Pyrex Journals

Pyrex Journal of Geology and Mining Research
Vol 1 (1) pp. 007-017 November, 2015
http://www.pyrexjournals.org/pjgmr

Original Research Paper

Lithofacies, Petrology and Depositional Environment of Limestone in Ohafia–Ozu Abam Area in Southeastern Nigeria

O.S. Okon[1*] and M.U. Uzoegbu[2]

[1]Department of Geology, Federal University, Oye-Ekiti, Ekiti State, Nigeria.
[2]Department of Geology, University of Port-Harcourt, Choba, Nigeria.

Accepted 12th November, 2015

Lithofacies and petrological studies of the limestones in the Nsukka Formation were carried out so as to understand their diagenetic history and depositional environments. The Nsukka Formation in the study area consists of two facies associations; shale-limestone and cross bedded sandstone. The limestone-shale facies association consists of the following lithofacies; rippled clayey sandstone, carbonaceous shale, heterolithic sandstone-shale, laminated grey shale, fossiliferous limestone, fine grained sandstone, silty shale, medium grained sandstone and carbonaceous sandstone. The cross bedded sandstone facies association consists of only cross bedded sandstone, which is made up of fine to coarse grained sandstones. Petrological analysis of the limestones shows that the limestones consists of allochemical biosparites or bioclastic packstones and grainstones. The textural and mineralogical characteristics of the limestones show that the limestones have undergone some diagenetic processes such as cementation, neomorphism, micritization, compaction and dissolution. Dolomitization is almost absent in the limestones. The shale-limestone facies association is interpreted as sediments from a lagoon / swamp, mixed tidal flat and shoreface to shallow marine shelf environments. The crossbedded sandstone suggests deposition in a moderate to high energy, upper shoreface shallow marine environment.

Keywords: Lithofacies, Diagenesis, Afikpo sub-basin, micritization.

INTRODUCTION

Several studies have been carried out on the limestones that abound in the Late Maastrichtian to Danian strata of the Nsukka Formation in the Ohafia-Ozu-Abam area of the Afikpo sub-basin in southeastern Nigeria. However, this studies concentrated on the paleontological (Mbuk *et al.,* 1994; Kumaran and Rajshekhar, 1992); petrological (Oti, 1983; Ibe and Ogezi, 1997, 1999; Ephraim and Odumodu, 2015) geophysical (Ekwere *et al.,* 1994), geochemical (Ekwere *et al.,* 1994; Ibe and Ogezi, 1997, 1999; Ephraim and Odumodu, 2015), industrial utilization of the limestones (Ekwere *et al.,* 1994; Ibe and Ogezi, 1997, 199; Ephraim and Odumodu, 2015) and diagenetic processes in the limestones (Odumodu *et al.,* 2015). Most of these studies did not discuss the lithofacies and depositional environments of the Late Maastrichtian to Danian strata of the Nsukka Formation where the limestones occur. Odumodu and Ephraim (2007), based on pebble morphometric results inferred a beach depositional environment, with considerable fluvial influence for the sandstone facies of the Nsukka Formation in Ozuabam area. Mode and Odumodu (2014) suggested the presence of five lithofacies associations for the Late Maastrichtian-Danian Nsukka Formation in the Okigwe area. The lithofacies associations were deposited in several environments ranging from lagoon/bay, upper to lower shoreface through to the proximal offshore. The major aim of this study is to study the lithofacies association of the Nsukka Formation, discuss the petrology of the limestones and depositional environment of the Nsukka Formation in the study area (Fig. 1).

Corresponding Author: nekyx@yahoo.com

2.0 GEOLOGICAL SETTING

The study area lies within the Afikpo sub-basin in southeastern Nigeria, between latitudes 5°28°E and 5°40'E and longitudes 7°42'N and 7°48'N (Fig.1). The stratigraphic sequence in the Afikpo sub-basin is well discussed in several literatures (Reyment, 1965; Murat, 1972; Petters, 1978; Agagu *et al.,* 1985; Hoque and Nwajide, 1984) According to Murat (1972) as well as Petters (1978), the Santonian tectonism caused the Anambra Basin and the Afikpo syncline to become downwarped to form the Anambra Basin and Afikpo syncline. Sedimentation started in the basins immediately after the post Santonian deformation and uplift of the Abakaliki-Benue Trough. The sedimentary detritus used to fill the basins were supplied from the Abakiliki uplift. The Nkporo Group, which consists of Nkporo Shale, Enugu Shale, Afikpo Sandstone and Owelli Sandstone, is the oldest sedimentary formation in the Afikpo sub-basin. The age of the Nkporo Group is Campanian to Lower Maastrichtian. The formation consists of dark grey shales, mudstones and occasionally thin beds of sandy shale, sandstone, shelly limestone and coal. The Mamu Formation conformably overlies the Nkporo Group. It consists of an assemblage of sandstones, shales, mudstones and sandy shales, carbonaceous shales and coal seams. The Mid-Maastrichtian Ajali Formation conformably overlies the Mamu Formation. It consists of thick, friable, poorly sorted, medium to coarse-grained sandstones, typically white in colour, with distinct mud drapes and burrows. It is one of the most extensive stratigraphic units in this basin. The Late Maastrichtian to Danian Nsukka Formation conformably overlies the Ajali Formation. The Nsukka Formation is overlain by the Paleocene Imo Formation. A geologic map of southeastern Nigeria showing the location of the study area is shown in Figure 2.

3.0 MATERIALS AND METHODS

The research method utilized involved desk study, fieldwork and petrographic analysis. The desk study involved study of existing literatures about the study area so as to understand the geology. The fieldwork involved graphic logging of outcrops and sample collection. Petrographic analysis involves microscopic examination of prepared thin sections under PPL and CPL in order to collect some information on lithology, fabric, texture and mineralogy. The identification of grain types and textures were aided with the color atlas for carbonate rocks of Adams and Mackenzie (2001). This will aid in understanding the diagenetic history of the limestones.

4.0 RESULTS

5.1 Lithofacies Association

Two sedimentary facies association was recognized in the Nsukka Formation in the study area. This includes (a) shale, limestone facies association and (b) crossbedded sandstone facies association.

Shale-limestone facies association

In the study area, the shale-limestone lithofacies association overlies the Ajali Formation. The contact between the two formations was observed at about 100 m close to the Igwu River along Ohafia - Umuahia road, where a rippled clayey sandstone of the Nsukka Formation overlies the Ajali Formation. The shale, limestone facies association was observed at the following locations;

(i) Ogbugbandu plantation, Ndi Oji
(ii) Kalaiyi stream, Ndi Uduma
(iii) Ndi Okoyi stream, Ndi Uduma
(iv) Ogoubi-Ndiorioma road, Ozu Abam
(v) Osusu nkwu / Ndiowa stream, Ndi Uduma
(vi) Ohafia-Ozu Abam road
(vii) Ndi-Ukpeze, Ndi Uduma Ukwu
(viii) Nkwesi-Ikpeta stream, Ndi Okwara
(ix) Orauke, Ndi Okereke
(x) Ogbueke stream, Ndi Okorie
(xi) Ndianku village
(xii) Akoli River, Ndi Uduma Ukwu
(xiii) Isiugwu track road, Ndiokorie
(xiv) Orua stream, Eziafor
(xv) Oboro village road cut.

Outcrops of the shale-limestone facies association of the Nsukka Formation are illustrated in Fig. 3a – o, 5e – h, Fig. 6 and Fig. 7. The shale-limestone facies association consists of several lithofacies which include;

(1) Rippled clayey sandstone

This lithofacies overlies the Ajali Formation. This lithofacies were observed and studied at Ugwu Okolo Ebem Ohafia (Location 1), at an outcrop before the Igwu River, along Ohafia-Umuahia road. It consists of 2 to 2.5 m rippled clayey fine to medium grained sandstones overlying trough crossbedded medium to coarse grained sandstone of the Ajali Formation.

(2) Black carbonaceous shale

The Black carbonaceous shale facies overlies the rippled clayey sandstone facies. This lithofacies were observed and studied at Location 1 (Fig. 5f & g), across the Igwu River on the Ohafia-Umuahia road. It consists of a 5m thick sequence of black carbonaceous shale. The sedimentary structure observed here is thin parallel lamination.

(3) Heterolithic sandstone-shale

The heterolithic sandstone-shale overlies the black carbonaceous shale facies (Location 1, Fig 5e). It consists of 7 m thick interbedded sequence of thin sandstone and shale. The sandstone thickens upwards as the shale becomes shalier. Sedimentary structure observed is thin horizontal lamination. The trace fossil present is Teichichnus burrows.

(4) Laminated Grey shale

The laminated grey shale facies occur at several locations. The laminated grey shale facies is interbedded with the fossiliferous limestone facies. The thickness of the beds varies from one location to another. Sedimentary structure observed is thin horizontal lamination. No biogenic structure were observed.

(5) Fossiliferous Limestones

The fossiliferous limestones occur at several locations as mentioned above (Fig. 3a – o). It occurs as beds at streams, rivers, road cuts, track roads and farmlands. Several boulders of these limestones were also found either embedded in clayey soils on several farms across the outcropping localities. The thickness of the limestones is variable from about 0.3 m to 3.5 m thickness. The fossiliferous limestone is fine grained, and milkish to greyish in colour. Macroscopic examination of several samples shows the abundance of several macrofossils, prominent amongst which are the gastropod Nerrinella and the bivalve Ostrea (Fig. 4a –g).

(6) Silty shale

The silty shale facies were observed at Aboichara stream, Ndi Okorie. (Fig. 7). It consists of 3 m. thick sequence of micaceous silty brown shale which is interbedded with well sorted, fine grained brownish sandstone.

(7) Fine grained sandstone

The fine grained sandstone facies occur within the shale-limestone facies association (Fig. 7). It occur as a 1m thick interbedded unit within the shales. No sedimentary structure or biogenic structure were observed in the fine grained sandstone facies.

(8) Medium grained sandstone

Medium to coarse, poorly sorted, no biogenic structures observed (Fig. 6).

(9) Carbonaceous sandstone

The carbonaceous sandstone facies is also present in this facies association (Fig. 6). It consists of fine grained carbonaceous sandstone with an estimated thickness of about 4m. No sedimentary structure or biogenic structure were observed in this facies.

Interpretation

This shale – limestone facies association occur in the basal part of the Nsukka Formation. The rippled clayey fine to medium grained sandstone suggests deposition in a wave dominated moderate energy, upper shoreface shallow marine environment. The black carbonaceous shale suggests deposition in a lagoon / bay and proximal offshore. The heterolithic sandstone and shale facies is interpreted as a mixed tidal flat deposit based on Dalrymple (1992) model. According to Reading and Collinson (1996), interbedded sandstones and shales indicate equal periods of suspension and bedload deposition with bedload deposition increasing seawards. The fossiliferous limestones were deposited in a shallow marine shelf. The silty shale, fine grained to medium grained sandstones suggests deposition in lower to middle shoreface environments. The carbonaceous sandstone is interpreted as a swampy or lagoonal sequence using Reinson (1992) model. The gross depositional environment of this facies association shows deposition in a lagoon / swamp, mixed tidal flat and a shoreface to a shallow marine shelf.

Crossbedded Sandstone lithofacies association

Outcrops of the crossbedded sandstone lithofacies occur along the Ohafia – Ozuabam road (Fig. 5 a & b), Ndi Ebeleagu junction (Fig. 5d), Ogo Ubi – Ndiorioma track road and at Oboro Ohafia erosion cut. It consists of fine, medium and occasionally coarse grained pebbly sandstone. It contains a lot of planar crossbeds. It is bioturbated with Ophiomorpha (Fig. 4 h & i) and Chondrites ispp (Fig. 4k).

Interpretation

The presence of planar crossbeds and fine to medium grained sandstones suggests that this facies was deposited in a high energy shallow marine environment. The presence of Ophiomorpha and Chondrites suggests deposition in the upper shoreface.

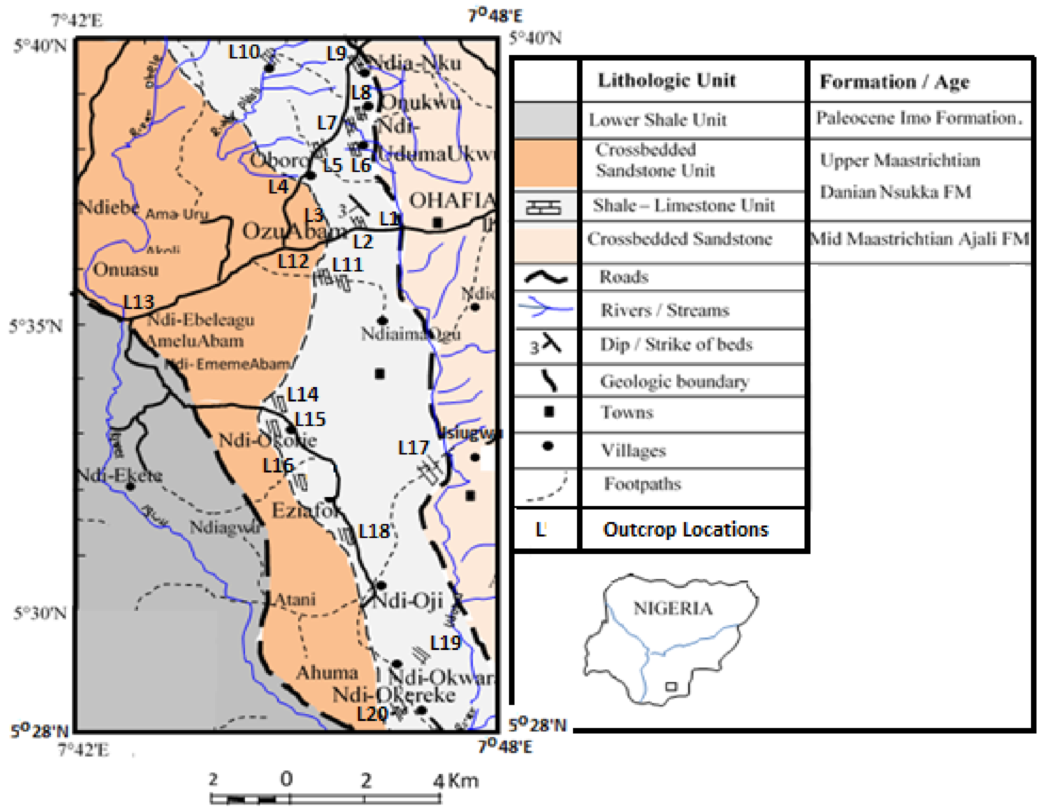

Fig 1: Geologic map of the study area showing outcrop location (modified from Ephraim and Odumodu, 2015)

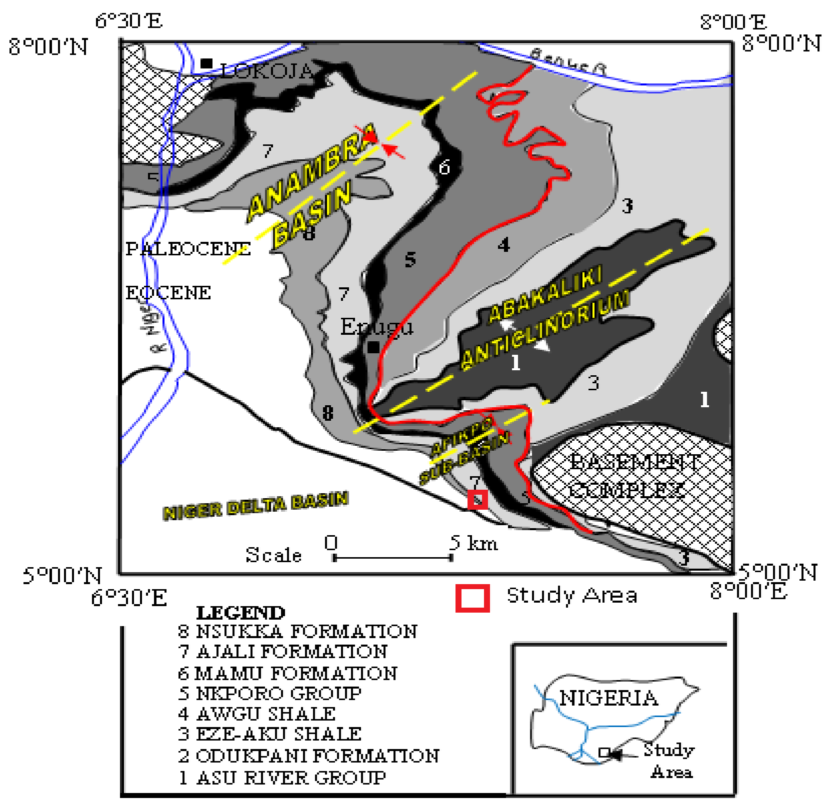

Fig 2: Geologic Map of the South-eastern Nigeria showing the study area (Ephraim and Odumodu 2015)

Fig 3: Outcrops of the Nsukka Limestones at (a) &(b) Ogbugbandu Plantation, Ndi Oji (c) Akoli River, Ndianku, (d) Ogbueke stream, Ndi Okorie (e) Ndianku village (f), (g) & (h) Ohafia-Ozu Abam road, (i) Akoli River, Ndi Uduma (j) Oboro village (k) Ndi Uduma Ukwu (l) Ndi Uduma Ukwu (m) Eziafor village (n) &(o) Akoli River forest

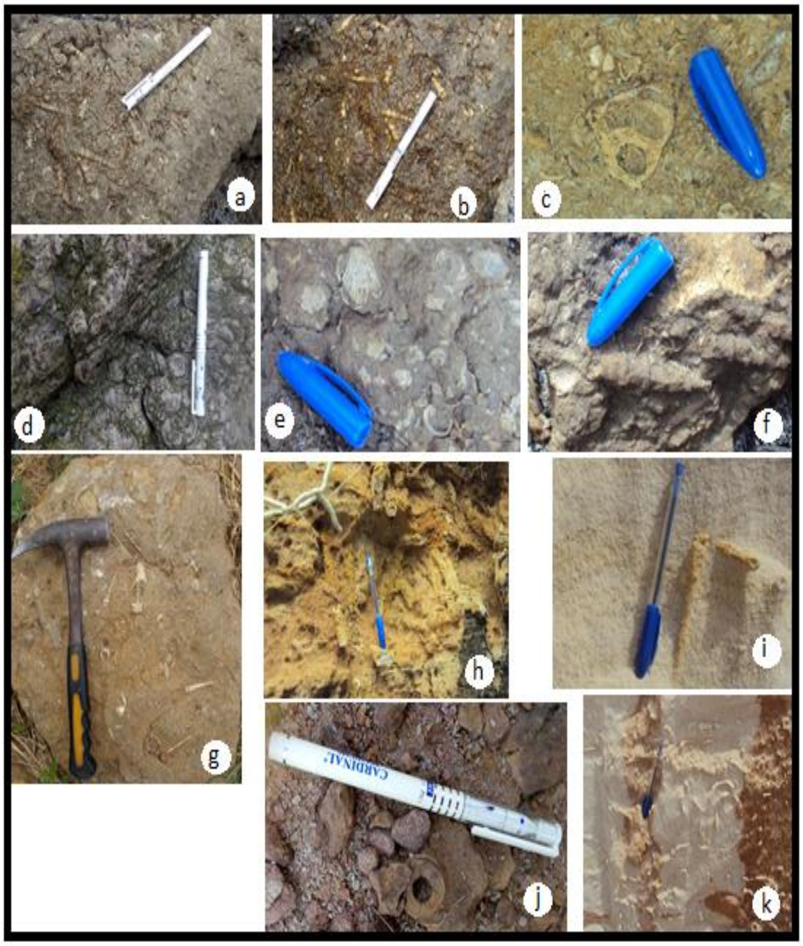

Fig 4: Fossils and Trace fossils from the Nsukka Formation (a), (b) & (f) the gastropod Nerrinella, (c) an unnamed gastropod, (d) & (e) the bivalve Ostrea, (g) unnamed bivalves and gastropods, (h) & (i) Ophiomorpha nodusa, (j) Teichichnus rectus (k) Chondritesisp

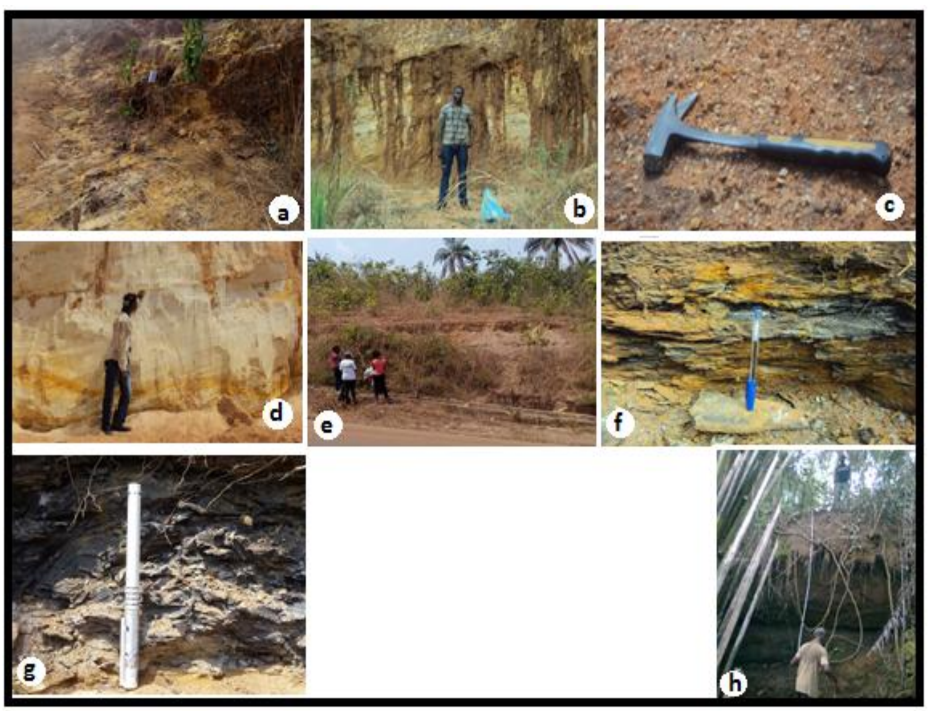

Fig.5: Lithologic sections at (a) & (b) Ohafia-Ozu Abam road (d) Ndi Ebeleagu Junction (e) Igwu River(Ohafia-Ozu Abam road, (f) & (g) Shale beds at Igwu River (Ohafia-Ozu Abam road) and (c) Pebble beds (g)

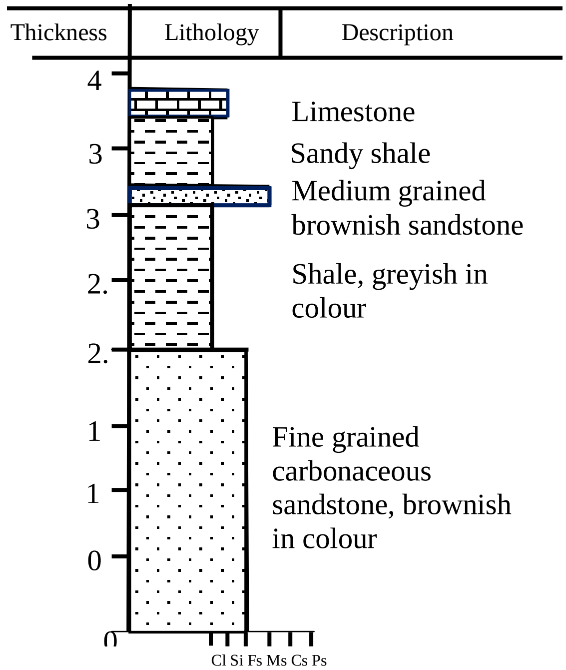

Fig 6: Litholog of Nsukka Formation at Ihule stream, Okirika

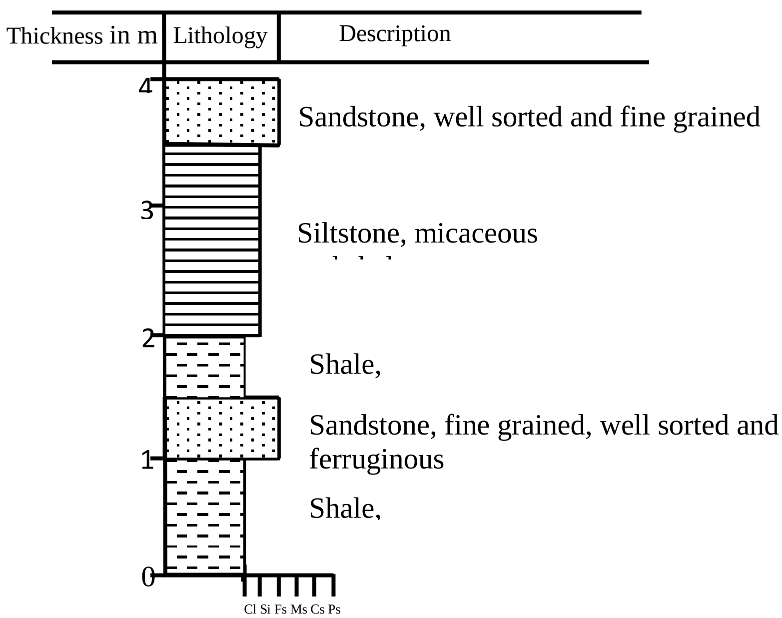

Fig 7: Litholog of Nsukka Formation at Abiochara stream, Ndi-Okorie

Table 1: Petrographic classification of Limestones in the study

Sample location		Composition of limestone (in wt %)				Composition of allochems (in wt%)				Folk(1974) Classification Scheme	Dunham(1962) Classification Scheme
Label	Description	Allochems	Micrite	Sparry cement	Ferrugenous fragment	Intraclasts	Oolites	Fossils	Pellets		
L1	Ogbugbandu, Ndioji	60	10	27	3	3	1	63	33	Biosparite	Packstone
L2	Kalayi stream, Ndi-Uduma	65	12	19	4	3	0	90	7	Biosparite	Grainstone
L3	Ndi okoyi stream, Ndi Uduma	71	5	24	0	5	0	92	3	Biosparite	Packstone
L4	Ndi-okwera,nkwesi ikpeta	62	3	33	2	8	5	65	22	Biosparite	Packstone
L5	Orauke Ndi-Okereke	29	20	46	5	8	0	57	35	Biopelsparite	Packstone
L6	Ogbueke stream Ndi Okorie	52	8	37	3	8	3	62	27	Biosparite	Packstone
L7	Ohafia road	75	5	14	6	8	0	62	30	Biosparite	Packstone
L8	Ndianku	50	12	30	8	4	2	23	71	Biopelsparite	Packstone
L9	Akoli river	38	10	50	2	5	3	60	32	Biopelsparite	Packstone
L10	Oduenyi limestone 1	55	13	29	3	22	0	73	5	Biosparite	Packstone
L11	Oduenyi limestone 2	52	24	19	5	75	3	20	2	Intrasparite	Packstone
L12	Isiugwu Rd, Ndi Oji	55	13	28	4	18	2	10	70	pelsparite	Packstone
L13	Ogbueke limestone, Ndi-Okorie	61	11	25	3	10	0	57	33	Biopelsparite	Packstone
L14	Ndi okorie	40	12	45	3	7	3	64	26	Biosparite	Packstone

5.2 PETROGRAPHY AND MINERALOGY

From the petrological studies of the thin sections, the limestone framework elements were observed to consist of allochems, micrite, sparry cement and ferruginous fragments. The allochems make up nearly 80 % of the rock fabric. Sparry calcite cement is next in abundance, micrite is low and ferruginous fragments are sparsely present. The results of the petrological classification of the limestones are given in Table 1. The petrological classification of these limestones shows that they are mainly allochemical biosparites. (Folk, 1959) or packstones and grainstones (Dunham, 1962) (Table 1). In most of the thin sections studied, the allochems are generally elongate and poorly sorted. The allochems consists mainly of fossils and pellets. Intraclasts and oolites are very few in the limestones. The limestones were observed to contain detrital quartz grains in some thin sections. The fossils consist mainly of foraminifera, gastropods and bivalves shell fragments which were observed in some thin sections as recrystallized calcite crystals. The fossils contain some nucleus of calcitic replacement or recrystallization of aragonitic shells which is known as neomorphism. The calcitic replacement as well as the absence of micrite suggests some considerable amount of solution in the limestones. Some of the gastropods and bivalves shells have been recrystallized to calcite. Foliated structures were also observed in some of the thin section. The foliated structures observed in the limestones are characteristic of oysters. Some bivalve fragments were observed in some thin sections to consist of equant calcite spar. Some of the peloids observed in the limestones are in most cases micritized gastropod and bivalve fragments.

5.3 DIAGENETIC FEATURES

Following Odumodu et al (2015) the petrological studies of thin sections of the limestones from the study area have revealed that the limestones have experienced five different types of diagenetic effects. Diagenesis in the limestones is observed from the textural and mineralogical characteristics of limestones. The diagenetic influences observed in the limestone include cementation, micritization, neomorphism, dissolution and compaction. The dolomitization features are very minor.

1. CEMENTATION

Cementation is defined as the process of precipitation of space filling crystals (Adams and McKenzie, 2001). Safer et al (2010) defined cementation as one important diagenetic processes that helps in transforming a weak sediment into a hard limestone. This process takes place where a great amount of intra particle fluids are oversaturated. In the study area, the cement type observed include mainly the carbonate type (calcite and aragonite) and some iron oxide. The main cement types observed in these limestones include blocky or equant mosaic calcite cement (Fig. 8). Drusy mosaic calcite cement, acicular aragonite cement and micritic calcite cement as observed by Odumodu et al (2015) were not seen. The blocky or equant cement is characterized by cements possessing calcite crystals of equal sizes.

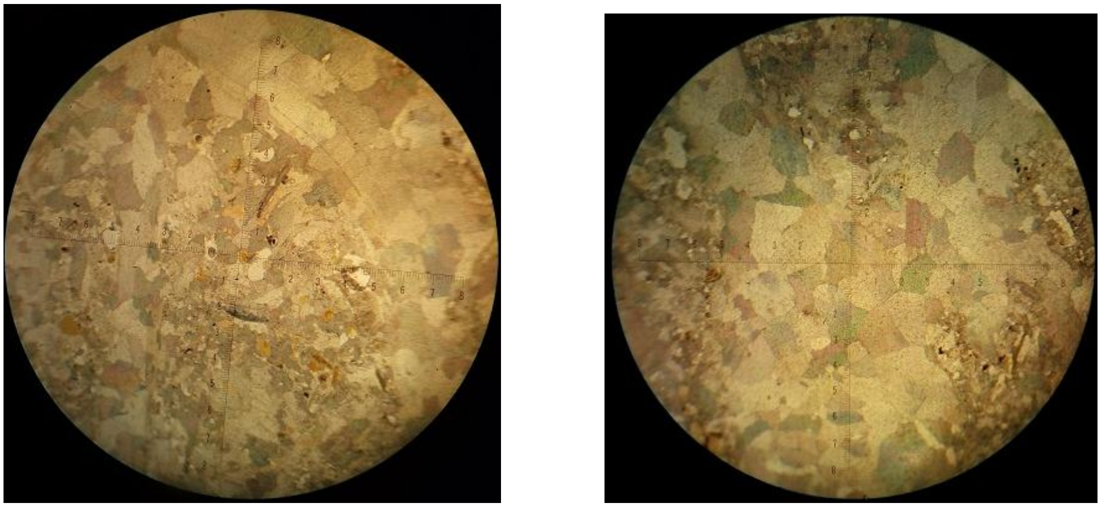

Fig 8: Thin section view of the limestone showing cementation features

2. MICRITIZATION

Micritization is the process whereby the margins of carbonate grains are replaced by micrite at or just below the sediment / water interface. The process involves microbes attacking the outside of grains by boring small holes in them, which are later filled with micrite cement (Adams and MacKenzie, 2001). Micritization is also defined as the processes whereby bioclasts or non-skeletal grains are destroyed by non calcareous algae, fungi and bacteria and forming a micritic cover around them (Safer et al, 2010). Some of the bioclasts are fully micritized while others are outlined by a thin micritic envelope. These micritized bioclasts were observed in all the thin sections studied.

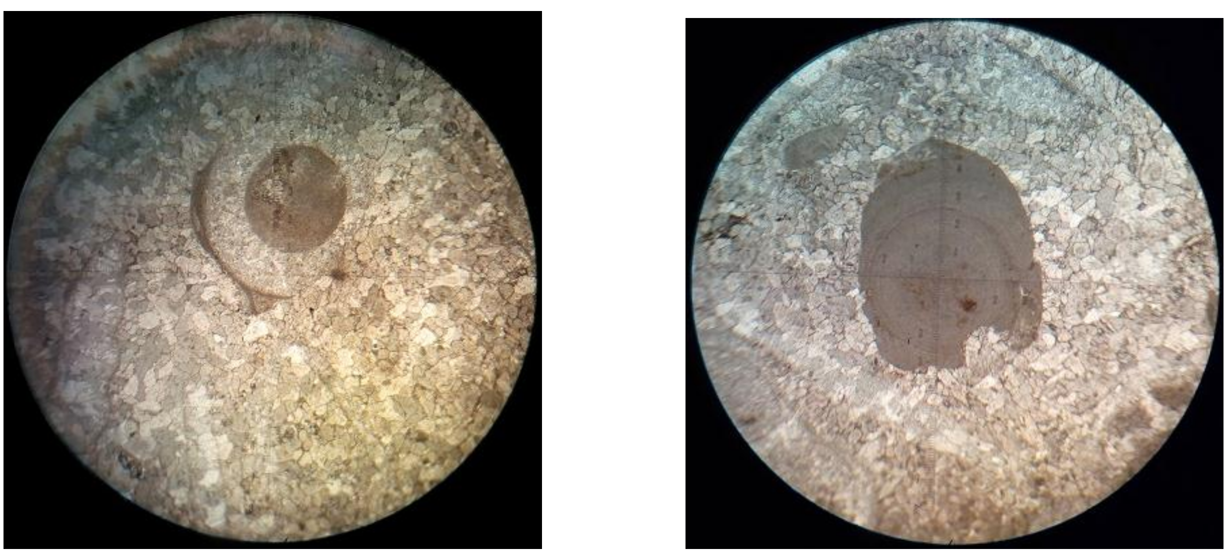


Fig 9: Thin section view of the limestone showing micritization features

3. NEOMORPHISM

Neomorphism is defined as the process leading to the formation of large sized crystals (Safer *et al.,* 2010). Neomorphism is an important process in the overall diagenetic transformation of these limestones as observed in thin sections with large crystals of calcite. Neomorphic features were observed in all the thin sections studied.


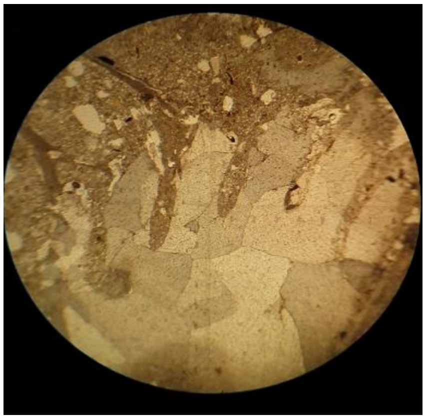

Fig 10: Thin section view of the limestone showing neomorphic features

4. COMPACTION

Compaction is an important aspect of diagenesis because it is a direct function of overburden pressure. The fracturing of coarse recrystallized calcite crystals as observed in the thin sections studied suggests the processes of compaction. In these slides, also many of the crystals of calcite undergo undulose extinction which in analysis is usually a direct response of crystals to pressure. In such crystals, the crystallographic axes are distorted by dislocation creep, creating various sets of crystallographic axes across the same crystal, causing the crystal to have a wavy extinction.

Fig 11: Fracturing of calcite crystals indicating compaction

5. DISSOLUTION

In terms of porosity and permeability, some parts of the rock unit under study can be said to be very porous and permeable while some other sections may not be as porous. This factor is a direct function of the solution cavities (dissolution). The rest of the samples however show lesser degrees of dissolution.

6.0 CONCLUSION

This study have shown that the Nsukka Formation consists of two facies Association, the shale – limestone and the crossbedded sandstone. The shale-limestone facies association consists of nine facies. The crossbedded sandstone consists of only the crossbedded sandstone facies. Petrological study of the limestones suggests that the limestones consists of allochemical biosparites or bioclastic packstones and grainstones. The textural and mineralogical characteristics of the limestones shows that the limestones have undergone cementation, neomorphism, micritization, compaction and dissolution. The shale – limestone facies association suggests deposition in a lagoon / swamp, mixed tidal flat, and shoreface to shallow marine shelf. The crossbedded sandstone facies association is deposited in a moderate to high energy upper shoreface environment.

REFERENCES

Adams, A.E. & MacKenzie, W.S. 2001. A colour atlas of carbonate sediments and rocks under the microscope. Manson Publishing, London, 180 p.

Dalrymple RW (1992). Tidal depositional systems. In: Facies models: response to sea level change edited by Walker, R.G. and James N.P. (Geol. Assoc. Canada) 195–217.

Dunham, R.J. 1962. Classification of carbonate rocks according to depositional texture. In: Ham, W.E. (ed) Classification of carbonate rocks. American Association of Petroleum Geologist, Memoir 1, 108-121.

Ekwere, S. J., Esu, E. O., Okereke, C. S. & Akpan, E. B., 1994. Evaluation of Limestone in Obotme area, (Southeastern Nigeria) for Portland cement manufacture. Journal of Mining & Geology, 30 (2): 145 – 150.

Ephraim, B.E. and Odumodu, C.F.R. 2015, Petrological and geochemical studies with insight into the industrial prospects of the Upper Maastrichtian – Paleocene limestone deposits in parts of Southeastern Nigeria. Submitted to Comunicações Geológicas

Folk, R.L. 1959. Practical petrographic classification of limestones. American Association of Petroleum geologist, Bulletin, 43, 1-38

Ibe, K. K. and Ogezi, A. E., 1997. Chemical and industrial characteristics of the carbonate rock of the Late Maastrichtian Nsukka Formation in Ohafia Area of S.E Nigeria. 33rd Annual Conference. Nigerian Mining and Geosciences Society. Jos. 11

Ibe, K.K. and Ogezi, A.E., 1999. Chemical and Industrial Characteristics of the Carbonate Rocks of the Late Maastrichtian Nsukka Formation in Ohafia Area of Southeastern Nigeria. Global Journal of Pure and Applied Sciences, 5 (2): 234 - 240

Kumaran, K.P.N and Rajshekhar, C., 1992. Foraminiferal linings' from the Late Cretaceous to Paleocene sediments of Ohafia- Ozu Abam area. Nigeria. Current Science, Vol. 62(3): 311-313

Mbuk, I. N., Rao, V. R., and Kumaran, K. P. N., 1985. The Upper Cretaceous – Paleocene boundary in the Ohafia – Ozu Abam area, Imo State, Nigeria. Journal of Mining & Geology, 22: 105 – 113.

McKenzie, D., 1978. Some remarks on the Development of Sedimentary Basins. Earth and Planetary Sci. lett, Vol.40, p.25-32.

Mode, A.W., Odumodu, C.F.R., 2014. Lithofacies and Ichnology of the Late Maastrichtian –Danian Nsukka Formation in the Okigwe area, Anambra Basin, Southeastern Nigeria. Arabian Journal of Geosciences, ISSN 1866-7511.

Murat, R.C., 1972. Stratigraphy and paleogeography of the Cretaceous and Lower Tertiary in Southern Nigeria. In: Dessauvagie, T.F.J. & Whiteman, A.J. (eds.), African Geology University of Ibadan, press. p. 251 – 266.

Odumodu, C.F.R., Ugwuonah, E.N., and Ephraim, B.E., 2015. Characterization of Diagenesis Processes of the Late Maastrichtian-Danian Limestone in Ohafia, Ozu Abam and Arochukwu Areas of South-eastern Nigeria. Journal of Natural Sciences Research. Vol 5. No 6.

Odumodu, C.F.R., Ephraim, B. 2007. Paleoenvironmental analysis of the Nsukka Formation, using pebble morphometry. Nat. Appl. Sci. J 8(1): 73-84

Ojoh, K., 1990. Cretaceous Geodynamic Evolution of the Southern part of the Benue Trough (Nigeria) in the Equatorial domain of the South Atlantic: Stratigraphic Basin analysis and paleogeography. Bull centres Rech. Explor-Prod. Elf-Aquitaine, Vol.14, P.419-442.

Oti, M.N., 1983. Petrology, Diagenesis and Phosphate Mineralization of Cretaceous Limestone in the Arochukwu/Ohafia area, Southeast Nigeria. Nig. J. Min. Geol. Vol. 20(1&2): p 95-103

Petters, S.W., 1978. Stratigraphy C. Evolution of the Benue Trough and its implication for the Upper Cretaceous Paleogeography of West Africa. Journal of Geology. P. 78,311 – 312.

Reading HG. & Collinson J.D. (1996). Clastic coasts. In: Sedimentary Environments: Processes, Facies & Stratigraphy edited by Reading, H.G. (Blackwell Science Ltd, Oxford, London) 154 – 231.

Reinson GE (1992). Transgressive Barrier Island & estuarine systems. In: Facies models: Response to Sea level change edited by Walker, R.G. and James, N.P. (Geological Association of Canada) 179 -194.

Reyment RA (1965). Aspects of the Geology of Nigeria. University of Ibadan Press, Nigeria,
145.

Reyment, R.A., 1965. Aspects of the Geology of Nigeria: University of Ibadan, Nigeria. P.145.

Saffar, A., Mousavi, M.J., Torshizian, H.A., Javanbakht, M., 2010. The investigation of Diagenetic processes and interpretation of paragenetic sequence of Tirgan Formation, Zavin section, NE of Iran. Paper presented on the 1st International Applied Geological Congress, Department of Geology, Islamic Azad University, Mashad Branch, Iran, 26 – 28 April, 2010, p. 2040 – 2044.

Serra, R., 2006. Dictionary of Geology. Academic (India) Publishers, New Delhi – 110008.

Uzoegbu . U. M., Ekeleme I . A., Kus J and Uchebo U .A., 2013. Petrology, rank and geochemical evaluation of Maastrichian coals from SE Nigeria: Implication for petroleum generation. IOSR Journal of applied geology and geophysics. Vol. 1(3), p. 23 – 41.