Testing Pre-Cambrian Marble Bodies in the Oreke and Owa-Kajola Areas, North Central Nigeria for Multiple Industrial Applications

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Abstract
The Oreke and Owa-kajola marble deposit are closely associated with metasedimentary and granitoids assemblages of the Pre-Cambrian Egbe-Isanlu schist belt of Southwestern, Nigeria. The marble and the associating rocks are of Pre-Cambrian age. The physical properties and loss on ignition measurements of the Oreke and Owa-kajola marble deposits were determined to establish its suitability for end-product use. The loss on ignition values vary from low to high (6.00 wt% to 42.50 wt%). The internationally recommended loss on ignition (L.O.I.) value is around 40 wt%. The dolomitic marble is the only type at Oreke and Owa-kajola that fulfils the specifications for use as filler in paper and other industries. The chemical analysis of end products shows that CaO content varies from 10.17 to 56.01 wt%. Other impurities are Fe_2O_3 varies from <0.04 to 10.60 wt%, Al_2O_3 from 0.05 to 13.20 wt%, MgO from 0.73 to 18.45 wt%, and SiO_2 from 0.32 to 44.56 wt%. The bulk samples have shown satisfactory properties (good strength and bulk specific gravity values) corresponding with the requirements of dimensional stones used in the building industry. Oreke and Owa-kajola marble deposits could provide the domestic markets building industry but it might be difficult to supply for the international market because of acute competition from other world deposits.
Keywords: marble, Oreke and Owa-kajola, mineralogy, geochemistry, mechanical properties

1.0 INTRODUCTION

The marble located within Oreke and Owa-kajola area of North Central Nigeria is of the Precambrian, located within the Precambrian Basement Complex of Southwestern Nigeria and closely associated with the Metasedimentary and Granitoids Assemblages of the Pre-Cambrian Egbe-Isanlu schist belt of Southwestern, Nigeria (Table 1). The wide range of application of marble and associated lime-rich rocks especially in construction, recent upsurge in urban development and new opportunities in the solid minerals development has induced local as well as foreign entrepreneurs' to show a keen interest in the exploitation of marble deposits in Nigeria and what determines the suitability of a marble deposit for the production of cement and construction purposes is largely its physical and chemical characteristics, hence the justification of this study.

Several workers have worked extensively on various geological, structural, lithostratigraphic, petrological classifications and age determination of the Nigerian Basement Complex. Notable among them are Jones and Hockey, 1964, Oyawoye, 1967, Grant, 1970, Ajibade,1976. However, this study is directed to the economic evaluations of the marble deposit using the Physical and chemical characteristics.

2.0 GEOGRAPHIC LOCATION AND GEOMORPHOLOGY

The study area is a marble deposit with associated rocks at Owa-kajola and Oreke. Owa-kajola and Oreke towns are located within Ifelodun local government in Kwara state about 50km from Ilorin the state capital. The area lies between N 08^0 30" to N 08^0 15" and E 005^0 00" to E 005^0 13". The area is not too accessible by motorable road network; only minor roads link Oreke to Omu-aran another major town and Owa-kajola is even less accessible due to the undulating topography of the area. These areas are transverse by bush parts created by lumber jacks, farmers and herdsmen. So an inter-network of numerous footpath exist linking farms, villages and streams together, Fig. 1. Oreke and Owa-kajola belongs to the subequatorial climate zone, characterized by heavy rainfall and short dry seasons.

The mean annual rainfall is 1500mm and the mean annual relative humidity is about 80%.The mean annual temperature is about 26.6^{o}C (Emofurieta, (1984). Dentritic drainage pattern is prevalent in the area.

The study area is covered mainly by tall palm trees and grasses typical of rain forest vegetation. The vegetation is thick and has been greatly affected by human interference through farming, bush burning with the development of seasonal forests in some of the area.

3.0 REGIONAL GEOLOGICAL SETTING

The Pre-Cambrian basement complex of Nigeria lies between the West African Craton in the west and the Congo Craton in the east. The rocks of the basement complex of Nigeria are loosely categorized into three main groups which are;

The migmatite gneiss complex: The migmatite gneisses are the most abundant rocks of the basement complex. They are divided into two types. These are the biotite gneiss and banded gneiss (Falconer,1911)). Petrogenetic and field evidences (De Swardt, 1953) show that the migmatite gneiss originated through silica-potash metasomatism of ancient metagranulites mainly between 2.8-2.0 Ga. However older dates of about 3.0 Ga have been reported (Dada, Brique, and Birck, 1998) who believed that such relict signatures indicate that the Precambrian terrain was part of an archean proto-shield affected by proterozoic crustal activities. Field evidences and radiometric dating have shown that the Nigerian basement complex bears the imprints of the major Orogenies in the earth history dating back to 3000 Ma and it undergone its most pervasive deformation and remobilization during the Pan African (< 600 Ma, Table 1).

The schist belt : The schist belt occurs prominently within the western half of the country. Though a few have been recently highlighted in central and southeastern parts (Elueze, 1992). They are mostly regarded to be of Proterozoic age (0.6-2.5Ga). Various types and grades of schists occur in the basement complex. They include mica schists, phyllite and biotite schist. They form lowland between quartzite ridges and are rare as continuous massive outcrops. The schist belts, which some author classified as metasediments shows distinctive petrological, structural and metallogenic features. The schist belts in the southwestern part of Nigeria include Iseyin, igarra, Egbe-isanlu, ifewara-ilesha (Rahaman *et.al.* 1983, Elueze, 1992, Annor *et.al*, 1996).

The lokoja- Jakura belt (Okunlola, 2001) and the southeastern belts (Ekwueme, 1987) are the recently highlighted belts. Although there seems to be some lack of consensus on locational delineation, geologic nomenclature, geodynamic setting and geochronological characteristics. The schist belt is of metamorphosed pelitic and sandy assemblages. The schist belt is of particular interest in that it is associated with a widespread occurrence of marble deposits in Nigeria. It is dominated by low-grade metasediments remnants of supracrustal cover during the Pan-African orogeny (Mc Curry 1976).

The Pan-African granitic series and associated minor rocks**:** According to Rahaman, Emofurieta, and Caenachet, (1983) the older granites are the most visible part of the Pan-African orogeny in Nigeria. The older Granites were first distinguished from the younger or plateau tin-bearing alkalic granite (Falconer, 1911). They range in size from plutons to the environment in which the granite is emplaced. Circular to elliptical bodies occurs in schist environment and more elongate bodies in migmatite Gneiss terrains.

The older granites are the most obvious manifestation of the pan African Orogeny and constitute about 40- 50% of the basement complex outcrop. They include rocks of a wide range of composition including tonalities, granites, granodiorites, adamallites, quartz Monzonites, syenites, and pegmatites, granitic – granodioritic compositions are the most common texturally, they vary from strongly foliated gneiss varieties to undeformed rocks. Under the granitic granodioritic rocks, (Jones, and Hockey, 1964) recognized three main groups of granites, an early phase comprising granodiorites and quartz diorites, a main phase comprising homogenous granites, syenites and coarse porphyritic biotite granite and a late phase comprising homogenous granites, dykes, pegmatites, and aplite.

4.0 LOCAL GEOLOGICAL SETTING

The major rock units identified in Oreke and Owa-kajola Area include:
Marble, Banded gneiss, Granite gneiss, Schists,Granites, Quartzites, Pegmatites and quartz veins, (Figure 2)

5.0 MATERIALS AND METHODS

A reconnaissance survey where detail lithological description of the outcrop at each location, taking into consideration the color, texture, Field characteristics, prominent sedimentary structures and composition was conducted. A total of fourteen (14) marble samples were collected at different sampling points Figure 2. The samples collected were taken to laboratory for treatment and standard laboratory preparation prior to analysis and thin section preparation. Mineralogical analysis of major minerals was done using X-Ray Difractometer and Geochemical analysis of major oxides and trace elements was done using inductively coupled plasma mass spectrography (ICP-MS) carried out at ACME Laboratories in Canada.The thin section and physical test were equally prepared in a standard laboratory for petrographical and physical characteristics studies.

6.0 RESULTS AND DISCUSSION

6.1 MINERALOGY AND PETROGRAPHY

Three grams from each representative sample of each marble variety was taken for the X-ray diffraction runs (Table 2). They were put in a holder and pressed within a glass plate to the level of the rim, and then they were kept in a multiple holder. Samples pressed into the holder were run in a Siemens D5000 X-ray diffractometer using a Cu $K\alpha$ source.Table 2 summarizes the main mineralogical characteristics of Oreke and Owa-kajola marbles. It is evident that all samples are rich in calcite as the dominant carbonate mineral, in addition to a variety of minor and trace phases in five petrographic classes of the studied marble deposit. Common minerals, other than calcite, are represented by quartz, talc, hornblende, edenite, albite, muscovite, biotite, chlinochore, ahydrite and dolomite. Dolomite is very scarce in carbonate at the Oreke and Owa kajola marble deposit indicating that the precursor limestone prior to regional metamorphism was Mg poor.

The reduction of the marble purity is sometimes caused by the effect of the fluids that pass through areas rich in different minerals in an early stage of diagenesis. Calcium carbonate might be also impaired by the epigenetic mineralization and dolomitization. Some marble samples (L4,L5 and L6) have calcite crystals with perfect cleavage and hence they are considered as good products for sculpture because they reflect light in a shimmering pattern and make the sculpture material more attractive. Microscopic investigation of Oreke and Owa-Kajola samples revealed that two petrographic types of marble can be identified.

Such classification is based essentially on the modal abundance of carbonates and accessory minerals (either minor or trace), and these petrographic types are: pure white marble, (samples L2,L3 and L4), dolomitic marble (sample L5 and L6). The given petrographic subdivisions agree with the mineralogical composition indicated by XRD (Table 2, Figures 3 and 4).

6.2 GEOCHEMISTRY

Ten different varieties of the Oreke and Owa-Kajola were identified from representative samples analyzed by the Inductively Coupled Plasma Mass Spectrometry (ICP-MS). Qualitative and quantitative analyses were conducted for determining the major oxides and trace element of the powdered samples of marble. Results are given in Table 3. Table 3 shows Calcium Oxide as one of the major oxides because calcium is known to be abundant in carbonate rocks. Table 3 shows that sample No: 5 contains the highest CaO (56.01 wt%). The lowest CaO content is recorded in samples No:8 and 12 (~ 10.17–12.0 wt%). Both samples are siliceous and contains considerable silica content (~ 44.56 and 41.6 wt%) that increases at the expense of the CaO content. Silica content in sample No: 5 is also considerably high (25.09wt%). Highest MgO content in sample is connected to common dolomite which is an exceptional case for Oreke and Owa-Kajola. MgO content (18.45wt%) in the latter sample is relatively high although the rock is very poor in dolomite. This suggests possible ionic substitution of Mg2+ for Ca2+ in the calcite structure.

Dolomite, quartz, titanium, and iron minerals are quite likely to be present in samples 1,3,8,9,12 and 14 and that because of the high portion of the MgO, SiO2, TiO2, and Fe2O3 in these marbles. K2O only occurs in very small quantities in sample No: 4. Quartz or SiO2 is the most common mineral that contaminates the marbles. The highest SiO2 content is displayed by sample No: 8 (44.56 wt%). Generally, the identification of CaO, Fe2O3, MgO, and SiO2 is important to characterize the quality of the marble material. Iron and magnesium are admixed in the structural lattice of calcite as well as calc–silicate minerals. The theoretical composition of calcium carbonate is 56 wt% CaO and 44 wt% CO2. The CaO of the marble of Oreke and Owa-Kajola ranges from 10.17-56.01 wt% and the CO2 from 5.80 wt% to 43.50 wt%. Evaluating chemical purity is important when assessing the marble's suitability for some specific uses. For example, very high chemical purity is required for filler applications. On the other hand, marble is widely used as a dimensional stone despite containing large amounts of fine grains of some sulfides (*e.g.* finely disseminated pyrite or marcasite). According to data of Table 3, the chemical composition of most Oreke and Owa-Kajola marbles is not commercially suitable for uses other than a dimensional stone. The calcite content that has been calculated from the ICP-MS analysis shows that sample numbers 5 (Dolomitic marble), 7, 9 and 10 (White Marble) are the only sample that has more than 97% calcite. Therefore, it is the most suitable variety for use in the paint and plastic industry as filler.

6.3 PHYSICAL TESTS

The mechanical tests were carried out by compressing cylindrically shaped marble samples between two points in a broch franklin load-testing machine. The point load index was calculated as ratio of applied load to the square of distance between loading points. The compressive and shear strengths were further determined by converting the point load index using the conversion method.

Mechanical tests on the marble samples in Oreke show a bulk density of 0.144g/cm^3 while that of Owa-Kajola has 0.222g/cm^{3}According to the bulk specific gravity result it shows slight variations (0.144 and 0.222 g/cm3) (Table 5). That might relate to the presence of small closed porosities. The true specific gravity for pure calcite is considered to be 2.71 at 20 ^{o}C.

The result of the compressive strength of 1686 N/m^2 and 1672 N/m^2, shear strength of 1428N and 1531N respectively makes both suitable as support material in construction. This result demonstrates that the Oreke and Owa-Kajola marbles are not susceptible to mechanical and chemical weathering. Therefore, it is considered a suitable product for the building industry (Table 6).

7.0 Conclusion

The mineralogy and the petrography of the samples have been examined. Calcite is the major mineral in the marbles and quartz appears as the second common and minor mineral in almost all varieties of the Oreke and

Owa-Kajola marbles. Other minerals present are Muscovite, Talc Hornblende, Edenite and very rare dolomite. In the field, the recognized sample varieties are termed white, grey and dark grey to black marbles. Based on XRD analyses and petrographic investigation, the present authors were able to classify the Oreke and Owa-Kajola marble into two major petrographic types as follows: pure white marble and dolomitic marble. Mineralogical and Textural evidence suggest that dolomite is very scarce in carbonate at the Oreke and Owa kajola marble deposit indicating that the precursor limestone prior to regional metamorphism was Mg poor.

The bulk samples have shown satisfactory properties (good strength and bulk specific gravity values) corresponding with the requirements of dimensional stones used in the building industry. The Oreke and Owa-Kajola marble deposits could provide the domestic market building industry but it might be difficult to supply the international market because of acute competition from the other world deposits. The chemical analysis of end products shows that CaO content dominate .Other impurities areFe2O3, Al2O3, MgO, and SiO2. The results of chemical analysis of some samples, when compared to other commercial marble products are similar. The dolomitic marble is the only type of marble at the Oreke and Owa kajola marble that fulfils the specifications for use as filler in paper and other industries.

An overall economic evaluation shows that despite the slight compositional variation of the marble bodies, they are useful as cement raw material; steel fluxes, fillers and extenders in the manufacture of glass & carbonate based chemicals and are also suitable as road bases and ornamental stones. Agriculturally, it can be useful as a soil acidity ameliorant (pH values of 8.2). The addition of these rock materials independently to acid soils reveal a remarkable increase in soil pH, decrease in exchangeable acidity and aluminium content of soil which is capable of increasing crop yield as a result of neutralization of soil acidity.

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Table 1: Generalized Geochronology for the Basement Rocks of Nigeria (Mc Curry, P (1976)

	Period (or epoch)	Activity	Remarks
540+40	Late Pan-African	Uplift, cooling, faulting, high level magmatic activity	Gold Mineralisation rare-metal Pegmatite's
650-580	Pan African	Granitic intrusion, pegmatite and aplitic development	Older Granite Magmatism
650-850	(Main Phase)	Orogenesis: deformation, metamorphism, migmatisation and reactivation of pre-existing rocks	
800-1000	Katangan	Geosynclinal deposition, intrusion of hypersthene-bearing rocks	Katangan metasediments
1900±250	Eburnean	Granite intrusion Orogenesis: folding, metamorphism and reactivation of pre-existing rocks	Eburnean granites
2500	Birimian	Geosynclinal deposition	Birimian metasediments
2800±200?	Liberian Cycle?	Possible formation of banded gneiss complex near Ibadan and Ilorin	
>2800	Dahomeyan	Crystalline basement	

Table 2. Mineralogical characteristics of five marbles from oreke and owa-kajola

Petrographic Name	**Sample Number**	**Major**	**Minor**	**Trace**
Pure white Marble	L2	Calcite	Quartz-Muscovite	----
	L3	Calcite	Quartz-Muscovite	----
	L4	Calcite	Quartz	----
Dolomitic Marble	L5	Calcite	Dolomite	Talc-Hornblende
	L6	Dolomite	Calcite	Edenite-Hornblende

Table 3. Icp-ms analyses of oreke and owa-kajola marbles

S/N	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	Cr_2O_3	LOI	Sum
1.	9.57	0.06	0.06	18.27	32.42	0.01	0.01	0.05	0.01	0.01	0.002	39.2	99.67
3.	9.93	0.07	0.06	18.45	32.80	0.01	0.01	0.04	0.02	0.01	0.002	38.3	99.69
4.	25.09	2.95	0.05	0.73	38.87	0.40	1.21	0.02	0.04	0.01	0.002	30.6	99.94
5.	0.32	0.05	<0.04	1.00	56.01	0.01	0.01	0.01	0.01	0.01	0.02	42.5	99.88
7.	0.39	0.07	0.05	1.02	55.87	0.01	0.01	0.01	0.01	0.01	0.002	42.5	99.93
8.	44.56	13.20	13.26	7.29	10.17	3.32	0.37	2.81	0.35	0.16	0.021	4.2	99.74
9.	0.75	0.05	0.04	2.00	54.83	0.01	0.01	0.01	0.01	0.01	0.02	42.5	99.93
10.	5.80	1.32	0.60	1.11	49.54	0.31	0.34	0.15	0.07	0.02	0.002	40.4	99.64
12.	41.86	13.07	10.60	11.22	12.08	2.58	0.98	1.08	0.10	0.11	0.041	6.0	99.73
14.	14.11	3.33	1.20	2.99	42.64	0.46	0.89	0.26	0.07	0.02	0.003	33.6	99.62

Table 4 analytical data of other comparable marbles

Oxide	1	2	3	4	A	B
SiO_2	0.43	3.81	1.18	-	9.57	9.93
TiO_2	0.01	0.17			0.05	0.04
Al_2O_3	0.06	0.16	0.08	0.02	0.06	0.07
Fe_2O_3	0.02	0.15	0.07	0.06	0.06	0.06
FeO	0.02	0.01				
MnO	0.03	0.01	0.03	0.03	0.01	0.01
MgO	0.58	20.75	1.75	26.85	18.27	18.45
CaO	54.17	31.0	53.64	38.28	32.42	32.80
Na_2O	0.03	0.05	0.01	0.03	0.01	0.01
K_2O	0.06	0.12	0.02	0.01	<0.01	<0.01
P_2O_5		0.03			0.01	0.02
LOI	43.81	43.56			39.2	38.3
Total	99.87	99.88				
$CaCO_3$			95.72	97.0		
$MgCO_3$			3.64			

1: Jakura marble Elueze, and Okunlola, 2003)
2: Burum marble (Elueze and Okunlola 2003)
3 : Ososo marble (Emofurieta, and Ekuajemi 1995)
4: Sharpfell marble (Dowrie et al, 1982) A: Owa-kajola marble (This study) B: Oreke marble (This study)

Table 5 showing physical (mechanical) properties of oreke and owa- kajola marble

Properties / description	Oreke	Owa-kajola
Na	0.435Cmol/kg	0.500Cmol/kg
Ca	178.643Cmol/kg	178.500Cmol/kg
Mg	7.294Cmol/kg	8.124Cmol/kg
K	0.038Cmol/kg	0.035Cmol/kg
pH	8.2	8.2
Porosity	94.57%	95.12%
Bulk density	0.144g/cm3	0.222g/cm3
Specific gravity	1.1957	2.5000
Loss on ignition	3.26%	3.40%
NH_4 content	0.038%	0.032%
Shear strength	1428N	1531N
Compressive strength	1686N/m2	1672N/m2
Hardness	3.0	3.1
Ex acidity	0.15	0.16
Cation exchange ratio	186.56	185.01

Table 6 physical properties of other comparable marble samples

Physical Properties	1	2	3	4	5	6	7
Apparent Porosity	0.68	0.65	0.65	-	-	0.68	0.68
Hardness	3.0	3.0	3.0	3.0	-	3.0	3.0
Bulk density	2.67	2.65	-	2.65	2.61	--	-
Compressive Strength	92.83	95.52	90.81	90.81	-	88.2	-
pH	8.3	8.5	8.1	8.35	8.6	8.5	
Specific gravity	2.70	2.70	2.71	2.73	2.75	2.67	2.73
C-E-C	-	-	-	-	-	-	-
Oil absorption ml/cc	18	18	19.20	18.40		18.71	20.15
LOI	42.01%	-	-	-	-	-	-

1: Burum marble (Elueze, and Okunlola, 2003) 2: Jakura marble (Elueze, and Okunlola, 2003)
3: Sharpfell marble (Dowrie, and John,1982) 4: Cheetor marble (Scott, and Dunham,1984)
5: Ososo marble (Emofurieta, and Ekuajemi 1995)
6: British whitening (Muotoh, Oluyide, Okoro, and Muogbo, 1998)
7: Indian marble (Ofulume, A.B (1991)

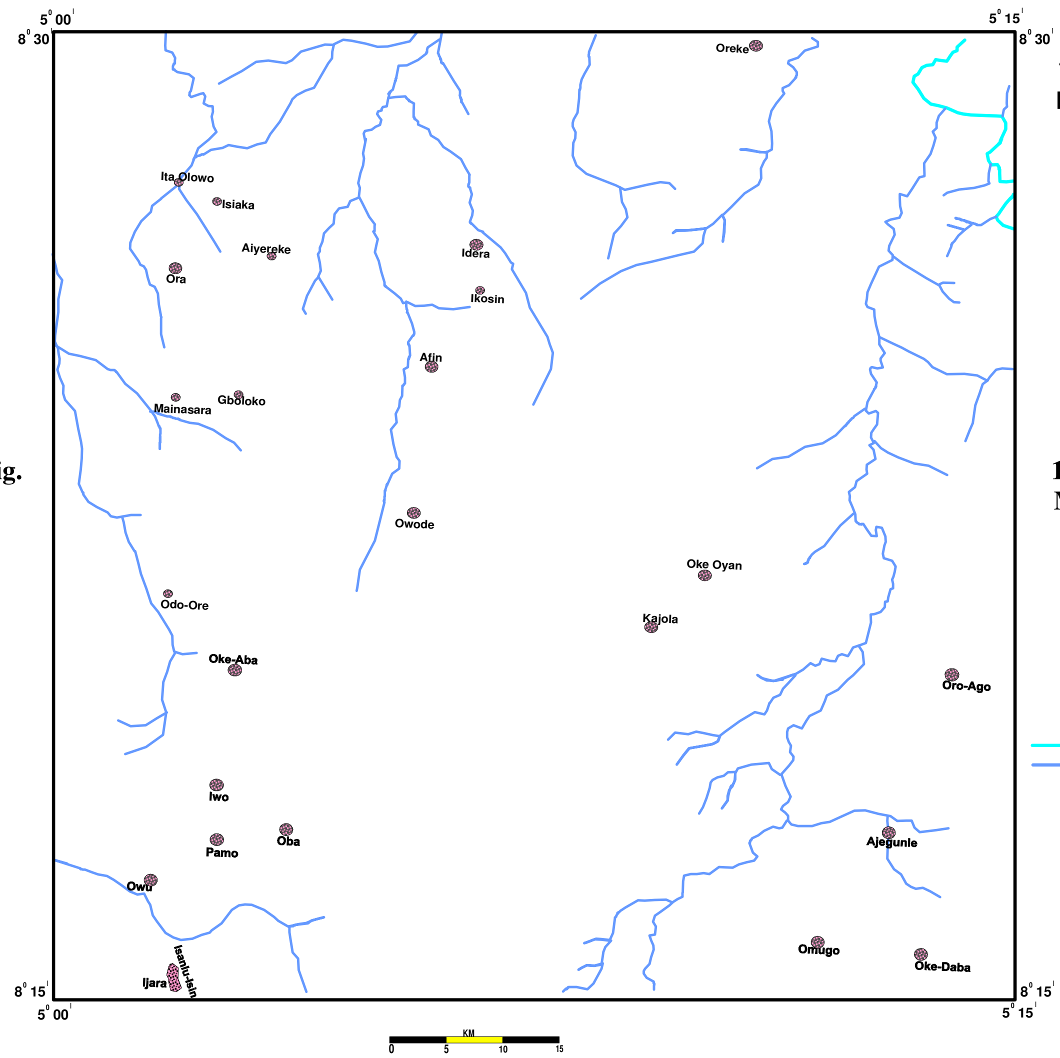

Fig. 1: Location Map of the Area

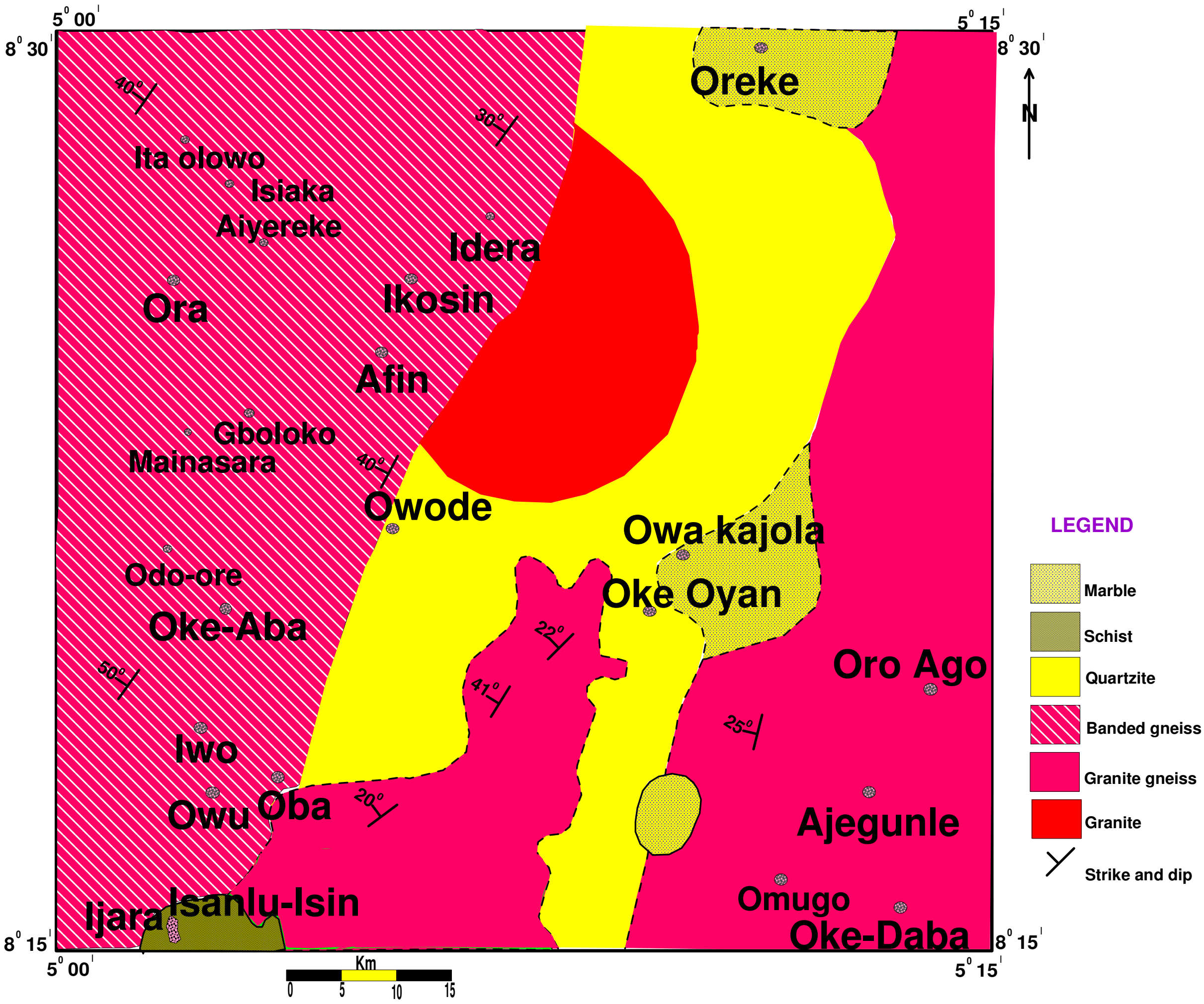

Fig: 2 Geological Map of Oreke and Owo-Kajola Area.

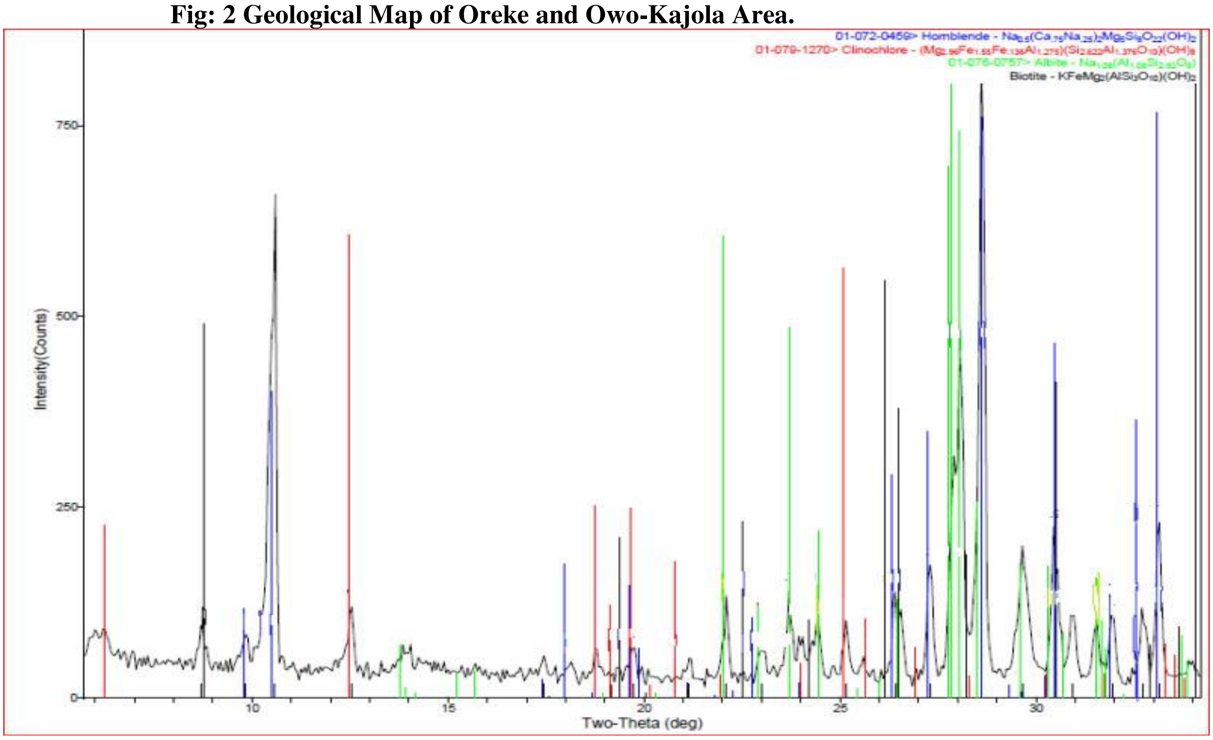

Fig. 3 XRD diagram for sample L1 from Oreke showing hornblende (in significant amount), albite (also significant), chlinochore (minor to moderate), biotite (minor to moderate amount).

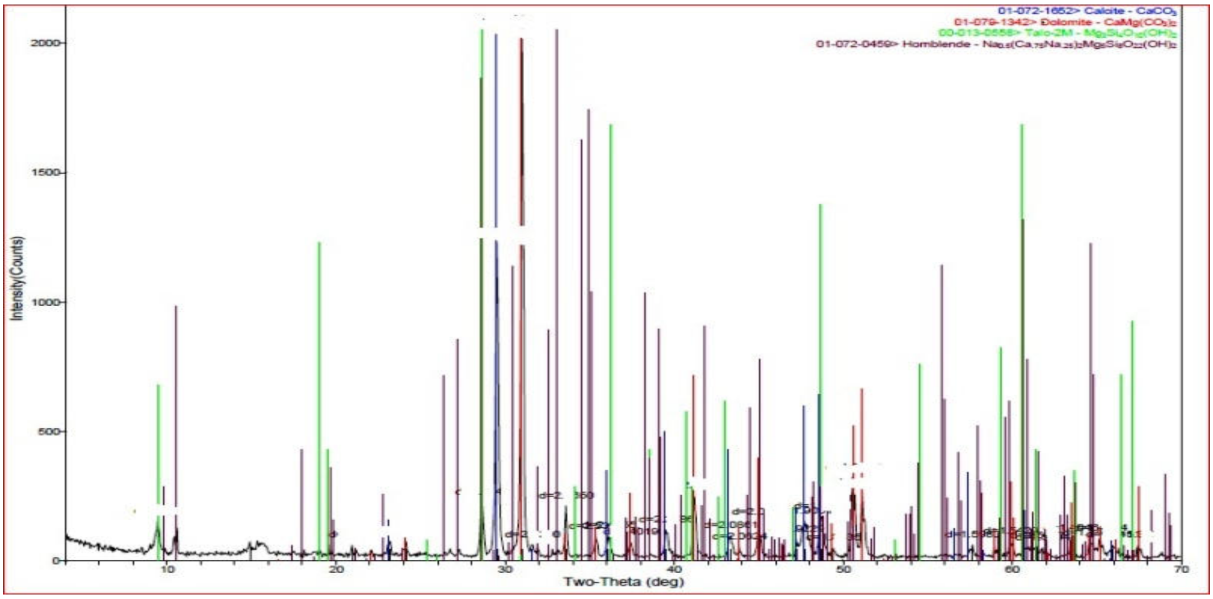

Fig. 4 XRD diagram for owa-kajola showing almost same proportion equal dominance of both calcite and dolomite in sample L5 (significant), talc (minor), hornblende (moderate)