates the lagoonal complex from the basin. Here the carbonate belt is narrow and devoid of tidal flats with pulses of siliciclastic influx which contaminated and inhibited carbonate production in the area. Deductions from this study indicate that the Mfamosing limestone was deposited in an environmental complex which consisted of oolitic/ skeletal shoal, barrier complex, tidal flat/ channel, shelf marginal and protected ponds, bays and lagoonal complexes.Based on the microfacies present, the conceived depositional scenario in this area is simply that of skeletal intra – bioclastic barrier. A conceptual schematic block diagram of the Mfamosing limestone in the area under investigation where the carbonate platform seems to have been fully developed with diverse depositional settings is given in Fig. 6

DISCUSSION

The Mfamosing limestone was analyzed from outcrops samples collected during field mapping and from two (2) wells drilled in this study area, (Well ODBH4/2 Odukpani village and ETBH3/2 Etankpini village) to a total depth of 51.85m and 45.07m respectively. The purpose of these analyses was to determine its paleaoenvironmental settings and its age. For the above objectives to be attained, samples were subjected to petrographic analyses to delineate the different microfacies types and their respective paleoenvironment. The petrographic studies reveal vertical and lateral variation in microfacies distribution and depositional environments. This has been explained using carbonate platform depositional models of Tucker 1981. These petrographic studies allowed the identification of five (5) principal microfacies types.

Depositional environments inferred from the microfacies analyses indicate that the Mfamosing limestone was deposited in a variety of environments consisting of tidal flats, lagoonal complex, oolitic shoals and shelf marginal environments with open circulation.

ACKNOWLEDGEMENT

We are grateful to the Laboratory technologists of the Department of Geology, university of Calabar for the preparation of the thin section slides. We are also grateful to Mr Monday Udofia The contributions of Inemesit Uwah and Otuekong Uko is acknowledged.

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