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OCCURRENCE, CHEMICAL COMPOSITION AND INDUSTRIAL QUALITY OF LIMESTONES IN GUYUK, NORTH-EASTERN NIGERIA

EYO E. NTEKIM and DLAMA K. ZIRA

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ABSTRACT

Limestone deposits occur within the Cretaceous shale-limestone stratigraphic units in Guyuk area of north-eastern Nigeria. Geologic investigations reveal three mappable lithofacies namely: crystalline limestone, bioclastic limestone and shelly limestones. These are interlayered with shales and mudstones and, in some places sandstones. Chemical analysis of the limestone by AAS and Flame atomic emission techniques reveal a mean composition of CaO(45.39%), MgO(2.28%), Fe_2O_3(3.57%), Al_2O_3(2.95%), SiO_2(6.6%) and [Na_2O + K_2O](0.17%). Calculated limestone saturation factor (LSF) of ca 171.53 and hydraulic modulus of ca 3.4 were obtained. These parameters suggest a moderate purity limestone that is suitable for the manufacture of portland cement. The rich magnesia appropriates to a magnesian limestone deposit.

Keywords: Cretaceous, Guyuk, Magnesian Limestone, Nigeria.

INTRODUCTION

Guyuk area lies between latitude 9°34' and 10.04'N and longitude 11°45' and 12°00E and is situated within the Southern Gongola and western Yola arms of the Upper Benue valley (Fig. 1). The Yola arm forms part of the Dadiya syncline, a complementary structure to the Lamurde anticline (Chukwu-Ibe,1981; Benkhelil,1986;Braide,1992). This depression hosts a sedimentary sequence which separates the Hawal Massif in the north from the Adamawa Massif in the south.

The sediments in Gongola Trough comprise sandstones, limestones, shales, siltsones, clay and mudstones (Carter et al,1963, Enu, 1980; Mode, 1993). These are contained in sedimentary formations which were deposited during the Cretaceous coastal fluctuations. The stratigraphic units include sandstones (Bima and Lamja Formations) and shale-limestone series (Dukul, Jessu, Sekule & Numanha Formations).

Earlier attempt at assessment of the Guyuk limestones (Gabako and Tedra, 1994) presented a poor quality carbonate rock. This probably was due to the impure samples used for the analyses (mainly surficial). Geological field mapping exercises by the Department of Geology, University of Technology, Yola and exploratory mineral survey work by a private company report the occurrence of limestone deposits in several locations in Guyuk area, adjoining areas of Ngurore district (southeast of Guyuk) and Pindiga (in Gombe State). This paper discusses these occurrences. Also examined is the chemical composition and industrial quality of the deposits.

OCCURRENCE

Geological mapping investigations show that limestone deposits are found within the shale-limestone stratigraphic units and outcrop substantially in specific locations at Bobini, Lakoro, Lamza, Dukul (Kurnyi), Lamja, Walu, Falu, Gora-Toro, Gunda and Sorenti/Lamza (Fig.1). The shale – limestone units are shallow marine formations deposited on the Yolde Formation during transgressive cycles in the Cretaceous. Recognised Formations include the Dukul, Jessu, Sekule, Numanha and Lamja. The Dukul Formation is a 60 to 150m thick deposit consisting of shales, siltstones and limestones. The limestone occur as thin layers alternating with thick greyish/brownish/yellowish shale beds (Carter et al,1963). Jessu Formation is an alternating sequence of shales, sandy mudstones and sandstones with subordinate limestone (Carter et al,1963; Tadco,1989). The Sekule Formation consists of shale sequences

EYO E. NTEKIM: Dept. of Geology, Federal University of Technology, Yola, Nigeria
DLAMA K. ZIRA: Adamawa State Water Board, Yola, Nigeria

interbedded with thin bands of bioclastic limestones (Carter et al,1963) which occur surficially as thin slabs (Tadco,1989). Numanha Formation is composed of thick loose shales with occasional bands of sandstone, mudstone and limestone (Carter et al,1963; Tadco,1989). The Lamja Formation is made up of fine-grained sandstones with shelly limestone interlayers, siltstones and a thin coal seam (Carter et al,1963; Whiteman,1982). Surface survey by Geology department, University of Technology, Yola reveals that Dukul and Sekule Formations are the limestone bearing units, but drill-hole data confirm occurrences in other units also. Appreciable deposits are found, in the Dukul, Sekule, Numanha and Lamja Formations. Occurrences in Jessu Formation is relatively low. Information from the exploratory drill holes indicate that the deposits concentrate mainly towards the surface (Fig.2), and only occur in traces below 15m, except in few cases e.g. Gendaure and Gora Toro. Typical stratigraphic sections through the limestone bearing formations are given in Table 1. Figure 3 is the vertical profiles through the prominent limestone deposits.

Three types of limestones are found within the marine formations in Guyuk area. These include bioclastic limestone, shelly limestone and crystalline limestone. The three lithofacies are found in the Dukul Formation occurring with mudstone beds (Carter et al, 1963; Mode, 1993; Mamman, 1997). Sekule and Jessu Formations have numerous horizons of bioclastic limestone types alternating with shale beds (Enu, 1980). The Numanha Formation has crystalline and shelly limestone types (Carter et al, 1963; Enu,

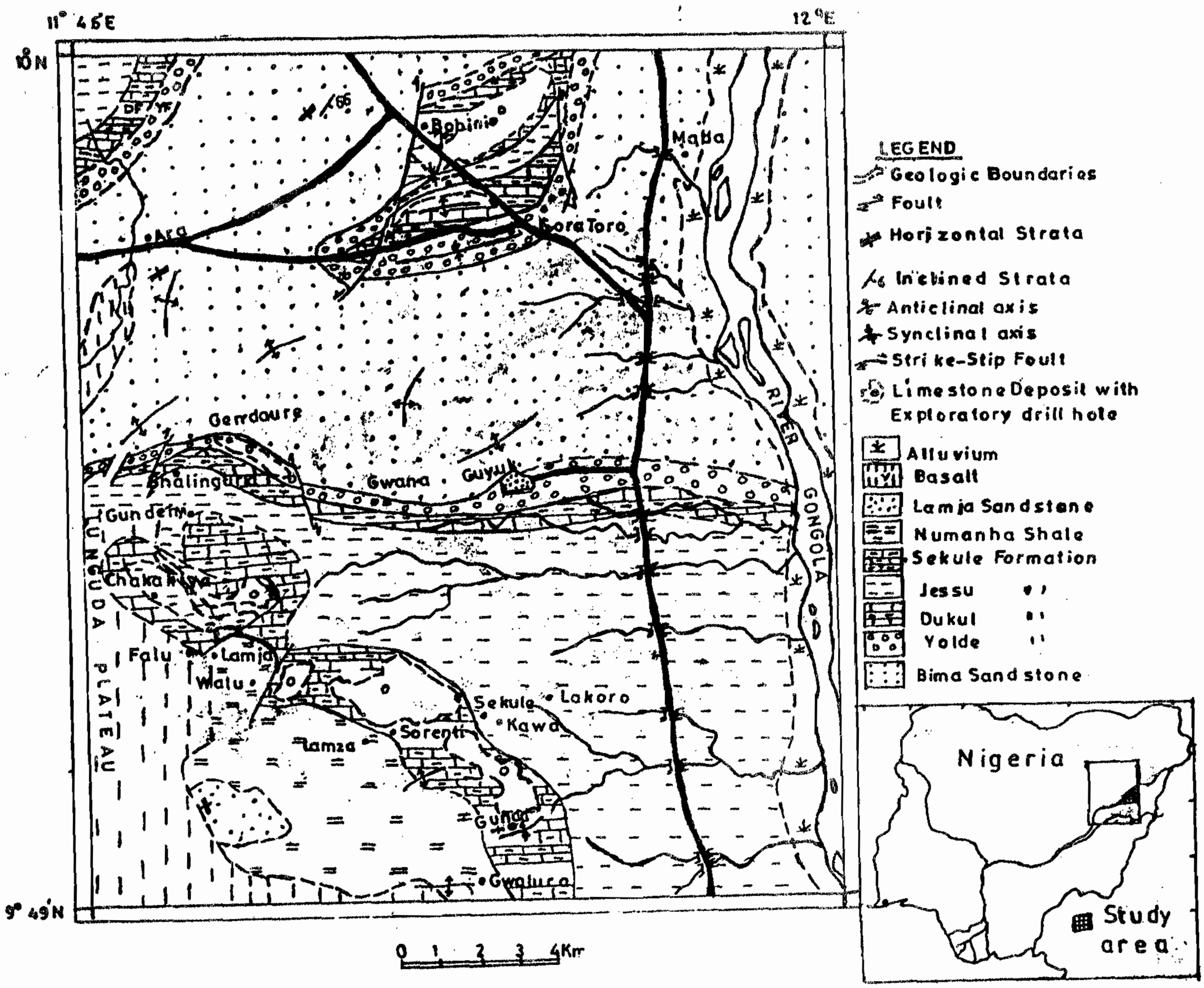

FIG.1 MAP OF PART OF GUYUK AREA SHOWING THE GEOLOGY AND MAJOR LIMESTONE DEPOSITS.

(Inset: Nigeria showing study area in Upper Benue valley)

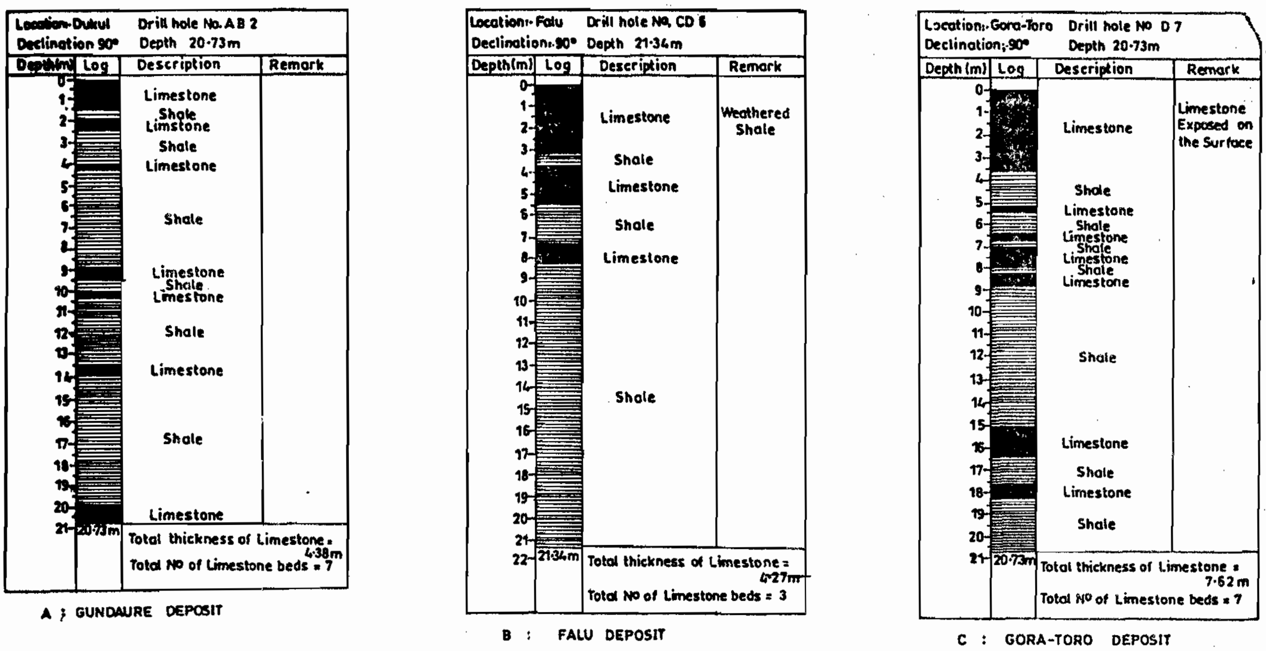

FIG. 2: DRILL HOLE SECTIONS THROUGH SOME LIMESTONE DEPOSITS IN GUYUK

(Courtesy: Tadco Nig.Ltd. Consulting Engineers)

1980). The crystalline type alternates with grey shales and mudstones while the shelly type alternates with shales only. The Lamja Formation contains few thin beds of both crystalline and shelly types intercalated with shale lamillae (Carter et al, 1963).

The crystalline limestone is grey in colour, fine grained, hard and massively bedded. The limestone generally occurs associated with grey shales, though it intercalates with whitish sandstone in Shalingura area (Fig.1). In Lamza area of Sekule Formation, it occurs as crystallised materials amidst the other limestone types, especially along joint and bedding planes. Carter et al (1963) described it as 're-crytallised limestone' (probably formed from precipitation of $CaCO_3$ from limy solutions). In Dukul Formation it occurs as basal limestone, averaging 50cm thick and generally dipping 18°SE. However, in Numanha formation, the rock occurs in thin bands and are dark brown in colour. It outcrops in Shalingura, Gendaure, Chahakiya, and Gwalura areas within Dukul formation; Swenswithire in Numanha Formation and Lamja. Drill hole section in Gendaure shows seven main layers of this limestone encountered within depths of 0 - 20.73m (Fig.2). The rock is fossiliferous.

The shelly limestone is compact, medium grained, massively bedded, yellowish in colour and rich in fragments of bivalve shells. In Lamza area (Sekule/Kawa) extensive thin slabs of dark grey and reddish varieties are seen also. This lithofacies overlies the crystalline types.

The limestone outcrops in several locations within all the formations, alternating with shales, though most prominently in Numanha Formation. Specific locations include Gunda (where it forms intensively jointed pavements), Gendaure (ungwar Laka), Walu, Falu, Bobini and Lamja. In Guyuk area they occur as floats and surface debris and the beds are low dipping (between 5 and 10°). Average thickness of the limestone layers here is 60cm for the upper strata and about 30cm for the lower beds. Lithologic section from a drill hole between Falu and Walu reveals three thick layers found within 0-15m depth, while that between Walu and Lamza shows two thin beds alternating with basaltic layers within 2-3.5m depth (Fig. 2). The rock is highly fossiliferous with mainly pelecypod fossil fragments. Ammonites, brachiopods and ostracods are also found in the rocks (Mode,1993).

The bioclastic facies type outcrop mostly in Sekuliye Formation, though few occurrences are encountered in some locations within Jessu Formation, especially Lakoro and Gora Toro. Other locations include Kawa, Gunda, Falu and Gwalura. It is compact, coarsely textured with broken shells, thinly bedded (averagely 1.5m thick), dark brown in colour and highly fossiliferous. The fossil fragments are mainly oyster shells. The rock is sometimes described as oyster limestone because of the numerous oyster shell constituents. This limestone is the predominant type of limestone in Guyuk area, and is probably a biofacies type of the shelly limestone. It is identified in the field as pavements of highly jointed, broken and rotated slabs on the surface. A drill hole at Gora Toro settlements reveals seven beds averagely 1.2m thick within a depth of 1-18 metres (Fig. 2).

PETROGRAPHIC CHARACTER

Petrographic examination reveals aggregates of calcite and dolomite on the numerous fossil fragments. In most cases the shells are replaced by the carbonates. However, crystals of dolomite are subordinate to the calcite. Calcite predominates in the thin sections of the studied samples, occurring as both particles and groundmass. The particles are slender pisolitic crystals of calcite while the groundmass is a finer-textured calcite bearing shells and fossil fragments. Samples from Bobini area contain both calcite and dolomite. Minor constituents

Table 1: TYPICAL STRATIGRAPHIC SECTIONS THROUGH THE DUKUL AND SEKULE FORMATIONS

Locality	Borehole Depth(m)	Lithologic Description
Dukul (Dukul Fm)	0 - 2.4	Massive grayish and shelly limestone
	2.4 - 3	Shale, light yellowish/grayish
	3 – 6	Shale,yellowish/grayish with limestone traces
	6 - 6.3	Limestone, grayish with broken shells
	6.3 – 12	Shale, grayish/yellowish
	12 – 13.8	Black shale
Bobini (Dukul Fm)	0 - 0.9	Limestone and clay, grayish
	0.9 - 1..2	Limestone traces and clay, yellowish
	1.2 – 3.9	Massive limestone, grayish
	3.9 – 6.6	Gray shale with limestone traces
	6.6 – 9	Shale, grayish/yellowish
	9 - 9.6	Gray shale with limestone traces
	9.6 - 10.8	Shale, grayish/yellowish/pinkish
	10.8 – 11.1	Limestone, grayish, shelly
	11.1 – 11.4	Gray shale
	11.4 – 11.7	Limestone, grayish shelly
	11.7 – 12.6	Gray shale with limestone traces
	12.6 – 13.5	Grayish/browish shale/clay with gypsum traces
	13.5 – 13.8	Limestone, grayish/shelly
	13.8 – 15	Gray shale with gypsum traces
	15 – 15.6	Gray shale with limestone traces
	15.6 – 17.1	Gray shale and gypsum
	17.1 – 20.1	Black shale with limestone traces
Lamza Lakoro (Sekule Fm)	0 - 1.2	Limestone, grayish
	1.2 - 2.4	Clay, grayish/yellowish/brownish
	2.4 - 2.7	Clay, brownish with limestone traces
	2.7 - 3	Clayey, shale, grayish/brownish
	3 - 6.3	Clay, brownish/grayish with limeston traces
	6.3 - 7.5	Gray shale with limestone traces
	7.5 - 8.1	Limestone, grayish
	8.1 - 9	Shale, grayish/brownish
	9 - 9.3	Limestone, grayish
	9.3 - 9.9	Gray shale with limestone traces
	9.9 - 11.4	Shale, grayish
	11.4 - 12.3	Gray shale with gypsum traces
	12.3 -15.9	Shale, grayish
	15.9 - 16.8	Gray shale with limestone traces
	16.8 – 19.2	Shale, grayish
	19.2 – 19.5	Gray shale with limestone traces
	19.5 – 20.1	Shale, grayish

TABLE 2 CHEMICAL COMPOSITION OF LIMESTONES IN GUYUK AREA

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SiO_2	7.20	2.00	15.80	5.00	1.40	8.40	5.02	1.80	8.00	12.00	17.20	11.40	14.60	0.50	6.00
TiO_2	0.16	0.02	0.22	0.12	0.05	0.25	0.08	0.05	0.29	0.13	0.18	0.12	0.29	0.00	0.15
Al_2O_3	3.49	ND	15.23	2.48	0.17	3.14	4.77	0.53	2.35	5.02	5.53	5.52	10.39	0.59	0.16
Fe_2O_3	3.79	5.00	5.00	3.04	0.90	8.94	2.93	1.61	3.50	4.05	6.29	5.36	2.32	2.15	3.65
MgO	0.40	4.03	ND	2.52	2.52	6.05	3.02	1.00	1.51	3.02	1.50	2.52	1.51	ND	2.82
CaO	44.16	47.67	31.55	45.57	51.87	37.85	45.37	51.20	45.57	42.06	37.40	46.27	38.96	53.08	46.27
Na_2O	0.05	0.05	0.35	0.12	0.03	0.11	0.12	0.04	0.08	0.06	0.29	0.10	0.20	0.03	0.08
K_2O	0.14	0.02	0.17	0.20	0.01	0.06	0.04	0.02	0.04	0.04	0.17	0.06	0.18	0.01	0.06
SO_4	0.08	0.08	1.63	0.20	0.63	0.20	0.08	0.15	1.30	0.13	0.25	0.25	0.60	1.30	0.13
LOI	37.70	39.60	27.20	37.65	39.15	32.85	37.50	39.75	36.60	33.20	30.80	32.95	30.40	41.50	37.85
Total CO_3%	45	48	32	47	54	46	46	53	46	42	38	44	39	54	48

Fe_2O_3 as Total Fe. ND = Not determined

Dukul Area 1 = Gendaure; 2 = Gundenyi/Gwana; 3 = Chahakiya; 4 = Gendaure Unguwar Laka (shelly); 5 = Gendaure Dev. Area; 6 = Falu Gawura (banded)
Gunda area 7 = Hawuye; 8 = Hawuye;
Lamza Area 9 = Sekule/Kawa (shelly); 10 = Sekule/Kawa (yellowish); 11 = Sekule/Kawa (dark grey); 12 = Sekule/Kawa (shelly, dark);
13 = Sekule/Kawa (shelly, reddish); 14 = Swenswithire;
Boboni Area 15 = Bobini

include quartz, opaque minerals (probably iron oxides) and chlorite.

Mamman (1997) discussed the petrography of the limestone in Dukul Formation, which host the largest quantity of the Guyuk deposit. According to him, most thin sections contain about 60-70% of colourless calcite grains, though some are somehow brownish, and the allochems constitute less than 10% of the rock. The allochems consist of angular to subangular medium-grained quartz grains whilst the matrix is a fine-grained lime mud.

CHEMICAL ANALYSES AND RESULTS

Twenty three (23) representative drill hole samples of limestones from the different locations in Guyuk area were analysed at the Chemical and Physical laboratory of the Nigerian Mining Corporation, Jos, Nigeria. Atomic absorption spectrophotometry was used to determine Fe_2O_3, MnO and Al_2O_3 while Flame atomic emission technique was used for Na_2O and K_2O. CaO and MgO were determined by titration using standard EDTA while TiO_2 was determined by light absorption technique. Gravimetric precipitation of $BaSO_4$ using $BaCl_2$ solution was employed to measure SO_4 while LOI was determined at 950°C. For SiO_2 the samples were digested in acid medium, filtered, ashed and hydroflourished to give silica residue.

Results of the analyses are presented in Table 2 while Table 3 gives the percentage of some industrial parameters. Included in Table 3 for comparison are results for Talum, Ngurore, Ashaka, Guyuk(Gabako and Tedra,1994) limestones in northeastern Nigeria and Mfamosing limestones in southeastern Nigeria. The average SiO_2 content of the Guyuk limestones is ca 6.66%, Fe_2O_3 is 3.57%, Al_2O_3 is ca 2.95% while CaO is 45.39%. This composition appropriates them as impure limestones (Greensmith,1978). The SiO_2, Al_2O_3. TiO_2 and Fe_2O_3 contents show relative enrichment in Lamza deposit over those of Dukul (Gendaure), Gunda and Bobini (Table 3). However, the Lamza limestones have the least MgO content (ca 1.68%). This value is, however, comparatively higher than values for Talum (1.01%) and Mfamosing(0.3% average). Mean SO_4 content is higher in Lamza deposit (ca 0.64%) though relatively lower than in the Ngurore limestones (with 1.48%). The Al_2O_3 and Fe_2O_3 contents of 2.95% and 3.57% in Guyuk limestones are relatively low when compared to those of Talum limestones which average 6.56 and 7.95 percents respectively. The observed values for Guyuk limestones are similar to the alumina and Fe oxide contents in dolomitic sandy limestone samples from Mfamosing (Ekwueme,1985). CaO constitutes the dominant component of Guyuk limestones though the concentration is generally less than 50%. The average value is lower than the 47.77% value for the Ashaka limestones (Tadco,1989) and the 51.04% value for the 'high purity' Mfamosing limestones (Ekwueme,1985). Pure limestones contain ca 56% CaO (Mason, 1966). The samples have very low alkalies (Na_2O +

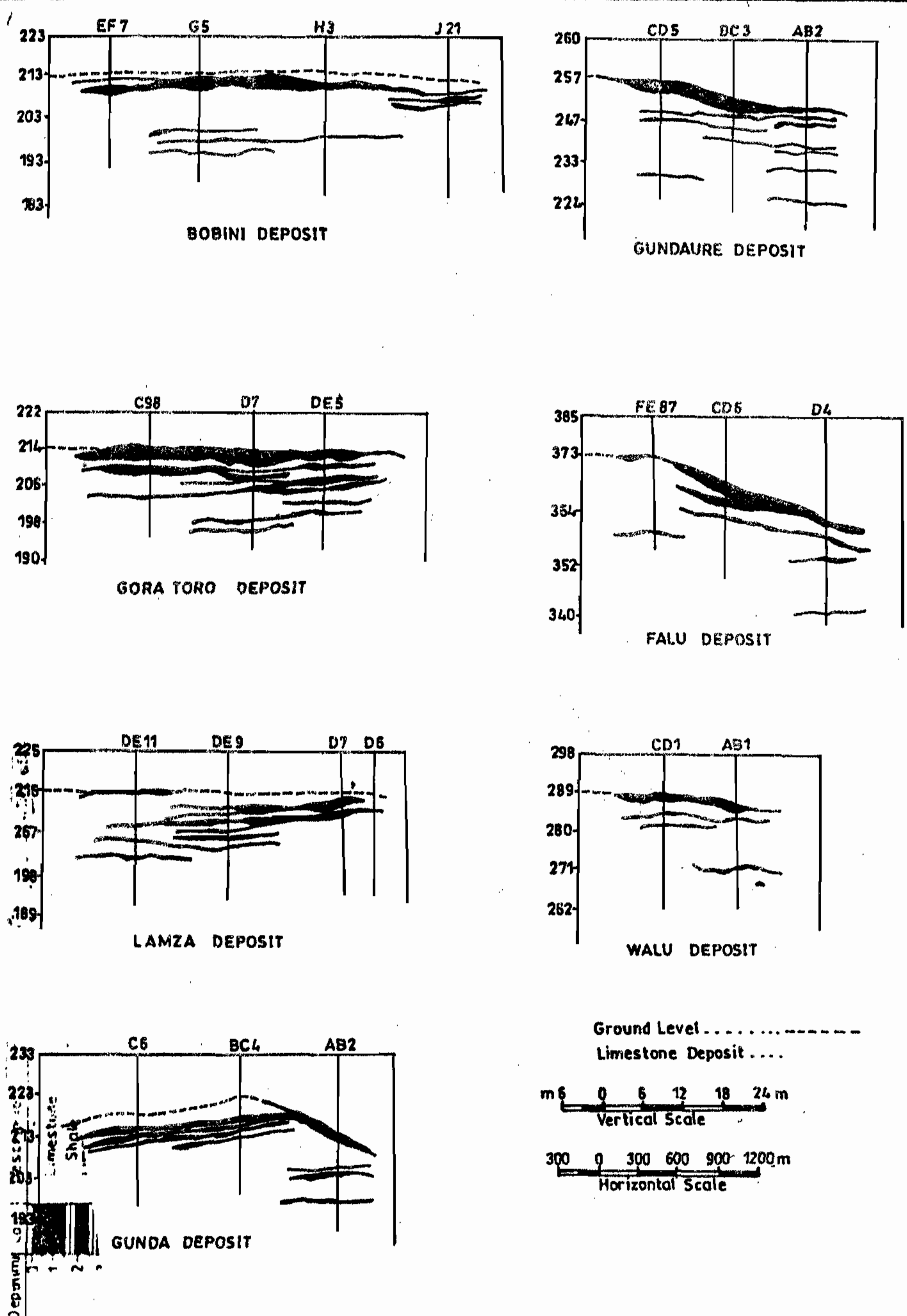

FIG. 3 : VERTICAL PROFILE THROUGH LIMESTONE DEPOSIT EXPLORATORY DRILL HOLES

(Courtesy: Tadco Nig. Ltd. Consulting Engineers)

K_2O) contents, generally less than 0.3%. Loss on ignition (LOI) values for the limestones range from 34.24% for Lamza samples to 38.55% for Gunda specimens.

DISCUSSION

Chemical composition of limestones in Guyuk area show that they have about 3.14 - 10.62% SiO_2 content. This appreciable silica can be attributed to presence of rock fragments, and quartz, which is usually interpreted as contamination in limestones (Mason, 1966; Greensmith, 1978; Taylor, 1996). However, the ca 6.66% silica content reflects a higher purity relative to the Ashaka(7.3%), Ngurore(12.8%) and Talum(8.8%) limestone deposits (Tadco, 1989). The low Al_2O_3 content of Guyuk deposit (2.95%) confirms it to be of higher purity compared to Talum and Ngurore samples with 6.56 and 6.78 percent respectively. Limestone units in these two areas occur as thin lamillae interbedded with thick shale beds (Tadco, 1989). Thus the higher Al_2O_3 content in the two deposits indicates

Table 3: COMPARATIVE CHEMICAL PARAMETERS OF GUYUK LIMESTONES AND DEPOSITS IN OTHER AREAS

Parameters	1	2	3	4	5	6	7	8	9	10
SiO_2	6.6	3.41	10.62	6.0	6.66	12.8	8.8	7.3	16.2	0.38
TiO_2	0.14	0.07	0.17	0.15	0.13	0.28	0.39	-	0.17	0.004
Al_2O_3	4.09	2.65	4.9	0.16	2.95	6.78	6.56	2.78	0.43	0.07
Fe_2O_3	3.76	2.27	3.95	3.65	3.57	0.32	7.95	1.18	12.5	0.1
MgO	259	2.01	1.68	2.82	2.28	0.00	1.01	-	26.88	0.3
CaO	43.11	48.29	43.89	46.27	45.39	43.46	39.56	47.77	8.78	54.87
Na_2O	0.12	0.08	0.13	0.08	0.1	0.08	0.09	-	-	0.03
K_2O	0.1	0.03	0.08	0.06	0.07	0.03	0.07	-	-	0.03
SO_4	0.47	0.12	0.64	0.13	0.34	1.48	1.55	-	-	-
LOI	35.69	38.55	34.24	37.85	36.58	33.45	32.38	38.66	32.05	-
Cement Production Ratio										
LSF	148.5	295.5	111.44	247.52	171.53	85.28	91.13	174.83	16.3	4294.2
Silica Ratio	0.78	0.69	1.2	1.57	1.02	1.8	0.61	1.84	1.3	2.4
Al-Fe Ratio	0.93	1.17	1.24	0.04	0.83	21.18	0.83	2.36	0.034	0.7
H M	2.86	5.8	2.25	4.72	3.44	2.18	1.7	4.24	0.31	99.76

1=Gundaure deposit; 2= Gunda deposit; 3=Lamza deposit; 4=Bobini deposit; Composite Guyuk limestone; 6=Ngurore deposit; 7=Talum deposit (Tadco, 1989); 8 = Ashaka deposit (Tadco, 1989); 9 = Guyuk limestone (Gabako and Tedra, 1994); 10 = Mfamosing limestone (Ekwueme,1985)

$$\text{Limestone saturation factor (LSF)} = \frac{100\,(CaO\% + 0.75\,MgO)}{2.8\,SiO_2\% + 2.2\,Al_2O_3 + 0.65\,Fe_2O_3\%}$$

$$\text{Silica Ratio (SR)} = \frac{SiO_2\%}{Al_2O_3\% + Fe_2O_3\%}$$

$$\text{Alumina – Iron Ratio (Al-Fe)} = \frac{Al_2O_3\%}{Fe_2O_3\%}$$

$$\text{Hydraulic Modulus(HM)} = \frac{CaO\%}{SiO_2 + Al_2O_3\% + Fe_2O_3\%}$$

possible contamination by materials of shaly composition. Majority of the studied samples, especially those from Bobini, Gunda and Gundaure areas contain notable quantities of dolomite. The appreciable magnesia content (>1%) in most of the samples (Table 2) is attributable to presence of this mineral within the fossil shells in the rock (Pettijohn, 1975). This appropriates the rocks as magnesian limestones (Greensmith,1978) or high magnesium limestones (Krauskopf,1979). The average lime content (ca 45.39%) appropriates the deposits as limestones of moderate quality. The Gabako Tedra's (1994) chemical data on Gora Toro/Bobini limestones were re-examined in the light of the present data on subsurface (insitu) outcrops. On the basis of their result, the authors had opined that the limestones do not conform with acceptable standards for cement manufacture. Their samples, which were 'chipped from the numerous boulders' of shelly limestones exposed in the area, are enriched in MgO(20.89 – 30.32%), Fe_2O_3(8.57 – 23.2%) and SiO_2(7.13 – 22.31%); and poor in CaO(1.31 – 19.69%) and Al_2O_3(0.22 – 0.54%). The sampling, restricted to 'only surface boulders', was deficient, thus affected the results. The appreciable mean concentrations of impurities (Table 3) indicate serious contamination by quartz and shaly materials (Greensmith,1978) and weathering. It is believed that the intense weathering and erosion of the fossiliferous boulders caused metasomatic alteration which is responsible for the very high MgO (ave. 26.88%) and Fe_2O_3 (12.5%) contents.

INDUSTRIAL QUALITY

Limestone is a versatile raw material as it belongs to various groups on the basis of usage and value. The soft and coral-rich varieties can be used in construction industry as low grade aggregates. High purity limestone is used in the metal and foundry industry for oxygen steel making and as flux for reduction of iron ore (Mason,1966; Anderson and Vernon,1971). In the glass industry, a specification of $CaCO_3$ >98.5%, Fe <0.035% and very low organic matter content <0.1% is required for the production of colourless glass (Abaa et al,1989). In the chemical industry, limestone (with 95% CaO, 1% SiO_2, MgO < 1.5% and LOI<3%) is used for production of lime for steel industry (Anderson and Vernon,1971; Boynton,1980). It can also be mixed with rock salt in solvay process to produce soda-ash used in fertilizer manufacture (Scott,1984). Pulverised and calcined limestone is used in consumer and industrial products as extender and asphalt filler in plastics, paint (white wash), paper and putty (Knill,1978; Scott,1984). In the cement industry, limestone (not necessarily of high quality) is one major component mixed with shale and clay in correct proportions (Adediran et al,1989; Agbazue,1992).

Chemical parameters are useful in assessment of appropriate specifications for different industrial uses of available deposits. Suitable composition can be obtained in a single deposit or by blending samples from different deposits. Generally, limestones of high chemical purity are required for the various applications mentioned above. In addition, the materials must exhibit high strength, white powder colour and contain MgO content less than 3% (Knill,1978). Scott (1984) posits that without any two of these properties limestone would have limited usefulness. For Guyuk limestone, a blend of the four major deposits (Dukul, Bobini, Gunda and Lamza) with varying chemical contents would give a good raw material composition. The mean chemical composition [CaO ca 45.39%, alkalies ca 0.17%, magnesia ca 2.28%; limestone saturation factor (LSF) ca 171.53 and hydraulic modulus ca 3.4] of limestones in the study area indicate a raw material of middle purity suitable for cement production. This negates the submission by Gabako and Tedra (1994) that Guyuk limestones do not meet requirements for cement manufacture. Acceptable specifications for cement raw materials are MgO <3%, alkalies ($Na_2O + K_2O$) < 1%, LSF > 90 (Scott, 1984); hydraulic modulus between 1.7-2.2 (Ekwere, 1992) and moderate CaO content of ca 30-50% (Lamar, 1961; Agbazue,1992). The low CaO and high silica contents and significantly high LOI in Guyuk deposits render them unsuitable for use in chemical and consumer products industries. These industries require limestones of high purity. On the basis of the mode of occurrence of the studied deposits (given by the vertical profile sections in Fig 3) to a depth of 10 metres, an indicated reserve estimate of 72,997,799 metric tonnes was calculated for the surveyed areas (Tadco,1989). Thus, a cement manufacturing factory in Guyuk area is viable.

CONCLUSIONS

Large deposits of limestones occur within the Cretaceous sediments in Guyuk area. Three lithofacies (the crystalline, shelly and bioclastic types) are mappable in the area. Chemical data indicate that the limestones are of moderate quality, with ca 45% of lime, 6.6% silica and relatively high amounts of alumina (3.25%) and iron oxide (3.99%). Their chemical compositions, viewed against specifications for various industrial applications, make them suitable for use in portland cement manufacture. Further studies on their properties to determine possible usage as aggregates for construction and fertilizer production is in progress.

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