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Evaluation of Albian Limestone Exposed at Dangote Cement Quarry, Tse-kucha Near Yandev, North Central Nigeria: A Geochemical Approach

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ABSTRACT

A geochemical study of Tse-Kucha limestone of the middle Benue Trough as exposed at Dangote Cement Company was carried out. The study aims at reconstructing the depositional history of the deposit using major and trace elements composition. The chemical compositions of the limestone exposed in the quarry were determined using inductively Coupled Plasma -Emission Spectrometry (ICP-ES) and Inductively Coupled Plasma – Mass Spectrometry (ICPMS) respectively. Petrographic study was also carried out to enhance the determination of biogenic contents of the deposit. Results of fifteen (15) samples collected for analysis put the range of major elements as follow: CaO (43.83-53.32), Al_2O_3 (0.49-4.02), $Fe_2O_{3(t)}$ (0.66-2.13), SiO_2 (2.11-10.00), MgO (0.44-1.06), and MnO (0.04- 0.97) respectively. Also the trace elements contents expressed in ppm were found to be Sr (340 – 656), Ba (14-3821), Zr (8-232) Rb (5-49), Ce (5-121), Pb (2-15), Zn (7-72). Interpretation of these results suggest a shallow marine possibly an off- shelf depositional model for the deposit.

Key words: *Limestone, Mineralogy, Evaluation, Off shelf deposition, Benue Trough*

1. INTRODUCTION

Tse-kucha limestone is a rock unit in the Asu River Group of Sediments of the Middle Benue Trough. This Group of Sediments has been found to evolve in Albian time (Wright, 1985). Asu River Group type section is located at the Tse-Kucha limestone quarry of Nigeria, where it is well exposed. These mineral (limestone) is been exploited for the production of cement. What determines the suitability of a limestone deposit for the production of cement is largely its chemical characteristics, hence the justification of this study.

Earlier researchers have worked extensively on petrology, sedimentologic, stratigratigraphic and paleogeographic significance of the Lower Cretaceous Asu River Group. Such researchers include, but not limited to; Nwachukwu (1972), Wright (1976), Nair and Ramanathan (1984) and Abimbola and Akande (1996). Akande et al (1988) classified porosity in the limestone in the Arufu- Akwana host rocks as both fabric selective and non fabric selective. However, this study is directed at the geochemical evaluations of the limestone deposit, that is using the major oxides and trace elemental concentrations to model the depositional environment.

2. GEOGRAPHIC LOCATION AND GEOMORPHOLOGY

The study area is a limestone deposit of Dangote Cement Company quarry, Tse-kucha near Yandev. Tse-kucha village is situated along Makurdi – Gboko express way, about 65km NW of Markurdi. It lies within latitudes $7^0 20^/$ and $7^0 30^/$ N and longitudes $8^0 56^/$ and $9^0 00^/$ E on part of Gboko sheet 271.

The Tse-kucha area is accessible via a network of major, minor roads, land, foot paths, which link the cement factory with neighboring settlements (Fig. 1). Tse-kucha belongs to the Tropical hinterland climatic region of Nigeria, characterized by heavy rainfall and short dry season.

The mean annual rainfall is 1000-1500 mm, annual relative humidity is over 60% and mean annual temperature exceeds 27°C. Dentritic drainage pattern is prevalent in the area.

The land is covered with tall grasses of savannah and tropical bush and it support agriculture of various type

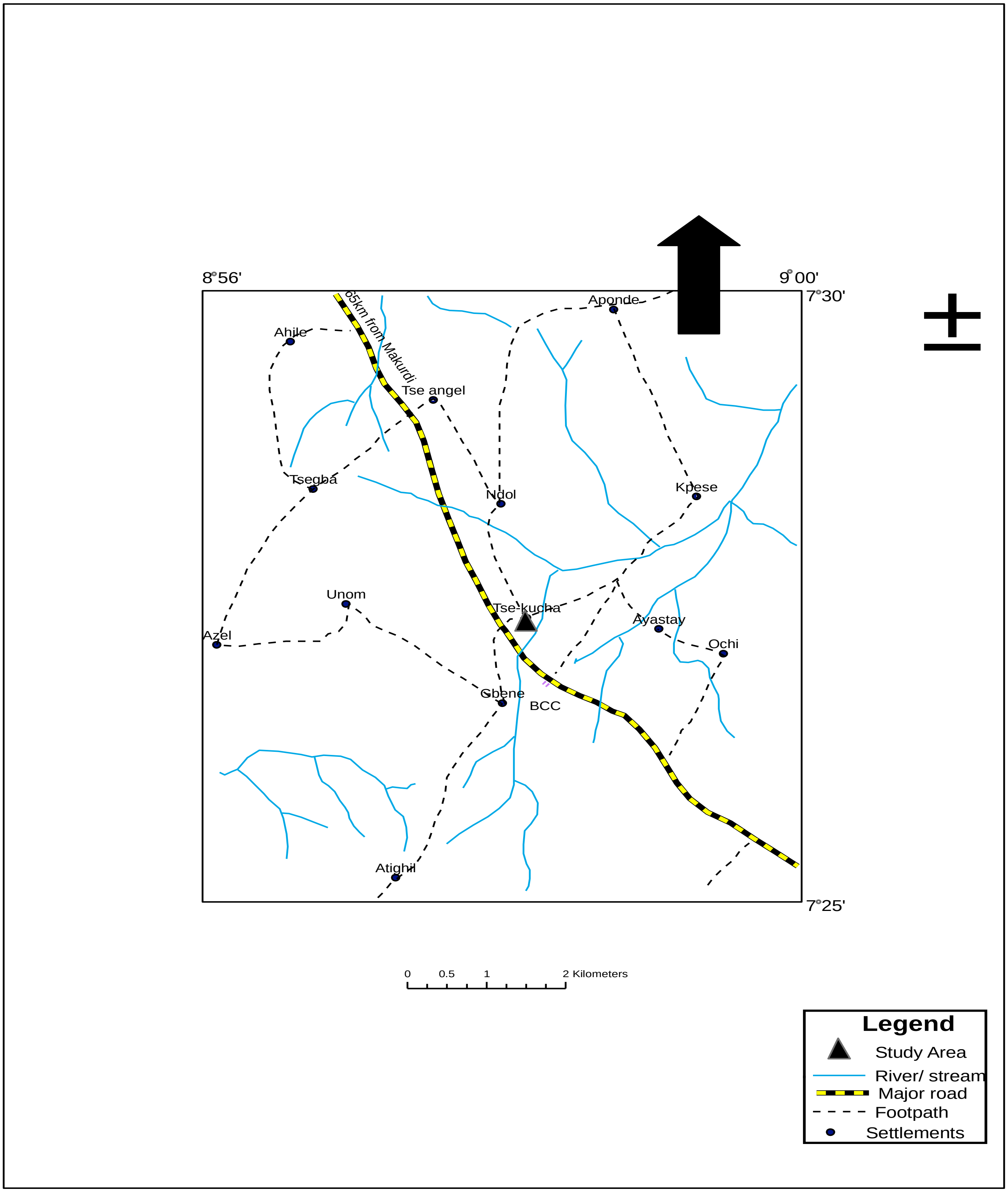


Figure 1: Accessibility of Tse-Kucha Area

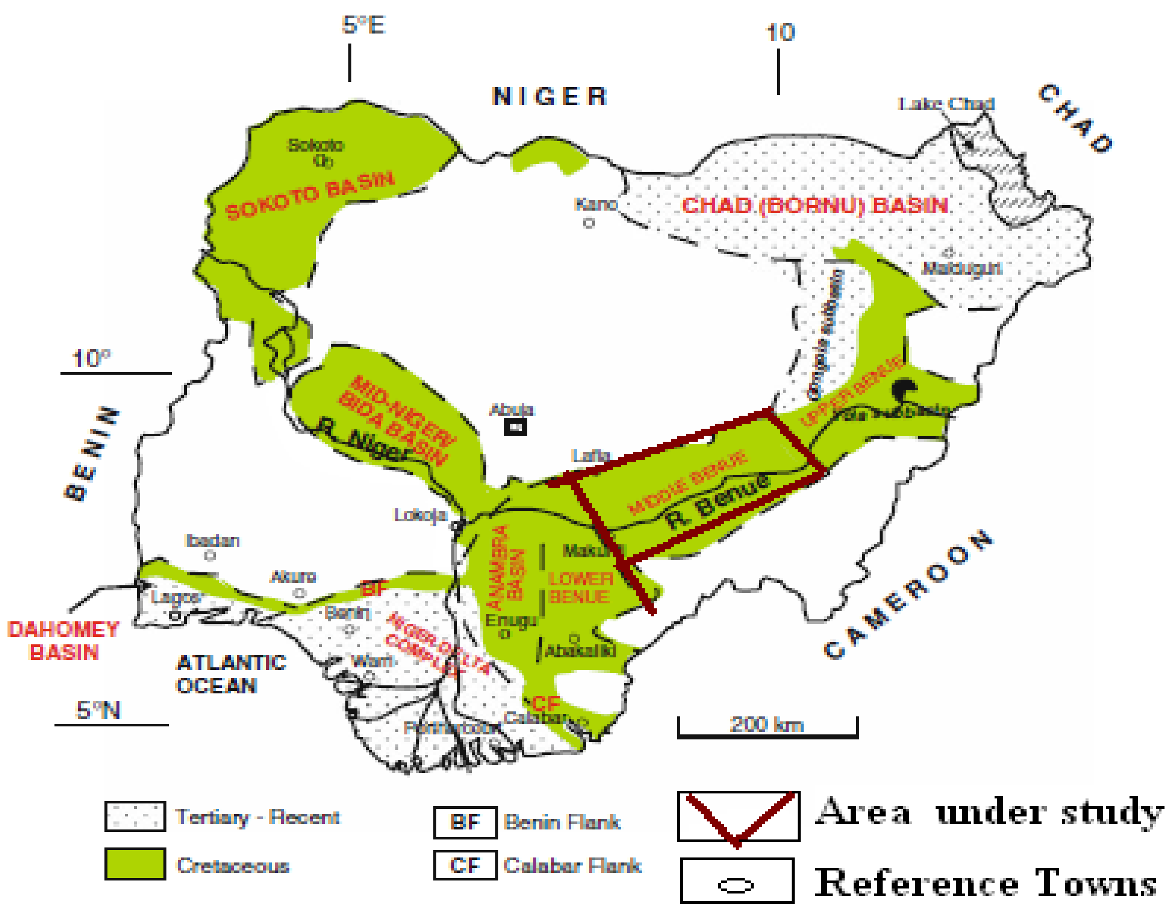
3. STRATIGRAPHY OF MIDDLE BENUE TROUGH

The study area falls within the Middle Benue Trough. The origin/evolution and stratigraghic Succession of the Middle Benue Trough have been discussed in details in Burke et al. (1970), Grant (1971), Nwachukwu (1972), Olade (1976), Offodile (1976), Adjihige (1979), Ofoegbu (1984) Nair and Ramanathan (1984), Benkhelil (1989) and Akande et al, (1992).

The formations in the Middle Benue Trough from the oldest to the youngest are as follow; Asu River Group (Albian), Awe Formation (Late Albian - Early Cenomanian). Keana Formation (late Cenomanian), Eze Aku Formation (Late Coniacian) and the youngest Lafia Formation (Campanian - Maastrichian) (Offodile 1976) (Fig. 2).

The sedimentation in the Benue Trough was controlled by two dorminant factors namely: the progressive eustatic rise in sea level from Albian and the consequent wide spread drowning of the continental margin and the creation of vast interior seaways during the Cenomanian and Turonian times and local diastrophism. Both processes resulted in the transgressive – regressive cycles that characterized depositional pattern.

Calcareous shales were deposited in the structural depressions during transgressive phase while shoal carbonates developed on submerged structural highs (platforms, horst) protected from clastic influx. Extrusive deltaic sediments, filling the subsiding basin and by predominantly fine clastics (shallow marine shales) deposits over the structural highs dominated the regressive phases (Fig.2).



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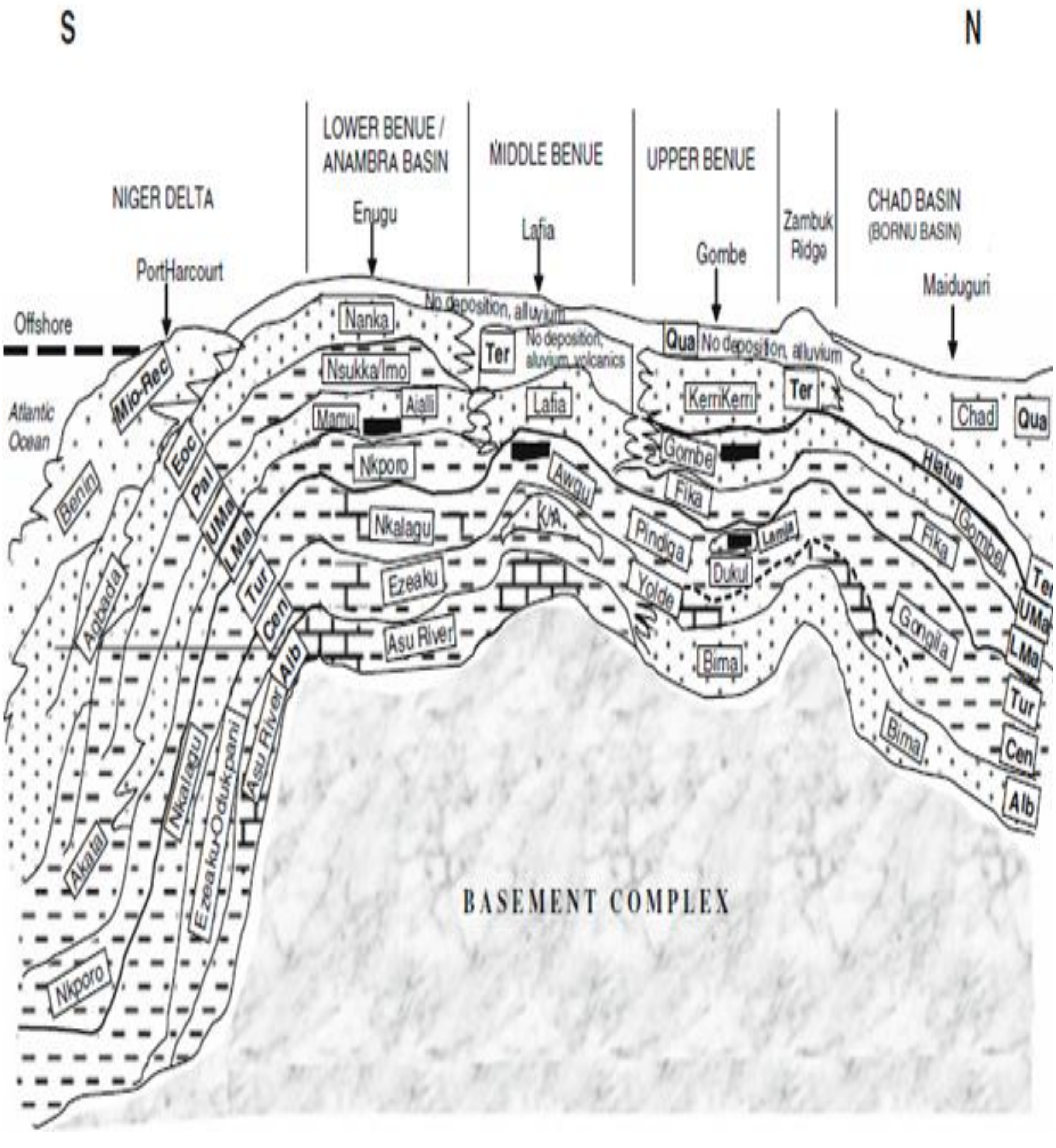

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Figure. 2: a) Map of Nigeria showing the Middle Benue Trough and other sedimentary basins of Nigeria;
b) Idealized N-S stratigraphic cross-section across the Chad Basin-Benue Trough-Niger Delta depicting a connected trans-Atlantic Sea way between the South Atlantic and the Tethys Sea during the Coniacian- Turonian (After Obaje, 2009)

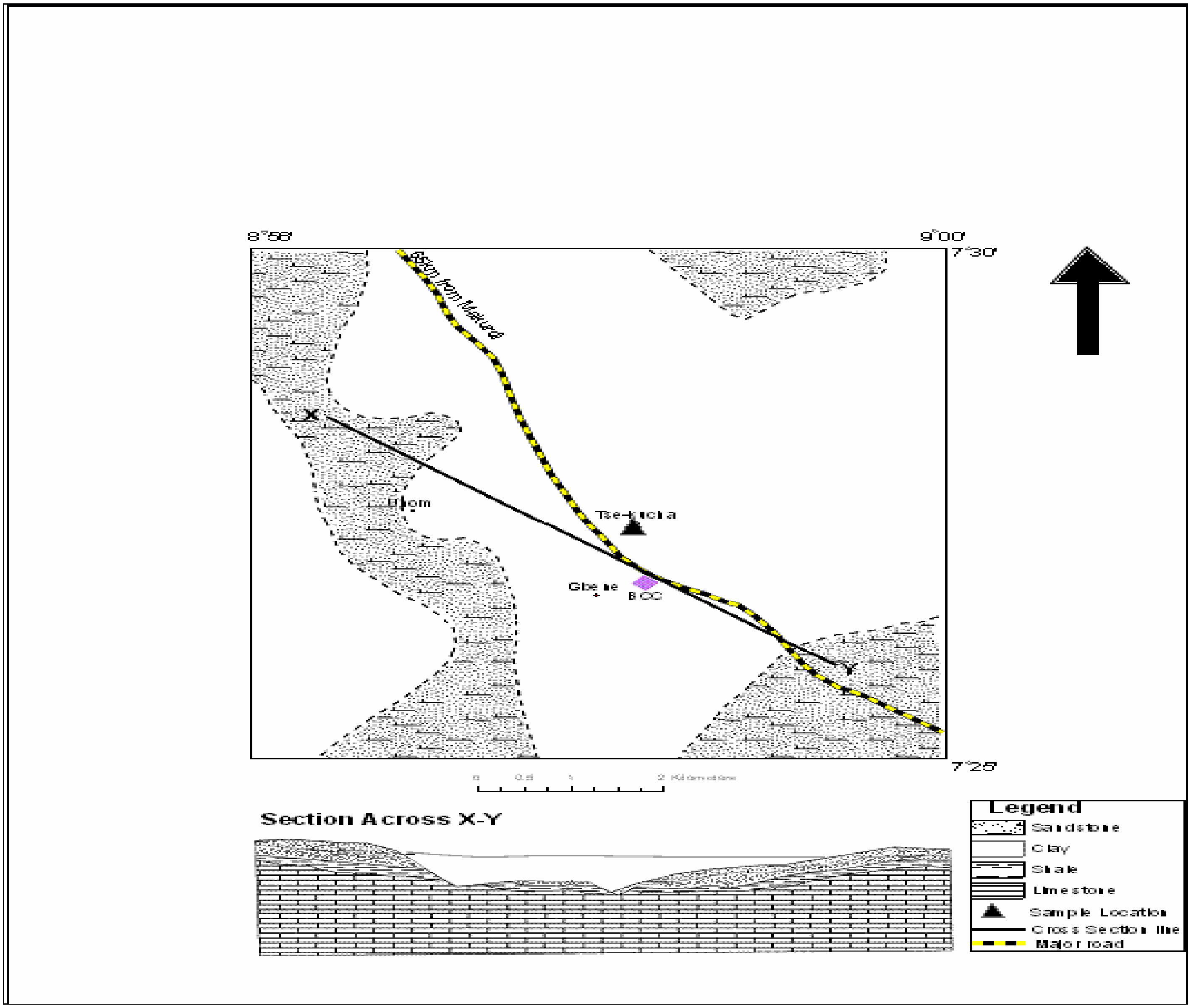


Figure 3:Geological map of Tse-Kucha area

4. METHODOLOGY

Geological Field mapping and sampling was carried out at a quarry site in Tse-Kucha village during the dry season. Mapping was on a scale of 1:25.000 cm. Each of the eight benches were sampled. The average thickness of each bench was measured and recorded. Fifteen (15) representative samples were collected from outcrops of the limestone deposit at Tse-Kucha to reflect a wide and uniform coverage of the different blocks.

The samples collected were taken to laboratory for treatment and standard laboratory preparation prior to analysis and thin section preparation. Geochemical analysis of major elements and trace elements was done using Inductively Coupled Plasma -Emission Spectrometry (ICP-ES) and Inductively Coupled Plasma – Mass Spectrometry (ICPMS) at ACME Analytical Laboratories Ltd, Vancouver. Canada. The thin section was equally prepared in a standard laboratory of the Geology Department, University of Ibadan, Nigeria. Mineral identification and modal analysis were carried out on the thin sections using petrological microscopes.

5. RESULTS AND DISCUSSION

Major Oxides

The result of the major elemental oxides shown in Table 1 indicates that the CaO concentrations of the limestone ranged between 43.83%-53.32% with mean value of 48.16%. The SiO_2 contents between 2.11-10.00% with a mean value of 6.39% and $Fe_2O_{3(t)}$ between 0.66-2.13 with mean of 1.43%, MgO and Al_2O_3 content vary between 0.44-1.06 and 0.49-4.02 with mean values of 0.70% and 2.20% respectively

Table 1: Major element compositions (Wt % Oxide) of limestones in Tse-Kucha near Yandev

Samples	TPQ	PQ3	QR3	O2	S3	R3	DE NORTH1	DE NORTH2	DE NORTH 3	DE SOUTH 1	DE SOUTH 2	DE SOUTH 3	DE MAIN2	Range	Mean
SiO_2	6.99	3.16	2.11	6.91	6.07	10.00	4.77	8.43	6.62	8.20	8.02	4.41	7.40	2.11 – 10	6.40
Al_2O_3	2.02	0.88	0.49	2.00	2.49	4.02	1.31	2.24	2.01	3.04	3.03	1.81	2.96	0.49 – 4.02	2.20
$Fe_2O_{3(t)}$	1.16	0.66	0.87	1.33	1.57	1.71	2.13	1.88	1.74	1.65	2.04	0.77	1.11	0.66 – 2.13	1.40
MgO	0.72	0.44	0.48	0.72	0.79	0.97	0.91	0.65	0.63	0.82	1.06	0.61	0.71	0.44 – 1.06	0.70
CaO	47.82	52.52	53.32	48.03	47.76	43.83	49.63	46.34	47.90	45.52	45.98	50.1	47.33	43.83 –53.32	48.20
Na_2O	0.14	0.05	0.03	0.14	0.07	0.15	0.11	0.13	0.08	0.03	0.09	0.06	0.07	0.03 – 0.15	0.09
K_2O	0.45	0.19	0.10	0.44	0.55	0.89	0.27	0.48	0.43	0.64	0.65	0.41	0.69	0.1 – 0.89	0.48
TiO_2	0.09	0.05	0.03	0.09	0.13	0.20	0.09	0.12	0.11	0.15	0.15	0.09	0.18	0.03 – 0.2	0.11
P_2O_5	0.07	0.05	0.07	0.07	0.13	0.13	0.19	0.08	0.08	0.10	0.11	0.17	0.23	0.05 – 0.23	0.11
MnO	0.07	0.05	0.05	0.07	0.05	0.05	0.06	0.11	0.09	0.05	0.06	0.04	0.04	0.04 – 0.97	0.13
LOI	40.40	41.80	42.40	40.10	39.90	37.90	40.40	39.40	40.20	39.70	38.70	41.50	39.20	37.90 – 42.40	40.12
Total	99.92	99.89	99.95	99.91	99.47	99.90	99.91	99.91	99.89	99.90	99.90	99.93	99.92		

Calcium Oxide (CaO) and Silica (SiO_2)

From the result of major oxides, CaO content is very high (> 43%). Petrographic studies also indicated that the limestone is essentially biomicritic and calcitic. The grains, matrix and cement constitute essentially the carbonate components. They are suggested to have been precipitated from solution by organisms. The skeletal remain of these organisms notably pelycypods, brachiopods, mollusc and echinoderms are the dominant bioclasts present in the limestone.

The relatively high level of CaO and low values of SiO_2 and MgO, (Fig. 4), indicated a high degree of purity of the limestone hence its suitability as raw material for cement. The CaO compares favourably with that of Bejide (2000) which is 46.88 % CaO but far lower than that of Sagamu, Ewekoro and Ibeshe with 89.2%, 80.3% and 75.7% CaO respectively (Akimosin et al, 2005).

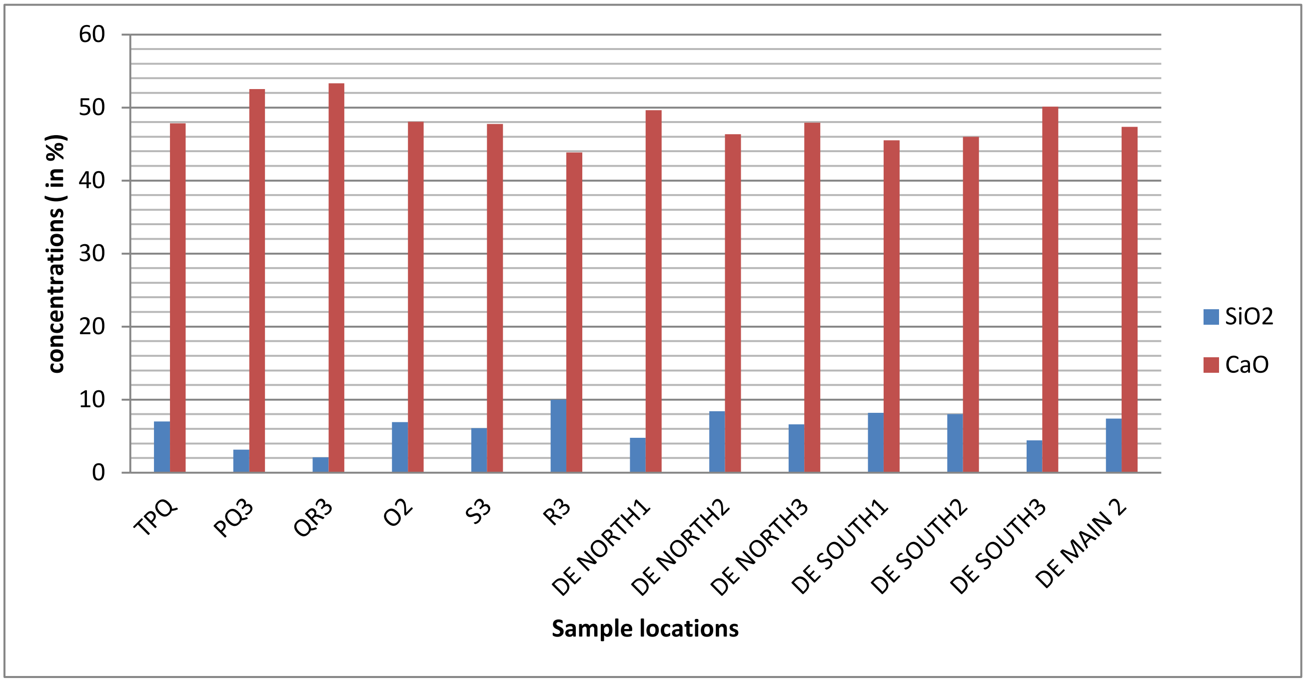


Figure 4: CaO and SiO_2 compositions (wt%) of the limestone in Tse-kucha

Magnesium Oxides (MgO) and Alumina (Al_2O_3)

The percentages of MgO and Al_2O_3 are low 0.44-1.06% and 0.49-4.02% respectively. Magnesium could be added through dolomitization process which is completely absent in this deposit. Also, Chave (1954) stated that marine invertebrate skeletal debris has low magnesium with increasing level in the phyla. Tse – kucha limestone is very rich in bivalves, bryozoans and gastropods (higher invertebrates) which are suspected to be responsible for the low level of magnesium in the samples. Magnesium concentration is also a function of temperature of formation, and often low in shells living in shallow waters (Pettijohn, 1984). Thus a shallow marine environment is proposed for Tse-Kucha limestone based on the aforementioned reasons. The aragonitic shells are usually magnesium deficient, such fossil shells namely bivalves are shallow marine dweller that are commonly found in the deposit. The low concentration of alumina is also indicative of low energy environment.

TRACE ELEMENT GEOCHEMISTRY, MINERALOGY COMPOSITIONS AND FOSSIL CONTENTS

Trace element concentrations of the Tse-kucha limestone are given below (Table 2). The elements are Sr, Zn,, Ba, Rb, Pb and Ce. The basal lithofacies appears to have trace elements distributions which discriminate it from the overlying lime mud facies.

Petrograghic studies of each slide from the sample were enhanced by point counting method for each mineral. Modal analysis revealed that calcareous fossil components dominate the entire rock (Figure 5); others components include quartz, Iron oxides and glauconite (Table 3)

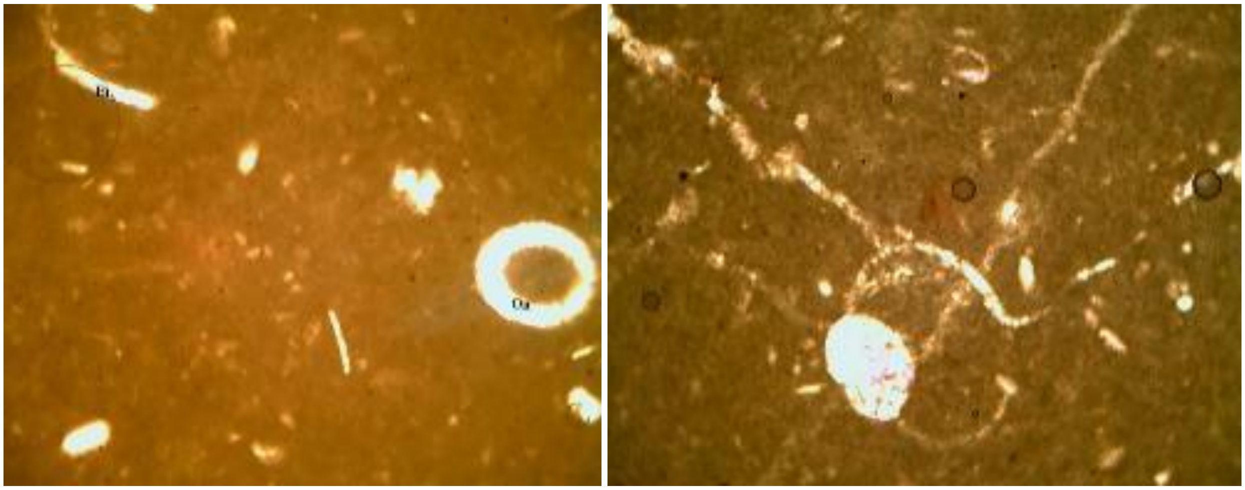
Table 2: Trace Elemental Concentrations of Tse-Kucha Limestone

Samples	TPQ	PQ3	QR3	O2	S3	R3	DE NORTH1	DE NORTH2	DE NORTH3	DE SOUTH1	DE SOUTH2	DE SOUTH3	DE MAIN2	Range	Mean
Pb	5	2	3	6	5	9	15	8	3	9	8	3	3	2 - 15	6.31
Zn	18	7	16	21	27	72	24	54	10	35	54	10	10	7 - 72	27.54
Rb	22	10	5	22	29	49	13	35	19	33	35	19	33	5 – 49	25.28
Sr	503	340	355	518	655	578	552	620	422	508	620	422	435	340 – 655	502.74

Zr	29	16	8	34	21	45	27	27	19	232	23	19	38	8 – 232	41.72
Ce	19	6	5	19	20	30	24	24	12	121	26	12	20	5 – 121	26.46
Ba	26	541	14	28	3821	36	28	69	51	32	34	51	26	14 – 3821	365.92

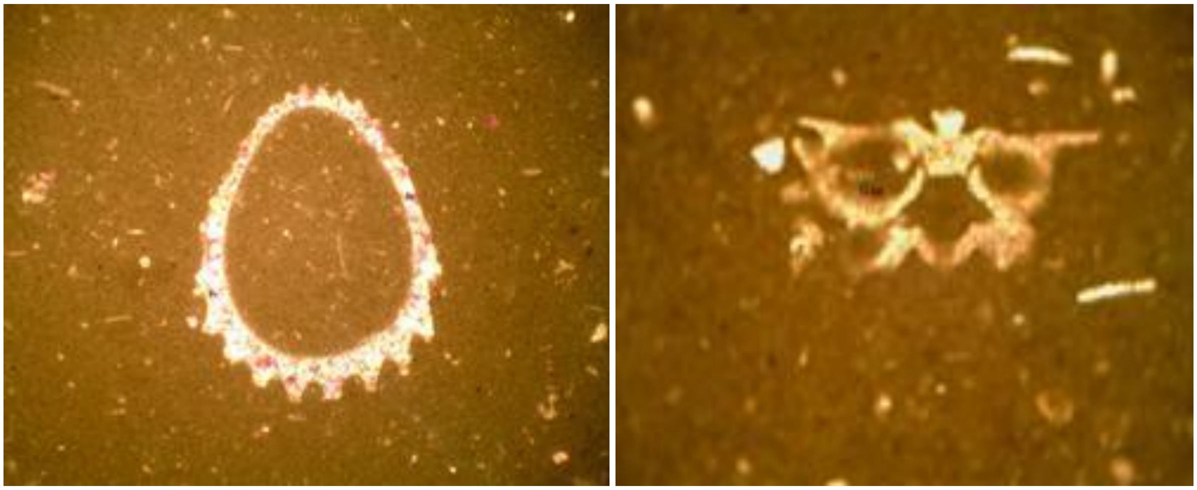
Table 3: Estimated Modal Analysis for Tse-Kucha Limestone in % (After Folks, 1959)

Samples	TPQ	PQ3	TQR	QR3	O2	S3	R3	DE NORTH 1	DE NORTH 2	DE NORTH 3	DE SOUTH 1	DE SOUTH 2	DE SOUTH 3	DE MAIN 1
Fossil fragments	45	60	55	55	50	50	50	60	55	50	40	55	50	60
Micrite	20	20	25	10	30	25	25	20	25	30	30	20	20	15
Sparite	10	5	10	10	10	15	15	10	5	10	5	10	10	5
Intraclast	-	-	-	-	-	-		-		-	-	-	-	-
Lithoelist	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Iron mineral	5	5	-	5	5	3	5	2	-	3	3	2	5	5
Quartz	10	5	5	10	-	2	-	-	5	3	7	3	5	5
Glauconite	5	2	-	5	-	-	5	3	-	2	10	5	5	5
Pyrite	5	3	5	5	5	5	-	5	10	2	5	5	5	5
Pellet	-	-	-	-	-		-		-	-	-	-	-	-
Remarks/ fossil	Micritised Bivalve & Oncolite	broken fragments of pelecypods and Gastropods.	Micritised Bivalve & Oncolite	Micrite invaded Gastropods.	High micrite, Biomicrite.	High micrite. Biomicrite.	Broken bivalve embedded in micrite	Calcite invaded Gastropods, Micrite undergoes neomorphism to sparite. Biosparite	High micrite. Biomicrite.	High micrite contents, Biomicrite.	High micrite contents, Biomicrite.	High micrite. Biomicrite.	High micrite. Biomicrite.	Many broken fragment of pelecypods and Gastropods.



A B

Figure 5: Photomicrograph of a bioclastic wackstone (Sample TQR). A lot of irregular fractures have caused brecciation of the rock matrix. (See B). Note the oncolite (On) and micritised bivalve (Bi) Fragment (See A). (Mag x40µm)



A B

Figure 6: Photomicrograph of a bioclastic packstone (Samples A=DE Main 1 and B=PQ3). The rock consists of many broken fragments of bioclastic grains. Note the complete pelecypods (Pe on A) and gastropod (Gas on B) shell having an internal micrite recrystallising to drusy calcite.

The distribution of Sr and Zn could be used to delineate the various lithofacies of the study area. For example, the basal lithoclastic floatstone facies appears to have trace element distribution different from the overlying lime mud (Table 2 and Figures 5 and 6). Brand (1983) proposed that trace element signatures can be useful tools in interpretation of depositional environment despite post digenetic alterations. Thus Sr, and Zn, in this study show diagnostic distributions that differentiate the pelagic fine micritic limestone facies from the basal coarser wackstone facies. The trace elements show higher concentration in the formal than the latter. Also, Sr in some cases are associated with deep sea carbonates (Frank 1975). All these features strongly suggest possibly an off- shelf depositional model for the Tse-kucha limestone.

6. CONCLUSIONS

Geochemical studies of the Albian Tse-kucha limestone have been vividly carried out and the results of major oxides and trace elemental concentrations, supported by petrographic analysis, have given some insights to the deposit under study. Trace elements distribution can and have been successfully used, in conjunction with other methods, to discriminate between shelf and deep sea carbonate. A shallow marine possibly an off-shelf depositional model has been postulated for the Albian Asu-River Formation, based on geochemical studies merged with the fossil contents.

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