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GEOCHEMISTRY AND ECONOMIC POTENTIAL OF MARBLE FROM IKPESHI, SOUTH-WEST, NIGERIA

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ABSTRACT

Nigeria is endowed with varieties of valuable solid minerals and rocks. These minerals/rocks are capable of boosting the economic potentials of the country if fully exploited. Marble is one of such rocks that occur prominently in Ikpeshi area of Edo State, southwest, Nigeria. Forty five (45) marble samples were subjected to geochemical, petrographic and physical analyses. Geochemical data show that the marble has variable geochemical characteristics; low dolomite CaMg $(C0_3)_2$ (1.35-7.44%) and high calcite $CaCO_3$ (82.78-95.61%) for those from other quarries and moderate dolomite (41.38-41.42%) and moderate calcite (61.03-61.58%) for those from the Golden Girl quarry. Physical tests indicate high tensile strength (17.342-31.550MPa), compressive strength (259.515-3892.73MPa) and shear strength (44.70-68.51MPa), respectively. Petrographical studies reveal that the marble contains calcite, dolomite, quartz, opaque mineral, actinolite, lead, feldspar and chlorite. Based on these characteristics, the marble from Ikpeshi is suitable as raw materials for manufacture of lime, drugs, toothpaste, paper and paint. It is also important in the production of livestock feed, electrical insulators, flooring tiles and terrazzo chips. The marble is unsuitable for cement production.

Keywords: marble, geochemistry, variable characteristics, unsuitability raw materials.

INTRODUCTION

Marble is one of the industrial rocks that is presently gaining prominence in the manufacturing sector of the Nigerian economy. Ikpeshi area lies within the Pre-cambrian Basement Complex of Southwest, Nigeria. The Basement rocks notably the migmatite gneiss complex, schist (metasediment), older granite and late intrusives [1, 2]. The schist occurs as a supracrustal cover on the Basement and consists of mica schist, metaconglomerate, calc-gneiss and marble and quartz biotite [3, 4, 5, 6, 7, 8]. The marble in Ikpeshi area occurs in large deposit, yet very little data are available on its chemistry. This study therefore presents data on the marble chemistry with the purpose of appraising its economic potentials and industrial applications

MATERIALS AND METHODS

Field study

A reconnaissance survey of Ikpeshi areas was carried out between October and November 2007. This was done in order to study the rocks especially the carbonate rocks from different quarry sites. A systematic field mapping of the marble deposits and other associated rock types was undertaken between January and April 2008 when outcrops were well exposed and dry weather conditions for quarry operation was most conducive. The marble deposits were quarried by different companies for different economic applications. (Table-1) The marble in Ikpeshi varies in colour from whitish, pinkish to grey while the texture ranges from fine, medium to coarse. In places, the marble is associated with banded calc-gneiss within the schist rock unit.

Table-1. Marble deposits in Ikpeshi areas.

#	Quarrying company	Marble deposit (location)	Rock type	Colour	Approx. coverage (km^2)
1	Freedom group of quarries	Igwe	Marble	White, black and grey	16
2	Somak	Ikpeshi	Marble	Greyish	4.5
3	Goopex	Ikpeshi	Marble	Greyish, White	3.0
4	Golden girl	Ikpeshi	Dolomitic marble	Pinkish “Off white”	2.0
5	Freedom group	Ikpeshi	Marble	Dark, grey, white	6
6	Golden girl	Atte	Calc gneiss and marble	“Zebra” coloured (greyish/white band)	1.0
7	Hussler	Igwe	Marble	Grey	2.25

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Sample collection

Forty five (45) representative marble samples of 500g each were collected from the studied area (Figure-1) by means of sledge hammer. Global positioning system (GPS) instrument was used to locate and determine the elevations and co-ordinates of sampled points.

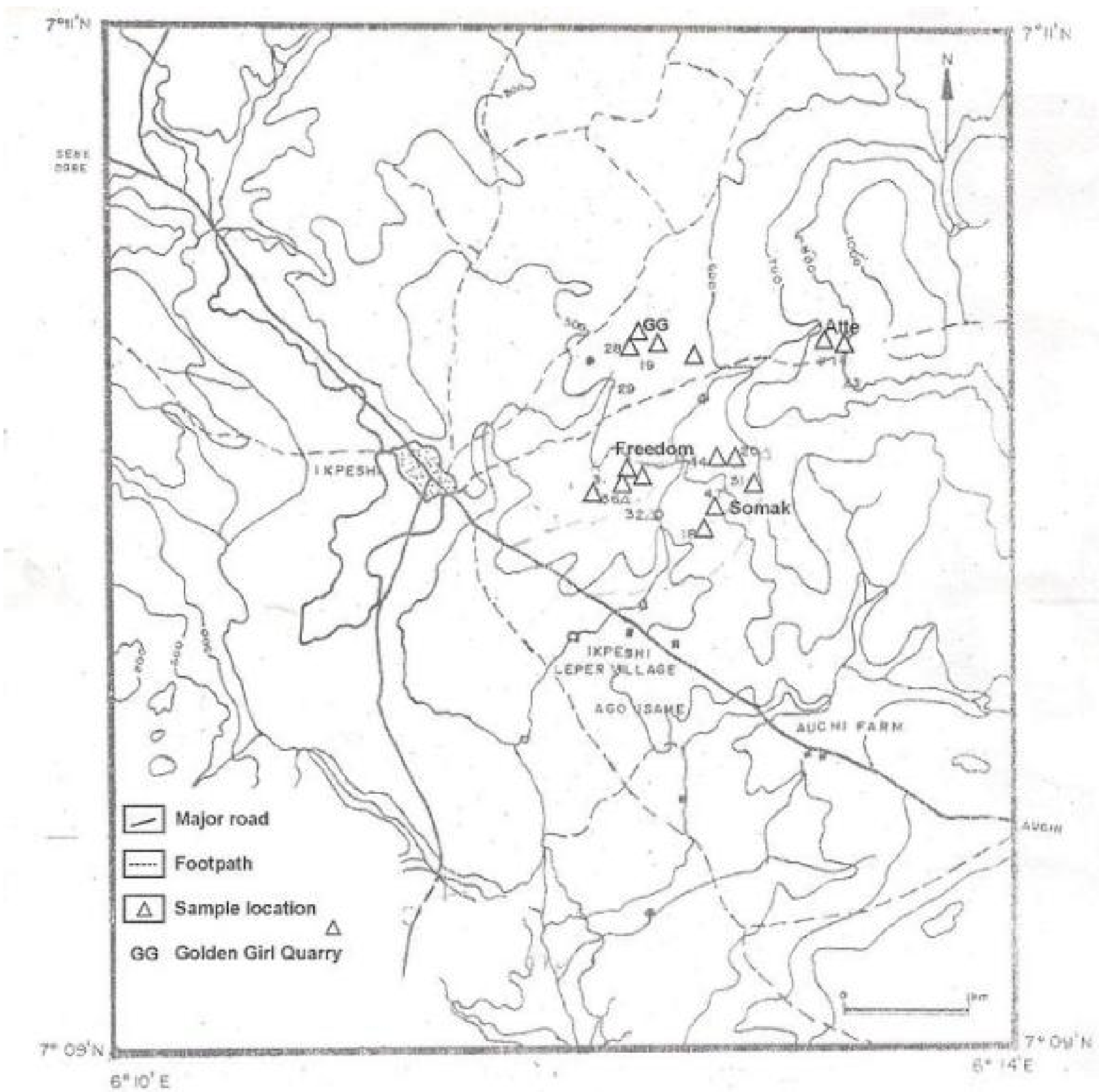

Figure-1. Topographic map of Ikpeshi showing sample locations. (Adopted from GSMN Auchi N.W. sheet 226)

Sample preparation

Twenty (20) of the samples were pulverized into powder (180μm mesh) using Denver pulverize requipment. They were sent to Activiation laboratory (ACTLAB) in Ontario, Canada for major and minor oxides geochemical analyses using the Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) method. Five samples (5) dually were analyzed using the X-ray fluorescence (XRF) and X-ray Diffractometer (XRD) in the Department of Geological Sciences laboratory in the University of Cape Town, South Africa. The whole rock CO_2 abundances were calculated following duplicate determination of $CaCO_2$ using the Carbonate-bombe method of Birch, 1981.

In the XRD method diffractograms were obtained with a Philip 1140 equipment using Cuk alpha radiation operated at 40KV, 30MA and $1^0 2^1$ per minute. Ten (10) samples were tested for their physical strength properties while another ten (10) samples were used for petrographic studies.

RESULTS AND DISCUSSIONS

Table-2 shows a variable geochemical characteristic of Ikpeshi marble. SiO_2 (silica) values are generally low ranging from 0.44% to 1.96%. Low content of silica has a negative impart on the economic use of marble for cement production. CaO (lime) varies from one quarry to another from 45.83-51.35% in Freedom quarry, 33.64-33.95% in Golden Girl (GG) quarry and to 48.36-

53.02% in Goopex quarry. MgO (Magnesia) is generally low (2.04-3.67%) except in the Golden Girl quarry which have 19.79-1981% range.

Table-2. Chemical characteristics of Ikpeshi marble (Vol. %).

Oxide	1	2	3	4	5	6	7	8	9	10
SiO_2	1.94	1.94	1.43	0.44	1.94	1.18	1.90	1.88	1.40	1.96
Al_2O_3	1.76	0.31	0.02	0.11	1.04	0.48	1.80	0.33	1.08	0.39
Fe_2O_3	1.23	0.18	0.03	0.08	0.05	0.26	0.77	0.16	0.47	0.36
MnO	0.04	0.05	0.01	0.02	0.01	0.01	0.01	0.08	0.01	0.09
MgO	3.67	2.45	19.81	19.79	2.14	3.54	3.56	2.04	2.65	2.59
CaO	48.05	51.35	33.95	33.64	50.08	50.3	45.83	48.36	53.02	49.59
Na_2O	0.40	0.09	0.01	0.03	0.06	0.01	0.28	0.58	0.2	0.01
K_2O	0.62	0.05	0.05	0.07	0.05	0.63	0.60	0.08	0.29	0.01
TiO_2	0.15	0.02	0.02	0.03	0.01	0.01	0.10	0.01	0.05	0.03
P_2O_5	0.06	0.06	0.02	0.05	0.04	0.17	0.04	0.08	0.13	0.03
TiO_2	41.98	43.5	44.66	45.75	44.53	43.32	45.30	45.61	40.7	44.23
Total	99.90	100.00	100.00	99.96	99.95	99.91	100.1	99.21	100.00	99.29
CaCO3	86.74	92.63	61.58	61.03	90.36	90.76	82.78	87.29	95.61	89.49
MgCO3	7.67	5.12	41.42	41.38	4.48	7.40	7.44	4.26	5.54	5.42

Columns: 1 - 2, 5 - 7 (Freedom Quarries)
3 - 4 Golden Girl quarry
8 - 10 Goopex quarry

Table-2 also shows the values for $CaCO_3$ and $MgCO_3$ equivalents of CaO and MgO contents. The carbonates are important in the assessment of the presence or absence of the mineral calcite or dolomite. [9] Points out that MgO values whose $MgCO_3$ equivalent exceeds 2% indicates the presence of mineral dolomite. [10] Suggests that carbonate rocks that contain less than 8% of $MgCO_3$ have isolated crystals of dolomite. Based on this, and evidence from the photomicrograph in Figure-2, the Ikpeshi marble contains isolated saddle-shaped crystals of dolomite. [11] Suggests that marble with less than 11% of $MgCO_3$ is calcitic, those with greater than 40% of $MgCO_3$ are dolomitic marble. These characteristics suggest that within the Ikpeshi geological environment calcitic marble with $CaCO_3$ of 82.78-95.61% and dolomitic marble at the GG quarry of $MgCO_3$ of 41.38-41.42% occur. The occurrence of dolomite and calcite in Ikpeshi marble is presented in histogram in Figure-3. The Loss on ignition (LOI) varies between 44.60-45.75% with the highest occurring at the GG quarry (45.75%). High LOI results from loss of water from clay mineral, montmorillonite and loss of CO_2 from carbonate minerals. High LOI in marble poses a problem to cement production.

An interpretation of XRD reveals the presence of Calcite, dolomite, illite, montmorillonite, quartz and Kaolinite. XRF result in Table-3 indicates low silica values (0.631-6.277 wt %) low magnesia (1.54wt %) except at the GG (13.642wt %) and varying lime content (42.518-53.983wt %).

Economic appraisal of marble

Ikpeshi in Edo State is an important marble producing area of Southwestern Nigeria. The marble and its associated minerals form sources of raw materials to a variety of consumer products such as paint, toothpaste, drugs, plastics, paper and animal feeds. The use of marble by industries has been based on its physical and chemical characteristics as well as its purity. The purity is a measure of the amount of CaO, SiO_2 and Al_2O_3 and or the presence or absence of impurities. Physically, colour is an important aesthetic element which widens the chances of marble marketability and pricing. Coloured chips, terrazzo and even white wares are in high demand. Coloured marble is used as pigments or stainer for emulsion paint production.

Production

Finely ground white Calcitic marble serves as good fillers, extenders and coating pigment. They stabilize the paint and act as a weather resistant [12]. As paper filler, it imparts high brightness to the sheets, surface smoothness and ink receptivity to printing. In plastic manufacturing, marble filler provides necessary reinforcements for greater impact strength, rigidity and stiffness.

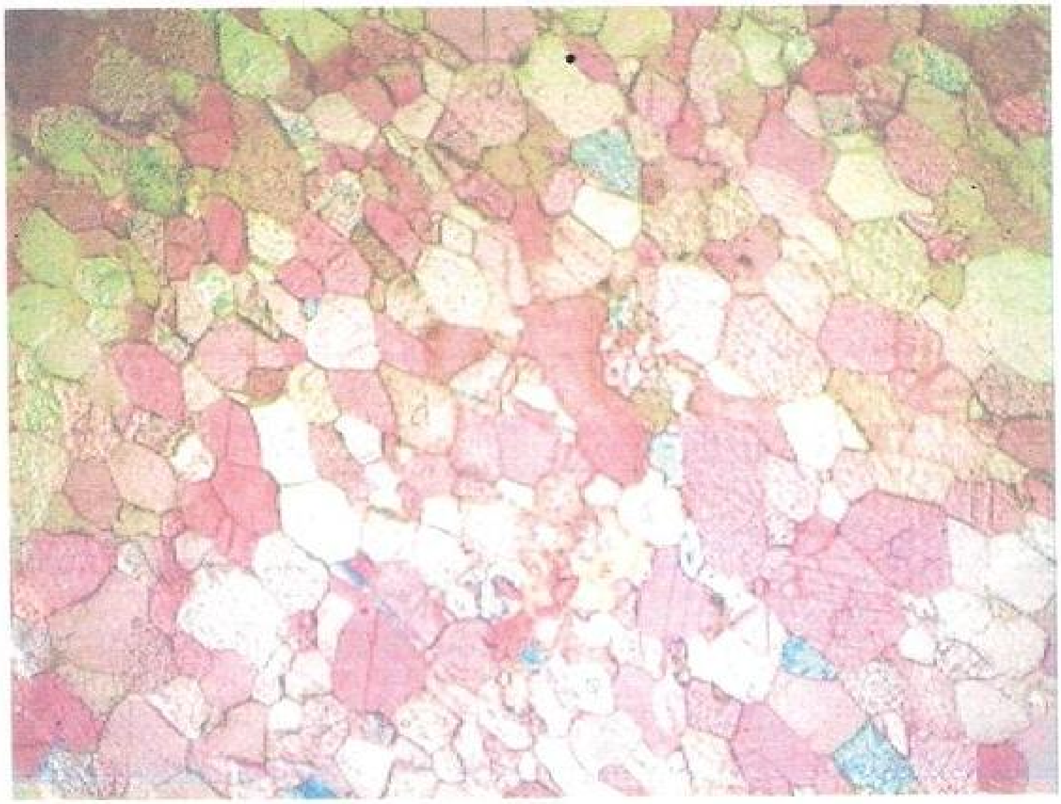

Figure-2. Photomicrograph of marble curved saddle-shaped dolomite crystals d = dolomite.

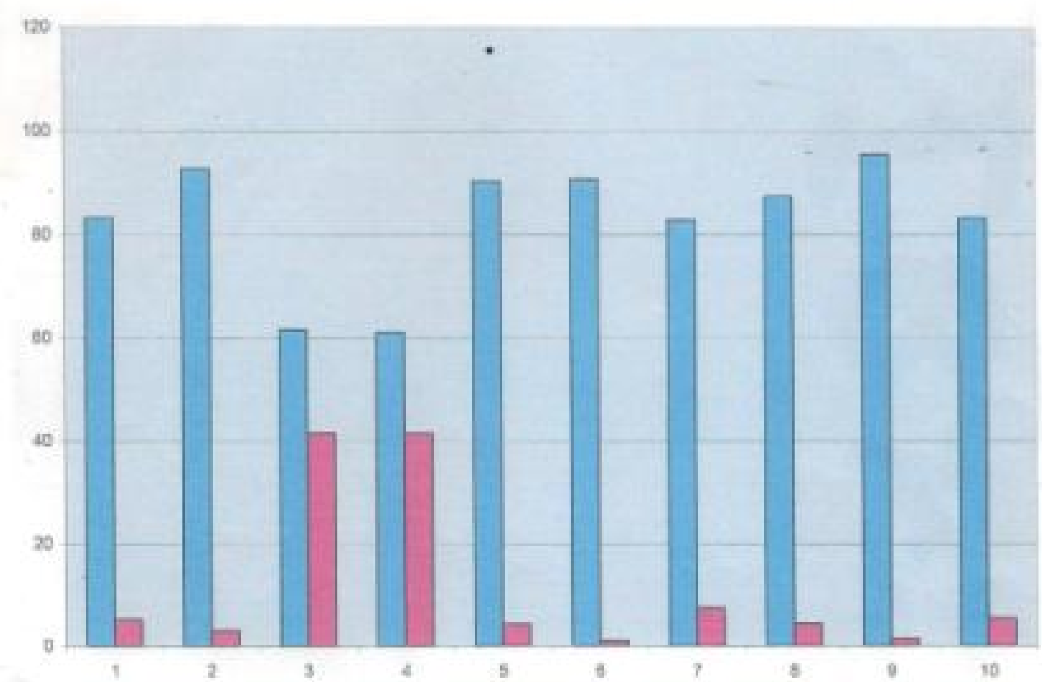

Figure-3. Histogram showing the calcitic and dolomitic marble from Ikpeshi.

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Table-3. Chemical analysis of Igarra and Ikpeshi marble using XRF method (Wt %).

Oxide	1	2	3	4	5
SiO_2	0.814	7.300	0.631	2.632	6.277
TiO_2	0.042	0.061	0.033	0.083	0.100
Al_2O_3	0.205	0.665	0.204	0.874	1.280
Fe_2O_3	0.329	0.357	0.162	0.349	0.614
MnO	0.018	0.028	0.017	0.016	0.027
MgO	0.753	4.399	13.642	1.54	2.818
CaO	56.665	49.551	42.518	53.983	49.433
Na_2O	0.235	0.340	0.290	0.467	0.571
K_2O	0.028	0.298	0.16	0.244	0.166
P_2O_5	0.065	0.033	0.029	0.072	0.024
SO_2	0.339	0.022	0.014	0.447	0.255
Cr_2O_3	0.011	0.008	0.004	0.005	0.009
NiO	0.001	0.001	0.004	0.003	0.003
H_2O	0.071	0.060	0.062	0.084	0.075
LOI	40.471	36.868	42.102	39.718	38.187
Total	100.046	99.990	99.728	100.131	99.837
Trace element in ppm					
Zr	185	115	13	197	129
Sr	2550	1507	230	2589	1613
Pb	4754	8	7	8	14

All Fe expressed as Fe_2O_3
H_2O = Loss of moisture at 110^0C
LOI = Loss of volatiles at 850^0C (H_2O + and CO_2)
Columns 1 - 2: Igarra marble from Geowork quarry
3: Pinkish dolostone from Golden Girl quarry Ikpeshi
4: Ikpeshi marble from Freedom Group of quarries
5: Ikpeshi marble from Goopex quarry.

Cement manufacturing

Ordinary Portland cement ((OPC) is produced by a mixure of the following proportioned raw materials; CaO, S_lO_2, Al_2O_3, Fe_2O_3, MgO and LO1 in Table-4 [13]. A comparison of the geochemical data of Ikpeshi marble with the standard values for cement production shows that the values of CaO, SiO_2, Al_2O_3 and Fe_2O_3 in the Ikpeshi marble are below the required standard, while the MgO, LOl, silica ratio (SR) and lime saturation factor (LSF) are significantly higher than the specified standards Table-4 [14]. Based on these chemical data, the Ikpeshi marble is unsuitable for cement production.

Paint production

Paint manufacturing requires essentially the physical and chemical properties of marble.

Physical requirements include good white or pink colour, small particle sizes (98% passing through 325 mesh) and absence of hard particles. Standard chemical specification provides that $Al_2O_3 \geq 2\%$, MgO + S_1O_2 > 75% and LOl must be within the range of 4-8% [12] The Ikpeshi marble satisfies all the physical specifications but it is chemically below the required standard (Table-5). The marble is therefore unsuitable for use for Paint production.

However, paint manufacturers have their individualized specifications so much so that they establish their peculiar standards as long as their brands of paint satisfy their quality, their customers and in conformity with their production formulations. In line with this, many paint industries in Nigeria source their raw materials for production from the Ikpeshi marble. However, the non-compliance to chemical specification/standard could make the paint have to unpleasant appearance and short duration.

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Table-4. Standard proportions compared with the analyzed Marble from the study areas for Cement production.

Oxide	**Ikpeshi marble** (maximum %)	**Standard %** (Rajput, 2008)	**(LSF) Lime saturation factor % Std,** **(**Lebahn and Kaminsky, 1971)
SiO_2	1.96	22.0	
Al_2O_3	1.80	6.0	
Fe_2O_3	1.23	3.0	
MgO	1981	2.50	
CaO	53.02	63.0	
K_2O	0.63	-	
Na_2O	0.58	-	
P_2O_5	0.17	-	
LO1	45.78	1.5	
SO_3	0.02	1.75	
LSF	635.56	-	66 – 102
$\frac{Al_2O_3}{Fe_2O_3}$	1.46		0.66
S.R	0.65	2.2 – 2.6	

Table-5. Standard requirements for Paint manufacturing.

S. No.	**Physical standard**	**Chemical standards** (Robert,1979)	**Ikpeshi marble**
1	Good white or pink colour	Al_2O_3.>2%	Max Al_2O_3 - 1.80%
2	Small particle size (98% Passing 325 mesh)	MgO + SiO_2, 75%	MgO -21.24
3	Absence of hard particle	LOI range 4- 8%	Min LOI – 40.70%

Table-6. Physical properties of marble from Ikpeshi.

Sample No.	**Unit weight** (Mpa)	**Bulk density** (kg/m^2)	**Specific gravity**	**Relative density**	**Tensile strength** (Mpa)	**Shear strength** (Mpa)	**Compressive strength** (Mpa)
1	1691.38	1.960	2.61	1.72	17.342	63.68	346.820
2	1308.0	1.835	2.78	1.33	19.706	44.70	276.816
3	1348.88	1.960	2.58	1.38	29.954	64.06	259.515
4	1678.03	1.667	2.96	1.71	31.530	68.32	3714.18
5	1962.00	1.736	2.73	1.82	22.859	50.86	2.854.67
6	1836.77	1.460	2.49	1.81	25.224	60.27	294.1.17
7	1667.70	1.653	2.54	1.70	26.801	62.86	3633.21
8	1538.82	1.570	3.34	1.57	24.436	68.51	3892.73
9	1962.00	1.820	3.11	1.74	30.742	77.92	3200.69
10	1744.00	1.903	2.67	1.18	29.166	60.88	4152.24

Marble flooring tiles, chips and fittings

Physical tests in Table-6 indicate that the Ikpeshi marble has high strength properties that enable it to be applied in a variety of industries to produce tiles, chips and fittings. Most of these industries are cited in Lagos, Nigeria. Flooring tiles add a unique look to rooms and they come up in splendid designs and styles. The installation of the finished product can be done even by the unskilled. Tiles have a very soothing cooling touch when installed due to its low heat conduction properties.

Marble chips are crushed pieces that are produced according to consumers' size demand and needs. Chips give gardens or landscapes exquisite cool look. Marble fittings are high strength materials that are fitted in places where hard substances impervious to moisture are demanded. Such places include fittings/tables used by butchers, fish retailers, lavatory, kitchens, and operation rooms in hospitals. The surfaces of such fittings are readily cleaned and afford no lodgment for disease germs.

CONCLUSIONS

Geochemical data of Ikpeshi marble indicate variable characteristics; high calcite and low dolomite on one hand and moderate calcite and dolomite at the Golden Girl quarry on the other hand due to variations in CaO and MgO contents. An economic appraisal of the marble and its associated minerals show that they serve as raw materials for a variety of products such as fillers, glass, papers, flooring tiles, chips and fittings. They also find applications in decorative construction, monuments, paint making but unsuitable for cement production.

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