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THE GEOCHEMICAL CHARARATERISTICS OF THE MARBLE DEPOSITS EAST OF FEDERAL CAPITAL TERRITORY (FCT), NIGERIA.

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ABSTRACT

The geology, petrography and geochemistry of the Federal Capital Territory (FCT), marbles were investigated with the view to establishing marble occurrences and their geochemical characteristics. Crystalline rocks of the Nigerian Basement Complex (migmatite – gneiss complex) underlie the area. Ten marble bodies were mapped. The marbles are metasedimentary in origin and were deposited in a structurally controlled basin. They maintain a consistent NNE/SSW (N26° E – N35° E) strike similar to strikes of major regional structures. The marbles are interbedded with mica schist, which is suggestive of periodic variation during their depositional history. The marbles have fine (0.2 – 1.0mm) to medium (1.5 – 4.0mm) calcite and dolomite grains, and exhibit porphyroblastic texture. The calcite and dolomite grains are uniformly distributed and constitute 97.00 – 99.78% of the marbles. The carbonate grains are idiomorphic to subhedral with triple junctions at angles of 110° – 130°, which is suggestive of an equilibrium and stable environment of crystallization. The mineral paragenesis (hornblende – plagioclase – garnet – wollastonite – tremolite – silimanite – zircon – orthoclase – apatite) is suggestive of amphibolite facies of metamorphism to which the marble host rocks have been subjected. It is here suggested that the organic matter of the FCT marbles were destroyed during metamorphism resulting in the production of garnet, biotite and hornblende. The marbles are dolomitic (MgO, 16.05 – 21.65%) and have average Mg/Ca ratio of 2:3. The Na_2O and K_2O contents are low (0.053% and 0.007% respectively), which is suggestive of a shallow marine depositional environment for the initial limestone material. The environment was rich in Mg and Ca and the Mg co-precipitated with Ca due to poisoning effect of Mg on calcite. The initial environment of limestone precipitation was of moderate temperature, hypersaline with respect to Ca and Mg and precipitation was influenced by microbial activity. The associated MgO was, therefore, precipitatory in origin and not replacement during metamorphism.

KEY WORDS: marble, dolomitic, geochemistry, precipitatory and Abuja.

INTRODUCTION

The marbles of the Federal Capital Territory (FCT) are found in the eastern part of Kuje (Fig 1). The marble localities include Burum, Taka-Lafia, Dibe Fadama, Dibe Kassa, Kasada and Kusaki (Fig. 2).

The occurrence of marbles in this area was, first examined and studied at Burum (Burum East Deposit) and described as dolomitic (Trustwell, 1956). In early 1962, a reconnaissance map of the area to the west (Burum West Deposit) was prepared by Bell (1963), including a further deposit of approximately 365.8 metric tones. A total indicated reserves of 4,927,000 metric tones of marble was established for the Burum West and East Deposits after a drilling programme by the Geological Survey of Nigeria in 1962 (MacLeod, 1963).

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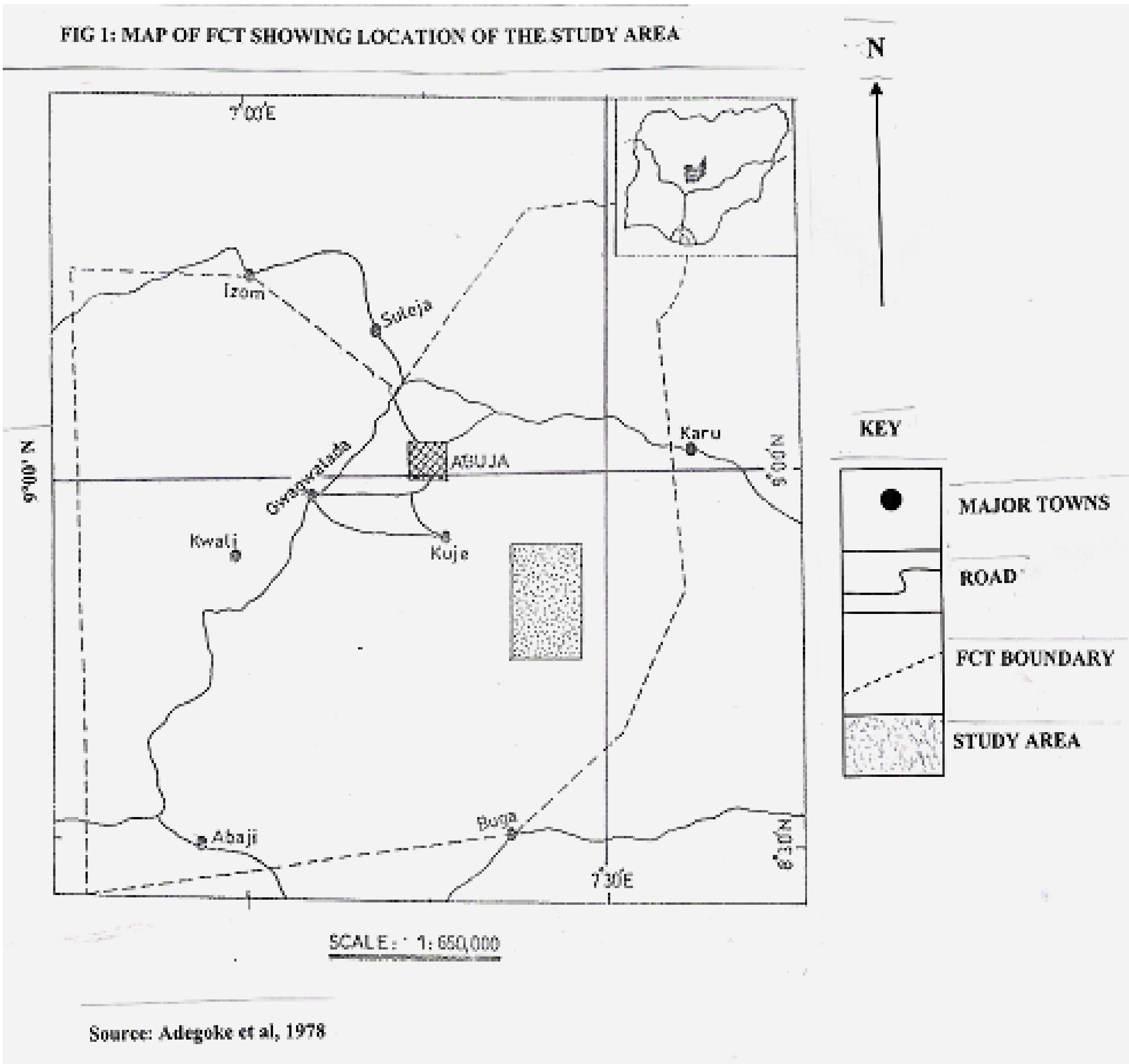

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FIG 1: MAP OF FCT SHOWING LOCATION OF THE STUDY AREA
Source Adegoke et al, 1978

Beltaro, (1968) carried out an investigation of an area south of Burum and found additional five more deposits – Taka – Lafia East and West, Kasada and Kusaki North and South. He found that all the deposits have similar chemical compositions (55.7, $CaCO_3$ and 38.2%, $MgCO_3$). In 1978, geological teams from Ahmadu Bello University, Zaria and Obafemi Awolowo University, Ile-Ife carried out the geoscientific investigations of the FCT. Both institutions described various petrologic units, but restricted the geochemical study to that earlier described by MacLeod (1963) and Baltaro (1968).

Danladi, (1993) carried out geological and compositional studies of the Burum (FCT) and Kwakiuti (Niger State) marbles. He considered the Burum marble as dolomitic (52.08% $CaCO_3$ and 20.13% Mg CO_3) and consisting of 98 - 99% by volume of calcite and dolomite. Ogunlowo and Amadi (1991a and b) also carried out engineering, chemical, mineralogical and geological investigations on the Burum East dolomite deposits.

Nigeria has two types of carbonate mineralization: - the younger unmetamorphosed limestones found in Cretaceous to Recent sediments and the older metamorphosed crystalline limestone (marbles) found in Pre-Cambrian metasediments.

The dolomitic nature of limestones is restricted to the crystalline limestones (marbles). The absence of dolomite in recently formed limestone has led to a general conclusion that the presence of dolomite in marbles is by the replacement of Ca by Mg during metamorphism. However, the occurrence of MgO in marbles is still a controversial issue – the “Dolomite Problem”. The discovery of dolomite in recently formed carbonates by Vasconcelos and McKenzie (1997) has added a new dimension to this controversy. Therefore, it is in line with this that the present research was carried out to determine the geochemical characteristics of the FCT marbles. This was achieved through an integrated study by the authors, on the geology, petrography and major oxides geochemistry of the marbles.

GEOLOGY AND PETROGRAPHY

The study area is located in the southern part of the Eastern Province of the Nigeria Basement Complex (Rahaman and Ocan, 1978). The area is underlain by migmatite-gneiss complex that forms the main petrographic frame work, while the remaining petrologic units (intrusive granite, supracrustal rocks and other minor intrusions) were later emplaced as intrusions, dykes, intercalations or veins. Most of the rock formations, structures and drainages have a predominant NNE - SSW trending direction corresponding to the regional strike.

Four of the five groups of rocks that make up the Nigerian Basement Complex are present in the study area. These groups in their ascending geochronology include:

iv. Small rock units and minor intrusions consisting of pegmatite, dolerite, quartz and basaltic dykes.

iii. The metamorphosed supracrustal rocks, consisting of schists, quartzites and marbles.

ii. The intrusive granite

i. The migmatite complex consists of migmatite, migmatite - gneiss and granite - gneiss.

Ten (10) marble deposits were mapped within the study area (Fig. 2) and are designated as Burum North (DBN), Burum West (DBW), Burum East (DBE), Taka-Lafia East (DTE), Taka-Lafia West (DTW), Kusaki North (DKN), Kusaki South (DKS), Dibe North (DDN), Dibe South (DDS) and Kasada (DKD). These are three deposits more than Baltero's (1968) findings and one deposit more than Kogbe's (1978) findings. This may suggest the possibility of other undiscovered occurrences of marble deposits elsewhere in the area probably covered by superficial materials. The marble bodies are found as narrow discontinuous, lensoid bodies and maintain a consistent NNE - SSW direction (N34°E – N40°E). They have sharp contacts with the surrounding mica schist (Fig.3 and 4), about 10 – 50m thick and characterized by a brown woody texture.

The marbles have weak foliation and in some places interbedded with mica schist (Taka-Lafia). The Burum marble deposits are associated with discontinuous amphibolite and pegmatite dykes (Fig. 4) while the Kusaki area is characterized by their association with quartzites. The similarities in their affinity for the structural fabric of the basement metasedimentary sequences (i.e. occurring in linear structurally controlled-features) is suggestive of a common origin. Structural plots of joints in rose diagrams revealed two major trends, a predominant NNE - SSW and a minor ESE - WNW while foliations are all trending in the NNE – SSW direction. According to Kogbe (1978), these two major preferred orientations are inferred to correspond to two major tectonic events that have affected the area during metamorphism.

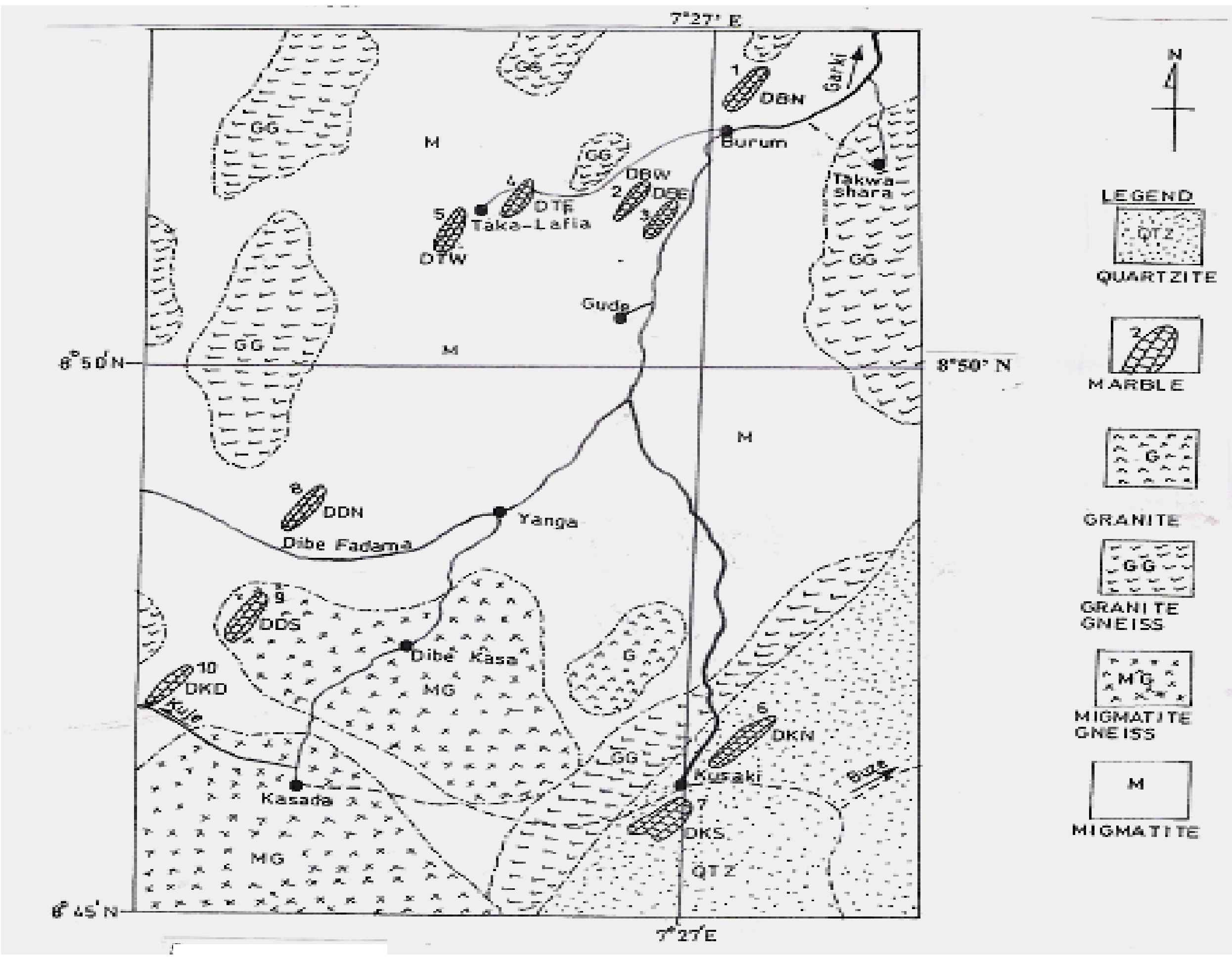

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FIG 2: GEOLOGY OF THE STUDY AND MABLE LOCATION
(Source: This Study)

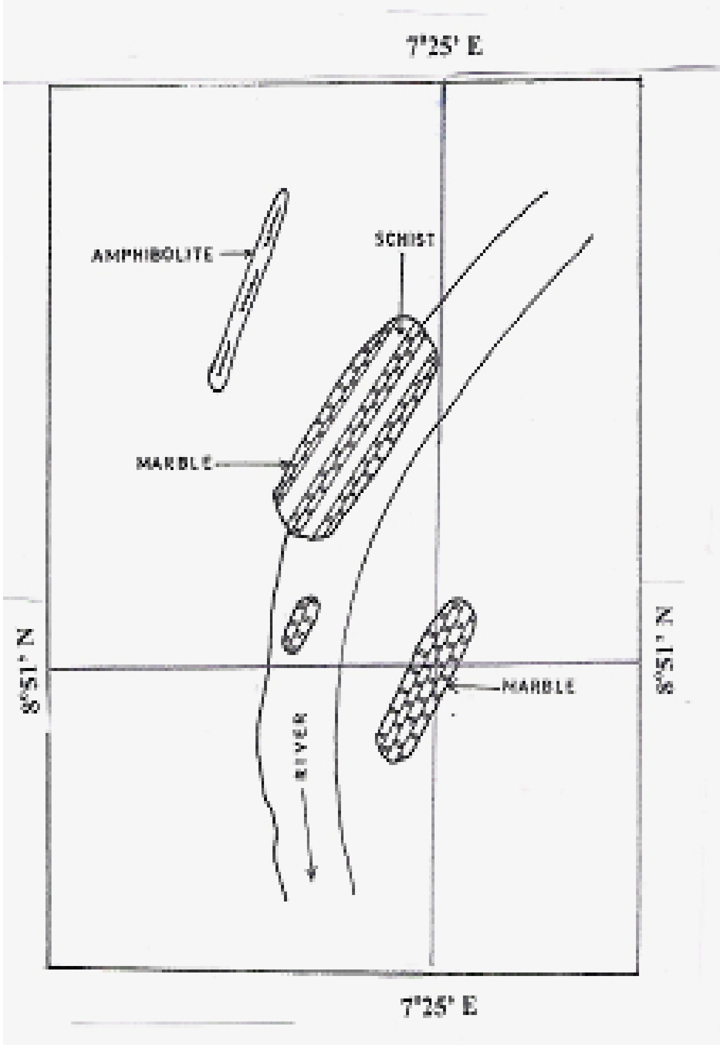

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FIG 3: A SKETCH OF MARBLE INTERBEDDED WITH MICA SHIST AT TAKA- LAFIA WEST MARBLE DEPOSIT (Source: This Study)

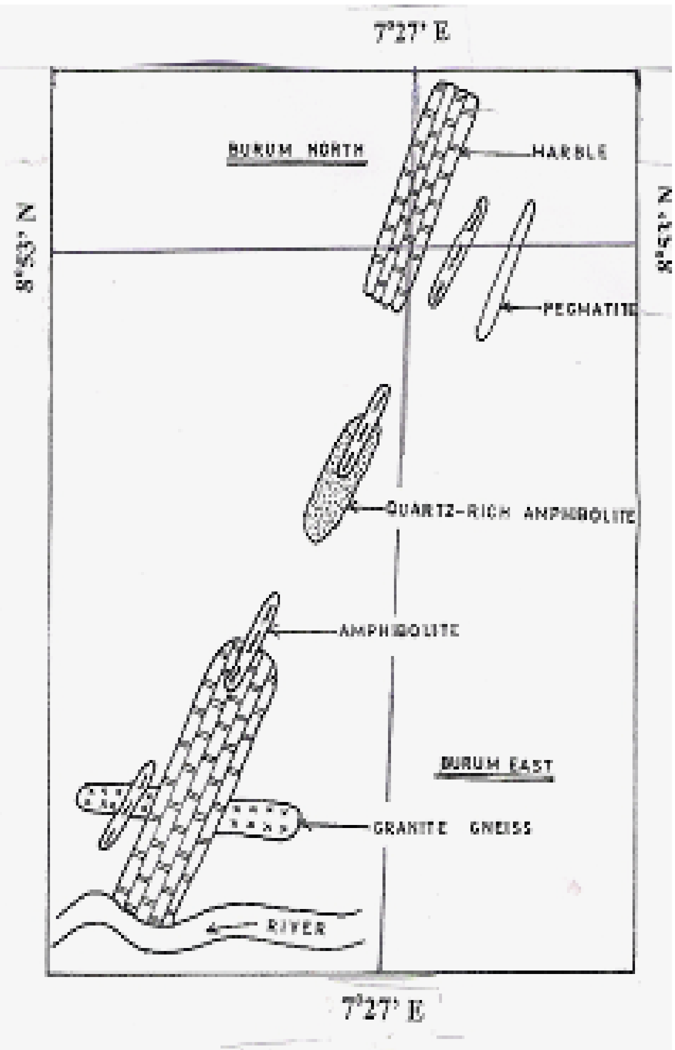

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FIG 4: A SKETCH OF BURUM MARBLE SHOWING DISCONTINUOUS AMPHIBOLITE & PEGMATITE (Source: This Study)

The earlier tectonic event is associated with the emplacement of major rock types like mica schist and marbles while the second event is probably associated with the later deformations of these rocks during the process of migmatisation.

Six marble samples and four other rock types were examined in thin- sections. The mineral paragenesis (hornblende-plagioclase – garnet – wollastonite – tremolite – sillimanite – zircon – orthoclase) of the marbles and the surrounding host rocks suggest an amphibolite facies of metamorphism to which the marbles have been subjected.

The marbles are fine (0.3mm – 1.0mm) to medium (1.5mm – 4.0mm) grained and, therefore, exhibit porphyroblastic texture (Fig. 5). The mineralogy is predominantly of homogeneous calcite and dolomite grains, ranging from 60% - 99% with impurities of hornblende, biotite, and zircon, in an approximate modal compositional range of 12% – 40%. The modal compositions of some selected marble samples are presented in Table1.

Petrography reveals two groups of marbles corresponding to their lithological affinities. The first group (Kusaki marbles) are associated with quartzite and intersected by basaltic dykes and 'transform' like faulting. The second group (Burum, Taka-Lafia, Dibe and Kasada) are associated with mica-schists. The later has estimated total carbonate percentage of 97% to 99%, while the former has 60%.

Similarly, the marbles which are associated with mica schists have a wide range of grain sizes (0.2mm – 4.0mm) with equilibrium triple junctions between 115° – 125° while those associated with quartzite are finer (0.2mm – 1.8mm) with equilibrium triple junctions between 110° – 130°. This implies that the marbles associated with mica-schist would have crystallized under a more stable condition and the other mineralogical compositions are not greatly influenced by the surrounding host rocks. Thin sections of the marbles show large crystals of calcite and dolomite and some "late formed" interstitial biotites with occasional garnets and amphiboles as minor constituents, (Fig. 5) and Table1.

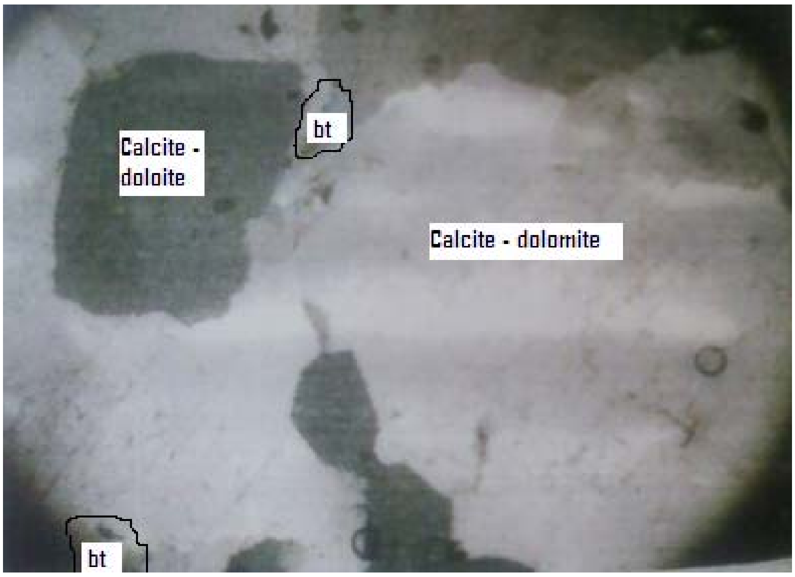


Fig. 5 Photomicrograph of Dibe South Marble (DDS) showing porphyroblastic texture with traces of interstitial biotite with preferred orientation (x 70)
bt = biotite. Source: present study.

Table 1: Estimates of Modal Composition of some selected Marble Samples, using a Petrographic Microscope.

SampleNumber	Location	Description	Modal Composition (%)						
			Calcite + dolomite	Biotite	Amphiboles	Ortho Clase	Zircon	Garnet	Total
DBN	Burum North	Marble	97.5	2.0	-	-	-	0.5	100
DKN	Kusaki North	Marble	60.0	35.0	3.5	1.0	0.5	-	100
DDS	Dibe South	Marble	98.0	1.5	0.5	-	-	-	100
DTE	Taka-Lafia East	Marble	98.0	2.0	-	-	-	-	100
DBE	Burum East	Marble	99.0	1.0	-	-	-	-	100

- = Nil
Source: Present Study

GEOCHEMICAL ANALYSIS

Ten samples, made up of representative samples from each of the marble outcrops, were selected, prepared and analyzed for major and minor oxides. The samples were first pulverized to very fine powder and then pellitized for an X – Ray Fluorescence analysis at the Chemical Laboratory of the then Nigerian Mining Corporation, Jos.

Analysis was made for SiO_2, CaO, MgO, Fe_2O_3, MnO_2, TiO_2, Al_2O_3, Na_2O and K_2O, while loss on ignition (L.O.I) was determined by igniting pulverized samples in a furnace. Standards were used for quality control purposes.

RESULTS AND DISCUSSION

The analytical results are presented in Table 2. The validity of these analytical results were ascertained by comparing the result with those carried out by Macleod (1963), Beltaro (1968), and Danladi (1993). All the analytical results show similarities in compositions.

Table 2: Analytical Result of Major Oxides (in Wt. %) of the FCT Marbles.

S/No	SAMPIE No	S.G.	LOI	SiO_2	CaO	MgO	Fe_2O_3	Al_2O_3	TiO_2	K_2O	Na_2O	MnO	P_2O_5	TOTAL
1	DBN	2.80	44.95	1.50	29.82	21.20	0.02	1.42	0.06	0.003	0.06	0.040	*ND	99.07
2	DBW	2.81	44.82	1.29	30.44	21.65	0.09	1.26	0.08	0.006	0.04	0.005	0.01	99.68
3	DBE	2.81	45.60	1.00	31.54	20.21	0.08	1.23	0.08	0.007	0.03	0.005	0.01	99.79
4	DTW	2.82	44.35	3.30	30.54	20.21	0.02	0.04	0.13	0.010	0.05	0.007	0.001	99.00
5	DTE	2.83	44.34	3.42	30.51	19.85	0.03	0.05	0.90	0.008	0.06	0.005	0.02	99.53
6	DKN	2.85	31.70	13.40	31.23	16.02	0.04	0.09	0.06	0.010	0.07	0.009	*ND	99.54
7	DKS	2.82	42.25	3.40	36.33	18.35	0.03	0.70	0.07	0.009	0.08	1.006	*ND	99.61
8	DDN	2.81	5.35	39.20	34.18	1.77	0.35	31.09	0.46	1.120	1.41	0.014	*ND	98.59
9	DDS	2.83	44.85	2.90	17.83	19.96	0.05	0.18	0.08	0.006	0.05	0.008	0.19	99.12
10	DKD	2.80	44.90	2.40	30.85	18.98	0.03	2.31	0.13	0.005	0.04	0.008	0.03	99.68
	AVER.	2.82	44.09	2.40	31.82	19.60	0.04	0.92	0.01	0.007	0.05	0.009	0.045	99.27

*ND: not detected. Total Fe as Fe_2O_3 Samples 1 – 7 & 9 – 10 = Marble and Sample 8 = host rock.

The compositional similarity of the analytical results indicate that the marbles have overall similar chemical characteristic with minor variations. The sample DDN with enhanced values of SiO_2 (39.20%), Al_2O_3 (31.09%), K_2O (1.12%) and Na_20 (1.41%) and very low L.O.I (5.35%), CaO (17.83%) and MgO (1.77%) is a non carbonate material (host rock).

DKN and DKS have values of L.O.I (31.70% and 42.28% respectively) which is slightly lower when compared with the other samples. DKN and DKS hosted by quartzite, have very high SiO_2 contents (13.40% and 3.40% respectively).

The marbles have high MgO concentration with respect to CaO. MgO has an average value of 19.60% while CaO has an average value of 31.82% giving an average ratio of 2:3 respectively. The DKN and DKS have slightly higher values of CaO (36.33% and 34.18% respectively). These higher percentage values of CaO are compensated for by slightly low percentage values of L.O.I and MgO contents in the samples. The marbles have similar Fe_2O_3 concentrations, but, values of Al_2O_3 are slightly high in DBN, DBE, and DKD.

The total percentage contents of $MgCO_3$ and $CaCO_3$ when calculated is found to range from 94.76% - 99.62%, which are slightly than that estimated from petrographic investigations (60.00 – 98.00%), MacLeod (1963), Baltero (1968). The present investigation also shows that there is about 3 – 5% excess CaO and MgO contents over L.O.I.

Using the triangular diagram of $CaCO_3$ - $MgCO_3$ - Others adopted from Harker (1939) and Carr and Rooney (1983) (Fig. 6), the marbles fall into two subdivisions of the carbonate rocks. Samples DKS and DKN, which have $CaCO_3$ values of 61.00% and 64.84% respectively fall within the pure calcite - dolomite marble field while the remaining marbles, which have $CaCO_3$ values in the range of 53.22% - 56.29% fall within the pure dolomite marble field (Fig. 6). The plot of Na_2O/Al_2O_3 vs. K_2O/Al_2O_3 of Garrel and McKenzie (1971) shows that all the marbles fall within the field of sedimentary and metamorphic origin (Fig.7).

SiO_2

Silica varies widely within the marbles. It ranges from 1.00% to 13.40% (average value 2.4%). The variation diagram of SiO_2 vs. CaO (Fig. 8a) shows SiO_2 increasing with CaO. Other variation diagrams (Fig.8b to d) show similar relationships and grouping, except CaO vs. MgO, where the relationship is an inverse relationship.
The high SiO_2 concentrations in DKN and DKS may reflect contamination from the surrounding quartzites.

CaO and MgO

The marbles have low concentration levels of CaO ranging from 29.82% to 36.33%, while the MgO value is relatively high (16.02% 21.65%), making the marbles dolomitic. The variation diagram of CaO vs. MgO (Fig. 8b) shows an inverse relationship.

Na_2O and K_2O

The concentration levels of Na_2O and K_2O in the marbles are very low, falling in the range of 0.03 – 0.08% and 0.003 – 0,010% respectively. According to Clarke (1911), Na and K concentration in marbles tend to decrease with increase in salinity, but tend to increase with depth. Hence, the environment of the deposition of the original materials that were metamorphosed to marble must have been a shallow, highly saline environment.

TiO_2 and P_2O_5

The marbles also have very low TiO_2 and P_2O_5 concentrations. TiO_2 has a range of values from 0.06 – 0.13% while P_2O_5 ranges from not detectable – 0.045%. The low content of Ti and P is probably due to the significant difference in their ionic potentials. Mason (1966) explained that elements with similar ionic potentials precipitate together during sedimentation. Hence, Ca and Mg on the one hand, and Ti and Mn on the other hand may precipitate together respectively. In the same vein therefore, the depletion of one of these elements in a sedimentary environment may be accompanied by the depletion of the other. Thus, Mn, Ti and P are not expected to be in abundance in the carbonate rocks consisting largely of Ca and Mg. In this case Mn, Ti and P will not co-precipitate with Ca and Mg during the sedimentary phase. Similarly, the same Mn, Ti and P will not replace Ca and Mg during metamorphism.

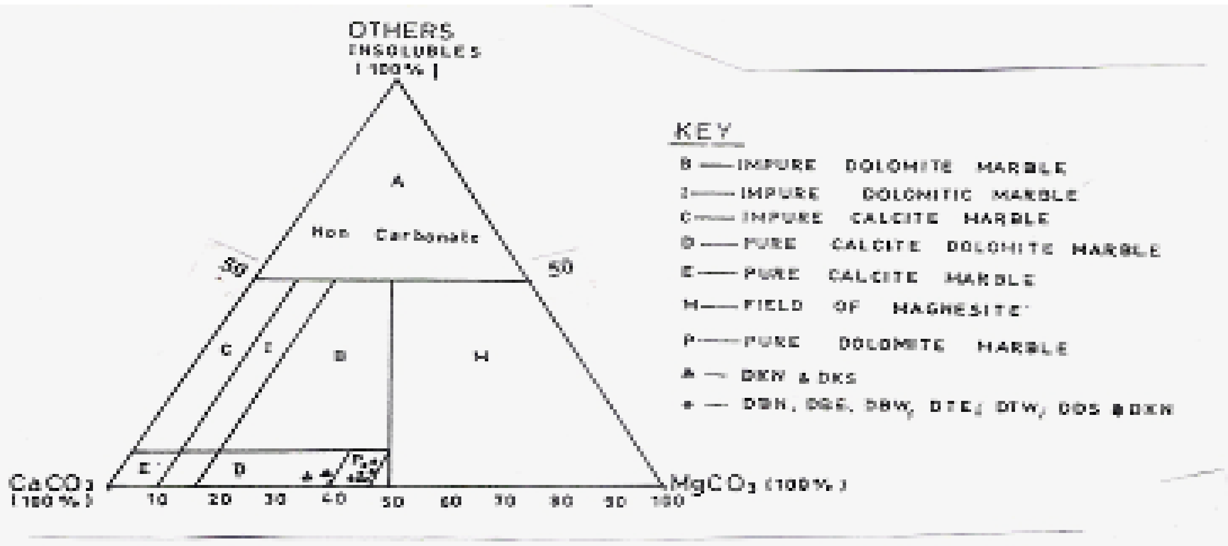


FIG 6: CLASSIFICATION OF THE FCT MARBLES
Source: Harker, 1950; whitten &Brook, 1972 and Carr & Rooney, 1983

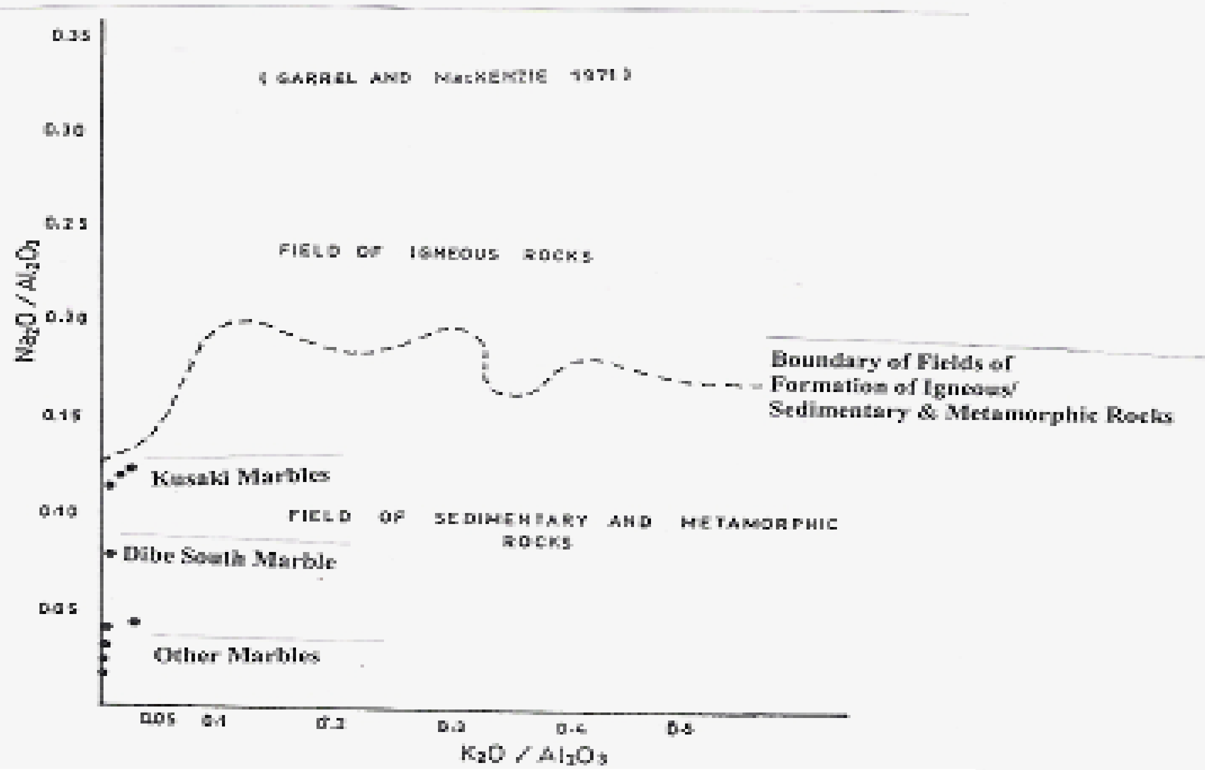
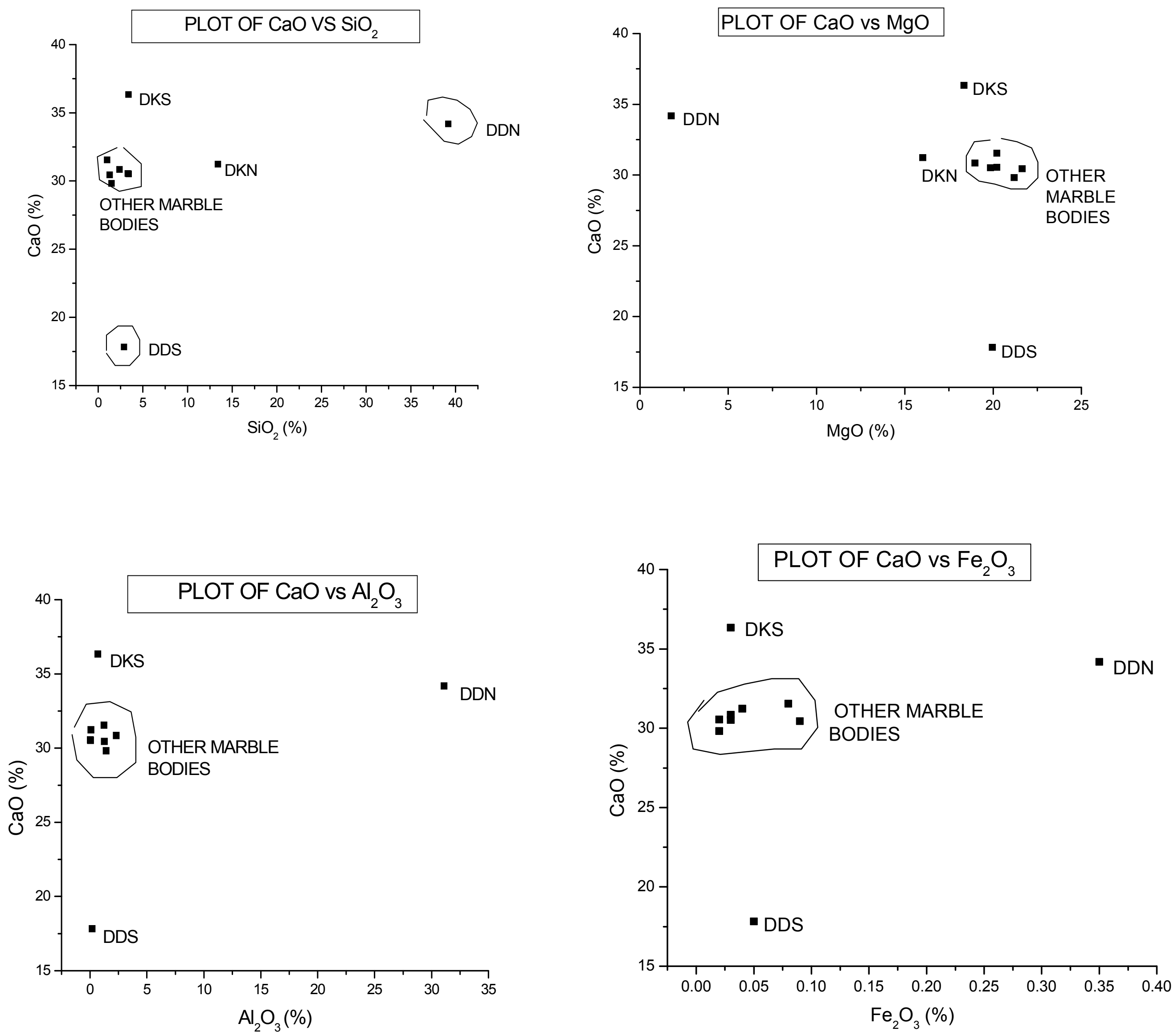


FIG 7: DETERMINATION OF FIELD OF FORMATION OF THE INITIAL LIMESTONE
(After Carrel and Mackenzie, 1971)



DDS = Dibe South Marble, DDN = Contact between Dibe north marble/surrounding quartzitic host rock, DKS = Kusaki south marble

FIG. 8: Major Element Variation Diagram of the FCT Marble Bodies. After Loubet and Lar (1999).

DISCUSSION

The plot of Na_2O/Al_2O_3 vs. K_2O/Al_2O_3, of Garrels and McKenzie (1971) shows that all the FCT marbles fall within the field of sedimentary/metamorphic rocks (Fig. 7). Thus, confirming the classification from field evidence and petrographic studies which show the crystallinity and the interbedding of the marbles with schist, a characteristic used in classifying them as metasedimentary in origin.

Clarke (1911) and Turekian and Wedepohl (1961) stated that carbonate rocks formed towards the deeper end of the marine environment could contain as high as 2 - 4% Na_2O. Thus, the low values of Na_2O (average 0.05%) of the FCT marbles would suggest a shallow, near shore, low energy “clean water” marine environment of deposition for the original carbonate material that was later metamorphosed to marbles during the Pan African Orogeny, as the marble are associated with basement rocks.

According to Rahaman (1976, and 1988), the association of carbonates and clastic materials and the almost total absence of volcanics, as is the case with FCT marbles, suggest that the environment of deposition was a miogeosynclinal environment.

The FCT marbles have high MgO/CaO ratio of 2:3. Folk (1974), noted that environments with high Mg/Ca ratio favours formation of dolomite and hinders calcite formation due to poisoning effect of Mg on calcite. This idea supports the homogeneity of the marbles as revealed by petrographic studies. This is an indication that the original environment was enriched in

Mg and dolomite is probably one of the initial mineral constituents of the limestone. In other words, the associated MgO was probably of precipitatory origin rather than replacement. However, McKenzie (1991) stated that dolomite, despite its thermodynamic stability and abundance in ancient rock records, are rarely found forming in Holocene environment. Oates (1933) investigated the limestone deposits of Tanganyika Territory and noted a gradual decrease in dolomite from the Pre - Cambrian marble to its total absence in recent limestones. Contrary to the aforementioned however, Clarke (1911) noted that during metamorphism of limestones, magnesium carbonate should produce dolomite. Lumsden and Lloyd (1997) grouped dolomites into three groups (A, B and O). The group A is typical of Holocene sediments, group B typical of lithified units and group O typical of evaporates. The characteristics of the marbles in the study area are similar to those of the Lumsden and Lloyd' (1997) group B.

Vasconcelos and McKenzie (1997) added another parameter (anoxic condition) in dolomitic carbonate studies. Their findings revealed that under anoxic condition Mg co-precipitates with Ca. This may bring the "dolomite problem" to an end. Although, Lumsden and Lloyd (1997) had recognized dolomite in Holocene sediments, while Vasconcelos and McKenzie (1997) discovered large modern dolomitic formation in Lagoa, Vermella, a shallow-water isolated coastal Lagoon east of Rio de Janeiro, Brazil. These findings led to the conclusion that the dolomite have formed as a result of microbial activity under anoxic condition. Lumsden and Lloyd (1997) noted an Mg/Ca ratio of 1:1 characterize high temperature dolomites and a ratio of 1:2 for low temperature dolomites. Thus, the FCT marbles with an Mg/Ca ratio of 2:3 would have probably formed under moderate temperatures.

Field geology reveals similarity of occurrences of all the marble deposits in association with mica schist. They maintain a consistent NNE/SSW orientation and they occur within narrow basins, which were probably initiated in structurally controlled depressions. The petrography and geochemical investigations confirmed these physical similarities.

The marbles are fine (0.3mm – 1.0mm) to medium (1.5mm – 4.0mm) grained, therefore, exhibit porphyroblastic texture. The mineralogy is predominantly that of homogeneous calcite - dolomite grains (geochemistry confirmed the presence of calcite and dolomite). The marbles associated with mica schist would have crystallized under a more stable condition (equilibrium triple junctions between 115^o – 125^o) than those associated with quartzite (equilibrium triple junctions between 110^o – 130^o)

CONCLUSION

From the ongoing discussion, it is clear that the initial limestones from which the FCT marbles were formed were deposited in a shallow, anoxic, hyper saline marine environment under moderate temperatures, with micro fauna and flora playing a vital role. The associated MgO is therefore, precipitatory in origin rather than metasomatic replacement.

Some of the FCT marble bodies show alternation with non carbonate material (mica-schist) and this is an indication that the process of deposition of the original limestone was affected by seasonal changes. The above statement is supported by a current research by the authors on an-ongoing limestone forming process in Jippal on the Jos Plateau. Also, in agreement with Holmes (1965), the organic materials may have been completely destroyed during metamorphism, as there is no evidence of pyrite and/or graphite which are likely derivatives from organic matter as is seen at the Jakura marble deposit, (Geological Survey of Nigeria, 1965). The dolomitic limestones must have undergone solid state recrystallization during metamorphism into dolomitic marble while silica reacted with carbonates to produce impurities such as garnet, biotite and hornblende as traces of these are seen in the FCT marbles.

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