ISSN 2250-3153

GEOCHEMICAL AND PALYNOLOGICAL EVALUATION OF LIMESTONE IN OHAFIA AREA, SOUTHEAST NIGERIA

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

[1] Department of Geology, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.

[2]Department of Geology, Federal University, Oye-Ekiti, Ekiti State, Nigeria.

[1]GSM: 08030715958; Email: mu.uzoegbu@mouau.edu.ng

Abstract: Late Maastrichtian to Danian limestone of Nsukka Formation in Ohafia and its environs were studied to understand the geological processes that affected the rock after its deposition. The Nsukka Formation in the studied area consists of two facies associations; limestone-shale 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. Palynological analyses of some of the samples indicated that the limestone of Nsukka formation is of Late Maastrichtian in age due to the abundance of *Spinizoncolpites baculatus* and *Lonapertites marginatus* species, with co-occurrence of typical Late Maastrichtian dinoflagellate cysts assemblage, such as, *Dinogymnium acuminatum*, *Senegalinium* sp., *Andalusiela* sp. and *Paleocystodinium* sp. The major geochemical element in the limestone samples that was analyzed includes CaO, MgO, SiO_2, Al_2O_3, Fe_2O_3, Na_2O, SO_3 and LOI. The limestone consists of CaO as the major constituent followed by SiO_2 while Al_2O_3, Fe_2O_3 and MgO form the minor constituents. Given the values (42.66% – 94.57%) quoted for calcium carbonate equivalence (CCE). The Ohafia – Ozu Abam – Arochukwu limestone has good potentials for use as petrofertilizers in liming processes.

Key words: Limestone, Geochemistry, Palynology, Petrofertilizer, Cretaceous, Ohafia, Nsukka, Nigeria.

INTRODUCTION

The studied area lies between longitudes 5^{o}22` to 5$^o$40`E and latitude 7^{o}42` to 7$^o$55`N within the Ohafia-Ozuabam-Arochukwu areas of southeastern Nigeria (Fig. 1). Limestone is a sedimentary rock composed largely of the mineral calcite ($CaCO_3$), which is formed either by organic or inorganic processes (Serra 2006). It is formed either by direct crystallization from water (usually sea water) or accumulation of shell or shell fragments. Most limestones are formed with the help of living organisms. Many marine organisms such as mussels, clams, oysters and corals extract calcium carbonate from sea water to make shells or bones. Microscopic organisms such as foraminifera are also involved in limestone production. Limestones can also be formed without the aid of living organisms. If water containing calcium carbonate is evaporated; the calcium carbonate is left behind and will crystallize out of solution.

Nigeria is endowed with large deposits of limestones in various parts of the country. Some appreciable deposits of limestones also occur in the Nsukka and Imo Formations. From the proposed study, these limestone deposits which occur in association with shales, fine grained sandstones and siltstones trend in a northwest to southeasterly direction from Onukwu to Ndi Uduma Ukwu in the north, through Ndi Okorie and Ndi Okereke to Asaga village in Southern Arochukwu which have a southward extension into the Obotme area (Ekwere *et al*, 1994) of the Calabar Flank. Reyment (1965) observed that the Nsukka Formation outcropping southwards of Okigwe consist of bands of fossiliferous limestones interbedded with sandstones, shales and sandy shales.

This paper deals with the evaluation of geochemical, palynological and depositional environment of limestone sediment in Ohafia-Arochukwu Areas of southeastern Nigeria.

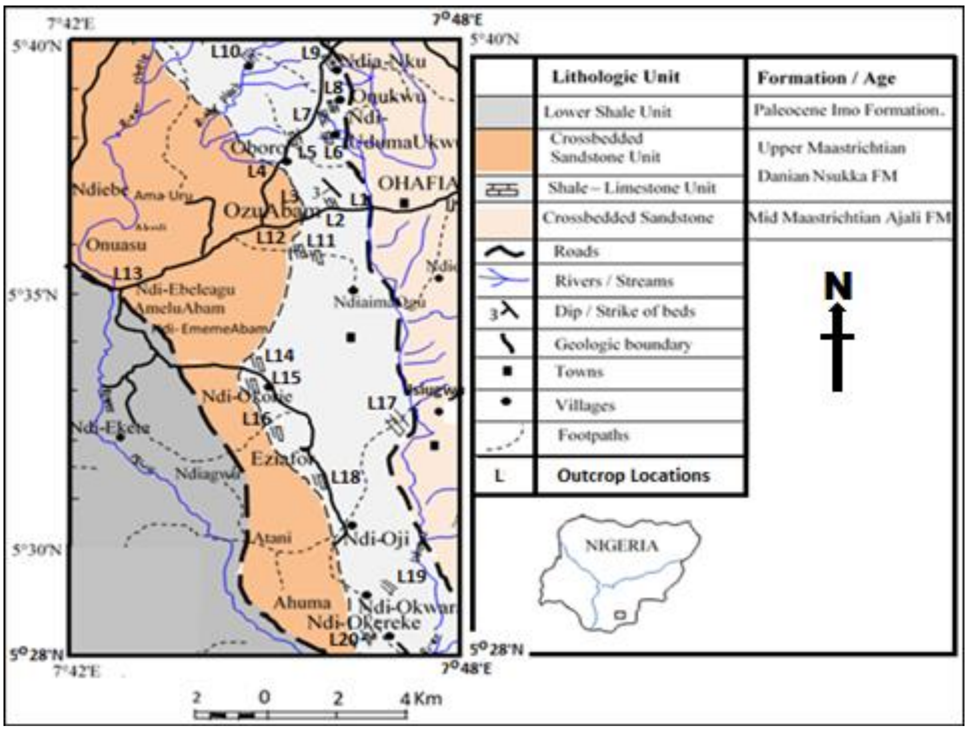

Fig.1: Geologic map of the studied area showing outcrop locations [in set: map of Nigeria showing location of the studied area (modified from Ephraim and Odumodu, 2015)].

.

STRATIGRAPHICAL SETTING

The oldest Sedimentary basin in Nigeria, the Benue –Abakaliki Trough originated in the Early Cretaceous as the failed rift associated with the opening of the South Atlantic (Reyment, 1965). The Benue Trough was filled by the Coniacian time. Some tectonic movements culminated into the Santonian epierogenic uplift and folding of the Albian-Coniacian sediment into the Abakaliki Anticlinorium along a NE-SW axis. The structural inversion of the trough led to the subsidence of the Afikpo Sub Basin and Afikpo Syncline on the west and southeast of the anticlinorium respectively.

Ojoh (1990) had noted that basin subsidence in the southern Benue Trough was spasmodic, being a high rate in pre-Albian time, low in the lower Cenomanian, and very high in the Turonian, which was related to the important phase of platform subsidence. This is taught to be the actual time of initiation of the Afikpo sub-basin creation, a process that gained momentum in the Coniacian and climaxed during the Santonian thermo-tectonic event. Thus the localized subsidence on the western reach of the southern Benue Trough and the continued sea level rise into the Coniacian, led to the installation of the Anambra Basin (Ojoh 1990).

Afikpo sub basin is sandwiched between Benue Trough and the Niger Delta. The main implication is that, after the Santonian thermo-tectonic event, there must have been a thermal decay, i.e. a detumescent stage that produced sag on which at least part of the Afikpo sub basin became superimposed. In the same manner, the establishment of the Niger Delta sedimentary regime from the Paleocene must have taken advantage of continued thermal sag. According to McKenzie (1978), there is usually a distinct thermal sag stage involved in post rift basin formation in response to the cooling and contraction of the lithosphere and the asthenosphere that were thermally perturbed during the earlier rifting process.

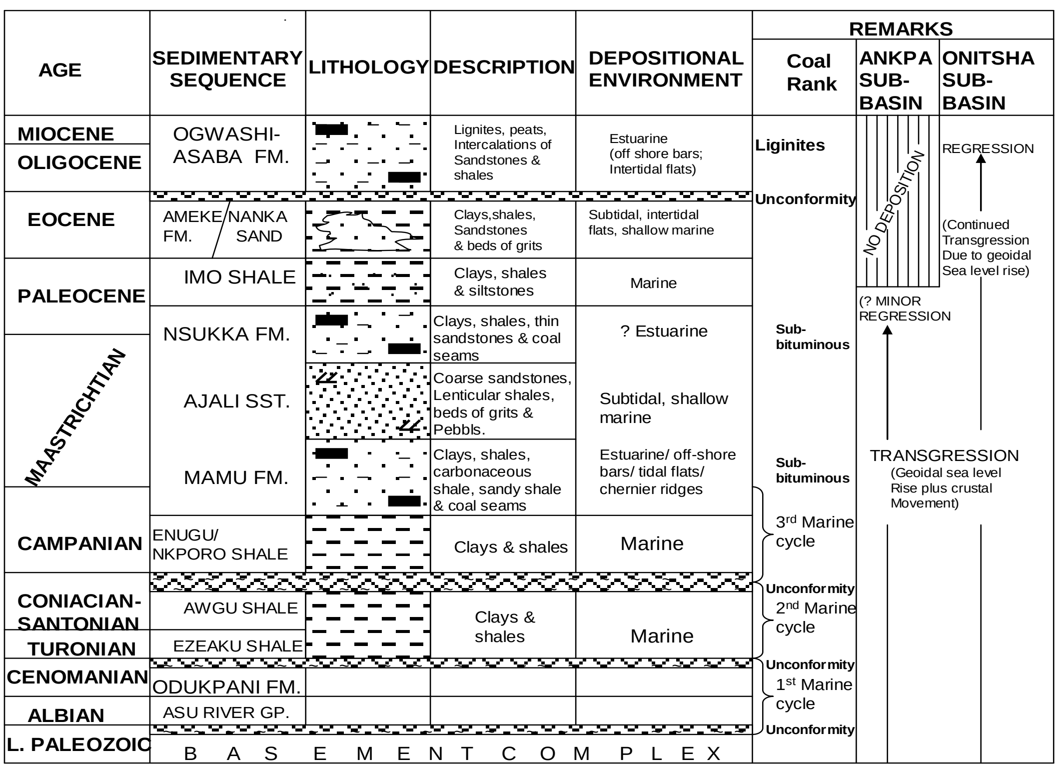

Fig. 2: The stratigraphy of the Anambra Basin, Nigeria (After Uzoegbu et al., 2013).

These newly subsided sedimentary basins, including the Afikpo Syncline, received sediments from the Campanian to Paleocene (Fig. 2). Sedimentation began subsequently in the Anambra Basin during post-Santonian times (Murat, 1972; Petters, 1978) after the deformation and uplift of the Abakaliki-Benue Trough. The uplifted Abakaliki anticlinorium supplied sedimentary detritus that were used to fill the basins from the Late Cretaceous to Early Tertiary times. The basal sedimentary formation in the Afikpo sub basin and the Afikpo Syncline is the Nkporo Formation. The Nkporo Formation is successively overlain by the Mamu Formation which in turn is overlain by the Ajali Sandstone. This Transgressive cycle is capped with the deposition of the Late Maastrichtian Nsukka Formation. The Nsukka Formation is successively overlain by the Paleocene Imo Formation, Eocene Ameki Formation and the Ogwashi Asaba Formation which have lateral continuities with the formations in the Niger Delta Basin.

MATERIALS AND METHODS

A total of sixteen representative samples of limestones were collected from the studied area and were subjected to laboratory analyses for geochemical and palynological studies. For palynological analysis the samples were treated with hydrochloric acid (HCL) to remove any carbonate and then thoroughly washed with distilled water after decanting the HCL. The addition of hydrofluoric acid (HF) to the samples was to dissolve and wash the silicates. The samples were further treated first with warm 36% HCL and then cold HCL to remove the fluoride gels. The separation of pollens and spores were done by adding 0.5% HCL and transfer the samples into small 15cc. Centrifuge tubes. The 0.5% HCL is decanted after centrifuging and the zinc bromide (s.g 2.2) was added and properly stirred with glass rod. The floating top part consisting of organic material was gently decanted into another tube. The organic material is then thoroughly washed with distilled water, dried and prepared for microscopic identifications.

The same number of samples was subjected to geochemical analysis and loss on ignition (LOI). Determination of geochemical information was performed by pressed rock-powder pellets using an XRF method developed and calibrated for carbonate rocks. 5g of the rock powder of each of the sample was weighed out and mixed with a few drops of polyvinyl alcohol and was spread for drying and to form a "puck". Further, a boric acid (backing) was placed on top of the rock powder and a pellet formed by applying pressure of 15 tons for about 15 seconds. After drying, the pellets were placed in the sample holder of the XRF spectrometer, and the fluorescence was measured at eight elements include SiO_2, Al_2O_3, Fe_2O_3, MgO, CaO, Na_2O, K_2O, and SO_3. For the loss on ignition (LOI), 1.0 g of each powdered sample was weighed into a porcelain crucible. Crucibles containing the samples were loaded on a silica tray and placed in a furnace that had been preheated to $350^{O}C$. The temperature was raised to $1100^{o}C$ and the samples were held at this temperature for 2.5 – 3 hours. The furnace was allowed to cool to approximately $650^{o}C$ and the samples were removed and placed in a dessicator.

When cooled to room temperature, the crucibles were weighed and the weight loss (LOI) recorded. The %LOI was added to the total % element oxides and the sum was found to be close to 100. The detection limit for all the major element oxides is 0.01%. The only exceptions are Fe_2O_3 and K_2O which have a detection limit of 0.04%.

RESULTS AND DISCUSSION

The limestone outcrops trend in a northwest – southeasterly direction from Ndi Uduma Ukwu in the north through Ndi Okorie to Ndi Okereke in the south. The limestones occur as beds or boulders within the shale-limestone unit. The outcrops are observed at road cuts, track roads, stream and river beds/channels and farmlands. Macroscopic examination of the limestones has revealed the presence of several fossils such as gastropods and bivalves. The limestones are also milkish white to light grey in colour, fine to medium grained with fossils and clay balls forming a coarse fraction. In the northern part of the studied area especially around Onukwu and Ndi Uduma Ukwu the limestones contain a lot of detrital input which appears to decrease southwards.

Palynology

The photomicrograph indicates some key palynomorphs species observed from the studied samples (Fig. 3). The samples 11, 16 and 26 were dated Late Maastrichtian age on the basis of high abundance of the *Spinizoncolpites baculatus* and *Lonapertites marginatus* species, with co-occurrence of typical Late Maastrichtian dinoflagellate cysts assemblage, such as, *Dinogymnium acuminatum*, *Senegalinium* sp., *Andalusiela* sp., and *Paleocystodinium* sp. (Table 1, 2). Sample 19 was assigned to Paleocene age based on high dominance of *Proxapertite operculatus*, with low occurrence of *Longapertites marginatus* and *Spinizonocolpites baculatus* species (Table 2), (Germeraad *et al*., 1968). The age however was further strengthened by the absence of a typical Late Maastrichtian species, *Dinogymnium acuminatum*, in the above samples.

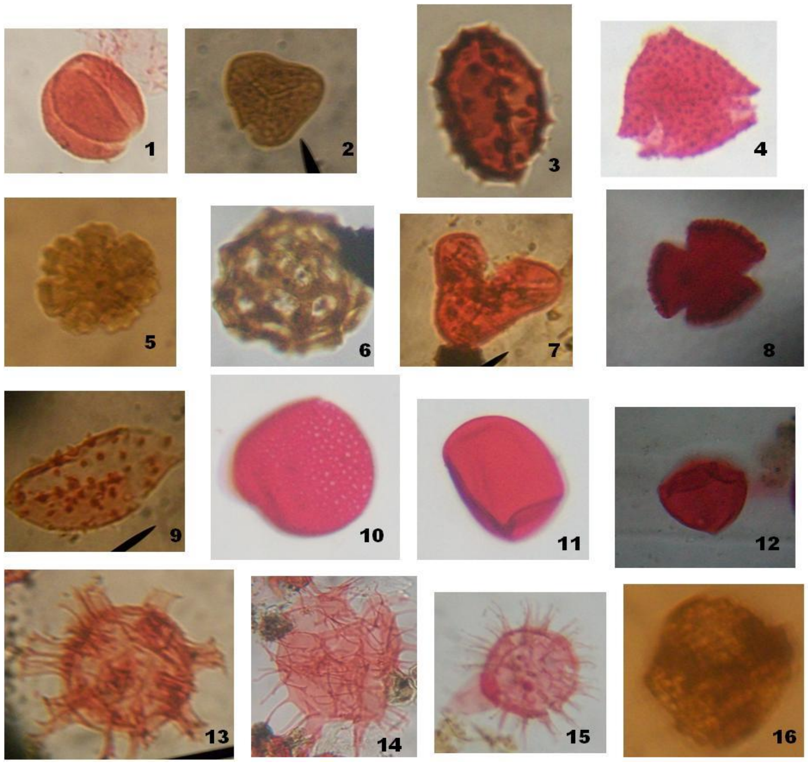

Fig. 3: The photomicrographs of some palynomorphs from the studieded samples (Numbers represent the individual species such as 1. *Proxapertites operculatus,* 2. *Foveotriletes margaritae,* 3. *Spinizonocolpites echinatus*, 4. *Echitriporites trianguliformis,* 5. *Ctenolophonidites costatus,* 6. *Buttinia andreevi,* 7. *Cyathidites minor*, 8. *Retitricolporites irregularis,* 9. *Mauritidiites crasibaculatus,* 10. *Proxapertites cursus,* 11. *Laevigatosporites ovatus,* 12. *Monoporites annulatus,* 13. *Oligosphaeridium complex,* 14. *Apectodinium homomorphum,* 15. *Coronifera oceanic,* 16. *Dinogymnium acuminatum*).

Reijers et al. (1997) in a study of the Afikpo sub basin suggested that the depositional environment of the Nsukka Formation was mainly a fluvial setting with some marine incursions that mixed in shoreface sedimentation. Mode (2004) using lithofacies with microfaunal data and suggested that the formation was deposited in a foreshore to shoreface and inner shelf environments. Adekoya et al (2011) and Nwajide (2005) studied lithofacies and palynofacies of the formation and concluded that the sediments were deposited in paralic and marine settings. Odumodu and Ephraim (2007), based on pebble morphometric results inferred a

Table 1: The occurrence and distributions of terrestrial sporomorphs in the studied samples.

Palynomorph Species	**Sample 16**	**Sample19**	**Sample 26**	**Sample 28**
Terrestrial Species				
Schizosporis parvus	1	0	0	1
Verrucatosporites usmensis	0	3	2	0
Laevigatosporites ovatus	7	5	4	5
Cyathidites minor	0	0	3	4
Leiotriletes adriennis	5	0	3	2

Cyathidites australis	1	1	1	0
Distaverrusporites simplex	2	0	3	0
Cingulatisporites ornatus	2	0	2	4
Foveotriletes margaritae	1	0	0	1
Spinizonocolpites echinatus	1	2	0	1
Spinizonocolpites baculatus	7	1	9	5
Proxapertites cursus	1	3	0	0
Retitricolporites irregularis	2	2	0	0
Ctenolophonidites costatus	0	3	0	0
Proxapertites operculatus	0	12	2	1
Pachydermites diederixi	3	0	0	0
Tricolpites hians	2	0	1	2
Longapertites marginatus	5	1	7	7
Psilatricolporites operculatus	1	0	1	0
Echiperiporites icacinoides	0	0	1	0
Mauritidiites crassibaculatus	3	2	4	0
Liliacidites nigeriensis	0	2	0	4
Striatopollis catatumbus	1	0	0	1
Monocolpites marginatus	3	0	2	4
Monoporites annulatus	0	1	0	2
Psiltricolporites minutes	0	2	0	0
Psiltricolporites crassus	0	3	1	0
Scabratriporites simpliformis	0	2	0	0
Syncolpites marginatus	0	0	0	2
Retibrevitricolpites triangulates	1	3	0	0
Psilatriporites rotundus	0	1	0	0
Retidiporites magdalenensis	0	0	1	3
Echitriporites trianguliformis	1	0	3	1
Proteacidites dehaani	2	0	2	1
Inaperturopollenites hiatus	0	1	0	0
Striamonocolpites rectostriatus	1	0	0	0
Constructipollenites ineffectus	2	0	1	2
Buttinia andreevi	2	0	3	1

beach depositional environment, with considerable fluvial influence for the sandstone facies of the Nsukka Formation in Ozuabam area. Oti (1983) investigated the mineralogy, petrology and phosphate mineralization of these limestones. Kumaran and Rajshekhar (1992) studied the foraminiferal linings in the limestones. Mbuk et al (1994) discussed the fossil contents of the Nsukka Formation in the Ohafia-Ozu Abam area.

Table 2: The occurrence and distribution of marine species in the examined samples.

Marine Species	**sample 16**	**sample 19**	**sample 26**	**sample 28**
Dinoflagellate cysts				
Dinogymnium acuminatum	3	0	1	2
Spiniferites ramosus	2	2	0	1
Ceratiopsis sp.	2	0	3	5
Operculodinium centrocarpum	0	1	1	0
Andalusiella sp.	2	0	4	1
Glaphyrocysta ordinata	1	1	1	0

Palaeocystodinium sp.	2	0	3	2
Oligosphaeridium complex	0	1	0	0
Cordosphaeridium inodes	0	0	1	0
Achomosphaera ramulifera	0	0	2	0
Diphyes colligerum	0	1	0	3
Apectodinium homomorphum	0	10	0	0
Damassadinium californica	0	0	0	0
Senegalinium sp.	3	0	3	1
Cleistosphaeridium sp.	0	0	0	0
Coronifera oceanic	0	0	3	1
Adnatosphaeridium multispinosum	0	0	0	2
Hafniasphaera septata	0	0	0	0
Cyclonephelium deckonincki	0	2	0	0
Turbiosphaera filose	0	2	0	0
Lingulodinim machaerophorum	0	0	2	0
Kallosphaeridium brevibarbatum	0	3	0	1
Adnatosphaeridium vittatum	1	1	0	0
Exocosphaeridium sp.	0	0	2	0
Fibrocysta sp.	0	3	0	0
Areoligera senoniensis	2	0	3	5
Histrichokolpoma rigaudae	0	1	0	0
Achilleodinium biformoides	0	0	0	0
Cometodinium whitei	1	0	2	1
Phelodinuim sp.	2	0	1	3
Forams test lining	1	0	0	2

Table 3 described and explained the percentage of individual pollens and spores as well as the depositional environments. Simpson (1956) and Reyment (1965) in their different studies simply described the Nsukka Formation as a paralic sequence. Mode and Odumodu (2014) in their studies on the lithofacies and ichnology of the Late Maastrichtian-Danian Nsukka Formation in the Okigwe area suggested the presence of five lithofacies association that were deposited in several environments ranging from lagoon/bay, upper to lower shoreface through to the proximal offshore.

Table 3: Summary of the *Palynomorphs* % frequency distribution and their paleoenvironmental inferences.

SAMPLE N0.	**PALYNOMORPHS % FREQUENCY**			**PALEOENVIRONMENTS**
	Spores	**Pollen**	**Dinocysts**	
16	23	50	27	Marginal marine (near-shore/mangrove swamp)
19	11	52	37	Marginal marine (proximal estuary)
26	20	43	37	Marginal marine (near-shore/mangrove swamp)
28	20	46	34	Marginal marine (near-shore/mangrove swamp)

Geochemistry

The major element in the limestone sample that was analyzed includes CaO, MgO, SiO_2, Al_2O_3, Fe_2O_3, Na_2O, SO_3 and LOI. The limestone consists of CaO as the major constituent, next to SiO_2 while Al_2O_3, Fe_2O_3 and MgO form the minor constituents. Among the oxides Na_2O is almost to nonexistent while K_2O occurs in traces (Table 4).

From simple stoichiometric composition employing a (CaO and $CaCO_3$) ratio of 0.56, the CaO content of the rock translate to calcite ($CaCO_3$), values of between 43 and 92 weight %. The measured chemical species that have been analyzed and the results presented as correlation coefficient and as co variation plot. Examination of changes of the measured chemical species with respect to CaO displayed positive correlation, while most of the major insoluble residue components, notably, SiO_2, Al_2O_3, Fe_2O_3 and K_2O are significantly decreased with increasing CaO content of the rock. Also strong positive correlation amongst SiO_2, Al_2O_3, Fe_2O_3 and K_2O are observed in Figure 4.

The chemical composition of the limestone reflects observed mineralogical compositions. The negative correlation existing between CaO and SiO_2 suggests that the rock comprises distinct silicate and carbonate fractions. The positive relationships existing between CaO and MgO (Fig. 5) together with distinct negative relationships displayed between MgO and major insoluble residue components, such as SiO_2 and K_2O reflects the presence of dolomite as part of the carbonate phases of the rock. The strong positive correlation exiting between CaO and LOI can

Table 4: Geochemical result obtained from the studied samples.

Sample N0.	Sample Name	Chemical Composition (%)								LOI (%)	$CaCO_3$ (%)
		SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O		
1	Osusu Nkwu	46.41	3.70	3.60	25.06	0.34	0.20	1.60	0.02	18.12	47.06
2	Oboro	29.08	4.18	4.65	33.68	1.10	0.55	1.09	0.01	24.77	60.78
3	Ndi Okereke	3.06	0.98	1.67	49.94	1.38	0.16	0.06	0.00	41.96	92.82
4	Isi Ugwu	7.50	2.02	5.58	46.24	1.07	0.44	0.13	0.00	35.96	81.08
5	Kalayi	3.91	1.29	1.95	50.27	0.80	0.13	0.08	0.00	40.38	89.73
6	Ozuabam Ohafia Road	8.87	2.19	4.14	46.12	1.16	0.78	0.24	0.00	35.64	80.64
7	Ndi Ukpeze	36.12	3.33	4.69	31.19	0.68	0.32	1.39	0.02	22.21	55.69
8	Oduenyi (Imo Shale)	3.80	0.60	1.13	50.74	0.75	0.13	0.14	0.01	41.64	90.01
9	Ozuabam Ohafia Road	9.56	2.21	3.89	45.76	1.09	0.78	0.26	0.00	35.14	78.70
10	Orua Stream	4.51	1.10	2.48	49.34	1.47	0.17	0.13	0.00	40.39	77.78
11	Oboro	30.88	4.33	5.12	32.05	1.72	0.68	1.14	0.01	23.87	56.41
12	Ndi Okereke	5.61	1.17	1.84	49.49	1.25	0.20	0.17	0.00	39.39	91.47
13	Ndi Ukpeze	36.07	3.21	4.12	31.66	0.53	0.57	1.38	0.02	22.44	55.86
14	Ozuabam Ohafia Road	10.09	1.86	3.55	45.70	1.33	0.78	0.32	0.00	35.49	83.29
15	Kalahi	3.33	0.98	1.31	51.25	0.92	0.17	0.07	0.00	41.29	90.90

16	Isi Ugwu –Ndi Oji Abam	6.90	1.72	4.41	46.90	1.05	1.38	0.13	0.00	36.57	82.56

be explained by considering that a significant proportion, if not all of the LOI is due to the carbonate phase. The strong negative correlation existing between CaO and the various insoluble residues suggest the relevance of the alumino silicates in the evolutionary history of a rock. A similar observation was made during the study of the geochemical signatures of the Nsofang marble in the Mamfe Embayment of south eastern Nigeria (Ephraim, 2012). Furthermore, limestones of Ohafia Ozu Abam area, the corresponding to low Al_2O_3 values measured in deposits of most of the studied locations having elevated concentrations of SiO_2 rule out the considerations of high detrital input in the limestones. Accordingly, significant amount of insoluble components such as SiO_2, Al_2O_3, Fe_2O_3, K_2O and Na_2O (Fig. 4) are most likely not sources from alumino silicate phase but probably introduced through skeletal remains given the fossiliferous nature of the limestones.

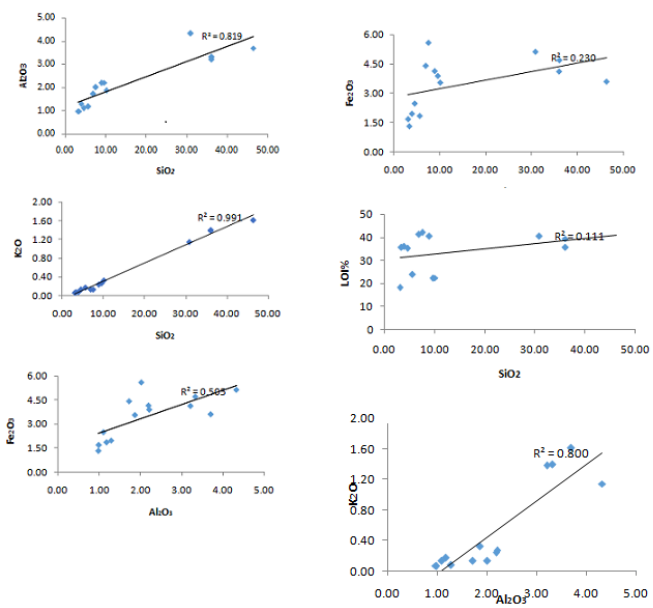

Fig. 4: Scattered plot diagrams of selected major elements and LOI (R^2: coefficient of determination) of the analyzed limestones

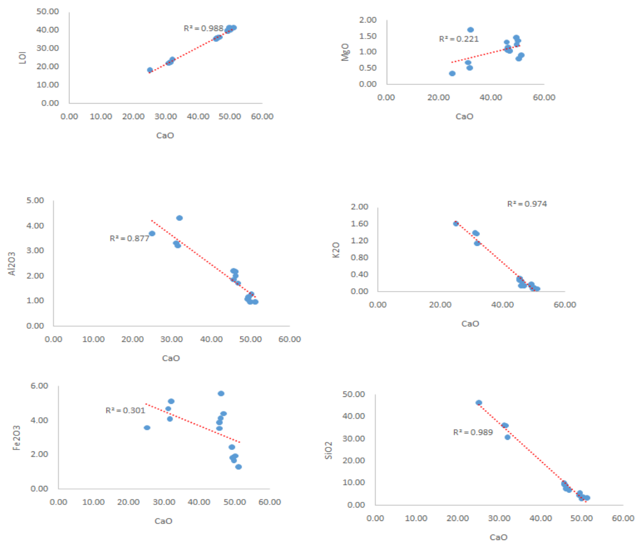

Fig. 5: Scattered plot diagrams of CaO versus selected major elements and respective coefficients of determination (R^2) of the analyzed limestones.

Ibe and Ogezi (1997 and1999) worked on the chemical and industrial characteristics of the carbonate rocks of the Nsukka Formation in the Ohafia Area. Odumodu et al, (2015) discussed the characterization of diagenetic processes of the Late Maastrichtian to Danian limestone in Ohafia areas of Southeastern Nigeria.

CONCLUSION

Late Maastrichtian age on the basis of high abundance of the *Spinizoncolpites baculatus* and *Lonapertites marginatus* species, with co-occurrence of typical dinoflagellate cysts assemblage, such as, *Dinogymnium acuminatum*, *Senegalinium* sp., *Andalusiela* sp., and *Paleocystodinium* sp. Also, Paleocene age has been assigned based on high dominance of *Proxapertite operculatus*, with low occurrence of *Longapertites marginatus* and *Spinizonocolpites baculatus* species. This was further strengthened by the absence of a typical *Dinogymnium acuminatum,* in some samples. The individual pollens and spores described the limestone sediment depositional environments as marginal marine (near-shore/mangrove swamp).

The geochemical composition indicates significant amount of insoluble components such as SiO_2, Al_2O_3, Fe_2O_3, K_2O and Na_2O are most likely not sources from alumino silicate phase but probably introduced through skeletal remains given the fossiliferous nature of the limestones.

REFERENCES

Adekoya, J.A., Aluko, A.F. and Opeloye, S.A. (2011), Sedimentological characteristics of Ajali Sandstone in the Auchi environs of Anambra basin, Nigeria. *Ife J. Sci*., 13(2): 52-67.

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

Ephraim, B. E. (2012). Investigation of the geochemical signatures and conditions of formation of metacarbonate rocks occurring within the Mamfe embayment of south-eastern Nigeria. Earth Sci. Res. SJ. Vol. 16, No. 2 (December, 2012): 39 - 56

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 Southeastern Nigeria. (pg to be determined)

Germeraad, J. H., Hopping, C. A. and Muller, J., 1968. Palynology of Tertiary sediments from tropical areas. Rev. Paleobot. Palynol. Vol. 6: pp 189 – 343.

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 Characteristic of the Carbonate Rocks of the Late Maastrichtian Nsukka Formation in Ohafia Area of Southeastern Nigeria. Global Journal of pure and Applied Sciences, Vol 5(2), p. 234-240.

Kumaran, K.P.N and Rajshekhar, C., 1992. Foraminiferal linnings' 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., 1994. The Upper Cretaceous-Paleocen boundary in the Ohafia – Ozu Abam area, Imo State, Nigeria. Journal of Mining and Geology, Vol 22, p. 105-113.

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

Mode, A. W. (2004). Ethology and paleoenvironmental significance of trace fossils from Cenomanian-Turonian sediments in the Upper Benue Trough. Nigeria. *Journal of Mining and Geology*, 29(2): 111—118.

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: African Geology (Ed. by Dessauvagie, T.F.J. and Whiteman, A.J.), 251-266. Ibadan University press, Ibadan, Nigeria.

Nwajide, C.S (2005). Anambra basin of Nigeria: Synoptic basin analysis as a basis for evaluating its hydrocarbon prospectivity . In Okogbue, C. O (ed.) Hydrocarbon potentials of the Anambra basin; geology, geochemistry and geohistory perspectives. Great AP Express Publ., Ltd., Nsukka. pp.1 – 46.

Nwajide, C.S. 2013. Geology of Nigeria's Sedimentary Basins. CSS Bookshop Limited, Nigeria P.277-346

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

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 Southeatern Nigeria. Journal of Natural Sciences Research. Vol 5. No 6.

Ojoh, K.,1990. Cretaceous Geodynamic EEvolution of the Southern part of the Benue Trough (Nigeria) in the Eqitorial 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.

Reijers, T.J.A., Petters, S.W., and Nwajide, C.S., 1997, The Niger Delta Basin, in Selley, R.C., ed., African Basins--Sedimentary Basin of the World 3: Amsterdam, Elsevier Science, pp. 151-172.

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

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

Simpson, A. (1956), The Nigeria coalfield. The geology of parts of Onitsha, Owerri and Benue provinces. Bull. Geol. Sur. Nigeria, 24, 1-85.

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.