Physico-Chemical and Mineralogical Characteristics of Obajana Marble Deposit, Central Nigeria: Implication for Economic Appraisal

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Abstract

Marble is one of such minerals occurring in Obajana area, Kogi State, Nigeria that can be exploited for various uses other than cement production that the area is well known for. Hence, the continuous investigation into its economic viability can never be over emphasized. The physical, geochemical and mineralogical attributes of Obajana marble was investigated for the purpose of its economic potential. Obajana marble is closely associated with meta-sedimentary and granitoid rock assemblages of the Precambrian Lokoja - Jakura Schist Belt of central Nigeria. Thirty (30) representative samples were collected from the bench crest and bench trough of the 3 pits investigated based on variation of colour, texture and structure during field investigations. Physical properties were determined for while optical microscope and X-ray fluorescence techniques were used to discern mineralogical and chemical composition of the samples. The colour ranges from whitish to dark colour minerals, with traces of brownish colour and are very attractive based on physical look. Physical parameters for the marble indicated varied compressive strength (13.84 – 93.60 MPa), hardness (3.05), specific gravity (2.72), colour brightness (83) and pH (8.3). Chemical data showed pit 1, CaO (50.30 - 53.99 %), MgO (0.00 - 0.38 %); pit 2, CaO (48.31 - 51.87 %) MgO (0.41-1.63 %) and pit 3, CaO (49.39 - 52.93 %) MgO (0.06 - 1.19 %) and in general reveal calcitic marble by virtue of the CaO : MgO ratios of the marble bodies. Also, mineralogy reveals that samples are composed mainly of calcite, with minor amounts of dolomite, quartz, magnesium oxide and iron. Appraisals of the functional potential of the marble based on physical, geochemical and mineralogical characteristics indicate that Obajana marble is suitable for cement feedstock, iron and steel fluxes, fillers in paints and paper making and as extenders in the manufacture of glass as well as useful in water treatment.

Keywords: Economic viability, Central Nigeria, Marble; Obajana, Mineralogy,

Introduction

Marbles are known to be products resulting from the metamorphism of sedimentary carbonates. It is believed to be moderately impermeable during the process of metamorphism (Nabelek, 1991). Varieties of marble bodies are widely distributed within the Precambrian Basement rocks of Nigeria. These bodies are commonly associated with the Schist belts which may be regarded as infolded belts (perhaps initially protobasins) into the seriously deformed and variably metamorphosed migmatite-gneiss-quartzite complex (McCurry, 1976). The Nigerian schist belts include the Igarra, Lokoja – Jakura and Egbe-Isanlu belts in the North-central part of Nigeria and Zungeru - Birni Gwari, Kushaka, Wonaka and Zuru in the North-west, Nigeria. These Schist Belts generally show distinctive petrological, structural and metallogenic features; occupying essentially N - S trending troughs, and are more prominent in the western half of the country (Elueze and Okunlola, 2003). However, other belts have been highlighted further to the Southeastern part of the country in various districts in Nigeria. Marble bodies are being mined and applied as ingredients for various industrial products and processes (such as cement manufacturing, fluxes in steel, agricultural lime for soil enrichment, chemical products, ceramic whiting, fillers / extenders in paints, plastics and paper manufacturing, sewage/water treatment, as dimension stones and construction purposes). The distribution, applications and industrial potentials of some deposits have been examined (Emofurieta and Ekuajeni, 1995).

Marble as one of the industrial rocks is presently gaining prevalence in the manufacturing sector of the Nigerian economy. The use of any of these marble deposits is strictly dependent on their physical, chemical and mineralogical properties. Few research works have been conducted on Obajana marble deposit, with most recent by Jimoh *et al.* (2014 and 2015).These works centred on the geochemistry and economic potentials of the marble deposits using X-ray diffraction (XRD) and Inductive coupled plasma mass spectrometry (ICP-MS). Therefore, the present work is intended to determine the physico-chemical and mineralogical characteristics of the Obajana marble deposit employing X-ray fluorescence (XRF), petrographic and physical techniques to evaluate their economic potentials.

Location of Study Area

The Obajana village is located between Latitudes 07° 54' N to 08° 00' N and Longitudes 06° 25' E to 06° 30' E. The deposit can be accessed through Obajana – Jakura road which is approximately 9 km Northeast of Obajana village. Another marble deposit is located at Oyo-Iwa area of Obajana village about 25 km from the old Kabba road junction, off Lokoja – Okene high way (Fig. 1). The topography of the studied area is highly undulating. The highland areas are defined by hills in form of ridges. The terrain is very rugged with quartzite ridges sometimes rising as high as 100 meters above the low lands. The deposit exists at the bed of River Mimi and to the east are quartz-muscovite schist ridges. The highest elevation is to the Northeastern part of the area, which is above 310 meters above sea level while the southern part has the lowest elevation of 255 meters above sea level. The area is drained mainly by River Mimi and its tributaries, which form a dendritic pattern of drainage and discharge its water southwards into River Niger.

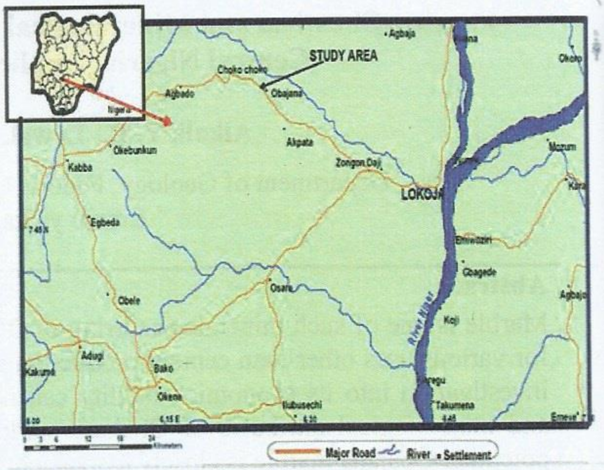

Fig. 1: Location map of Obajana area, Kogi State, North-central Nigeria

Methodology

The methods adopted in this study include field investigations and laboratory work. The field investigation encompasses visual observation and description, and collection of marble samples while the laboratory work involves determinations of the mineralogical, geochemical and some of the physical attributes of the marble deposit.

Field Investigations

A total of 30 marble samples of about 150 g each were collected from 3 pits within the study area with the aid of a sledge hammer. A global positioning system (GPS) was used to establish the coordinates and altitudes of the sampled points. Fresh samples were collected systematically from bench crest and trough which were based on colour variation, textural and structural characteristics of the marble. Proper labelling of the samples was done in accordance to how they were collected in the field. For example, 10 samples were collected from each of the pits; in pit 1, it was labelled as P1S1, P1S2, P1S3.......P1S10 samples and the same pattern was adopted for the remaining 2 pits, making a total number of 30 samples which were selectively and properly packaged in the respective sample bags.

Laboratory Work

Standard laboratory procedures were employed in these studies. The laboratory analyses were divided into three: physical test, geochemical and petrographic analyses. The representative samples of the marble from the 3 pits were subjected to following analyses. Optical microscopy was used to determine the mineralogical composition of the marble samples at the National Geosciences laboratory of the Nigerian Geological Survey Agency, Kaduna. Also, X-ray fluorescence technique was geochemically carried out on the pulverized marble samples. In addition, the physical (mechanical) characteristics of the marble such as hardness, compressive strength, specific gravity, pH and colour were determined. Both geochemical and physical attributes of the marble samples were conducted at the Quality Analysis (QA) laboratory at the Dangote Cement Company, Obajana, Kogi State, Nigeria.

Results and Discussion

The Field Relation and Mode of Occurrence of Obajana Marble

Obajana area is underlain by the Nigerian basement rocks in the Lokoja - Jakura schist belt which are dominated by metasedimentary rocks, chiefly, quartz-mica schist with small occurrences of quartzite, marble and silicate facies iron-formation. These metasedimentary rocks are interbanded with meta-igneous rocks such as granite gneiss (Olobaniyi, 2003). The regional trend of rocks in the area is N-S with a dip in the western direction. The marble deposits occur as low-lying outcrops, scattered as lenses within quartz mica schist about 9 km Northeast of Obajana town. The marble having roughly NE-SW trend and thinning out in the south-direction, the marbles are of gray to white in colour, medium to coarse grained in nature with few mica specks. The host rock in the study area includes schist, quartzite, granite gneiss and pegmatite. The schist that outcrops extensively along the access road to the site is of two varieties. One is mica schist while the other one is quartzo-feldspathic schist. In the south, quartz, quartzite cobbles / pebbles and ferruginized quartzite boulders and cobbles occurred extensively, while in north east of the area, granite gneiss outcropped extensively. Granite and pegmatite outcrops were also noticed. The marble is overlain by 2 meters and 8 meters thick overburden soil as revealed from the boreholes drilled in this area, the marble occurrence is up to 70 meters thick from the surface.

The samples collected from the pits were studied and described in hand specimens. In terms of colour, the samples range from whitish to dark colouration, with traces of brownish colour and are very attractive on physical look. White colourations indicate the presence of calcite and quartz, typical example of the white samples is P1S8 while the dark minerals indicate the presence of ferromagnesian mineral which are denser compare to other samples, a typical example is P2S9. The texture varies from medium – coarse grained, presence of cleavages, some of the samples are very hard and cannot easily broken by hand. Visually, P1S6 was named as calcite marble and suggested raw material for cement industries.

Physical Characteristics of Obajana Marble

Hardness

Hardness is the resistance that the surface of a substance offers to abrasion. Obajana marble samples were experimented on compressive machine and have values between 3.0 - 3.05. The hardness of calcite is given as 3 on the Moh's scale and that of dolomite as 3.5 to 4, whereas that of glass is about 5. According to Buckley (1898), the hardness of a marble as a whole may be different from that of the individual grains that compose it. The hardness is influenced by the degree of cohesion between the grains finest – grained varieties. Hardness of the mass as a whole is an indication of "Workability", and is an important property, as the cost of quarrying marbles that are worked slowly by tools is much higher than the cost of quarrying those easily worked. High resistance to abrasion is desirable in marbles that are to be used for sills, steps, or floor tile, all of which are exposed to the friction of the feet of pedestrians.

Specific Gravity

The marble samples from pit 2 and 3 are denser because they contain more of heavy minerals. The specific gravity was determined using jar water, the specific gravity of a substance is its weight compared with the weight of an equal volume of water. The specific gravity of calcite from pit 1 is 2.7 and that from pits 2 and 3 is approximately 2.9 each. Consequently, samples from pit 2 and 3 are heavier than those from pit 1.

Colour

The colour of a marble is one of its most important physical properties and based on field study, most of Obajana marbles are generally greyish to whitish in colour due to pure calcite and some are dark colour with trace of dark mineral which may be due to presence of iron and magnesium oxide. Colour is governed by the nature of the constituents; marble may consists of pure calcite or dolomite. Dale (1912) posited that a serpentine marble is greenish because the prevailing mineral serpentine is green in colour. Thus, variations from the white colour of a pure marble are due to admixtures of foreign substances. Red, Pink, or reddish – brown shades are due to the presence of manganese oxide (MnO) to hematite (Fe_2O_3), yellow – brown, yellow, or cream colours are caused by minute grain of hydrous oxide of iron, limonite ($FeO(OH).nH_2O$).

Translucence

Most of the sample taken from pit 1 is shiny in nature which makes it capable of reflecting light. Marble differ greatly in their capacity for transmitting light. The more translucent varieties and fine grained are best adapted for ornamental purposes. According to Dale (1912), certain artificial treatment are known to increase the translucence of marble, usually the effects of such treatment are far less permanent than the material itself and consequently can be recommended.

Texture

Normally, the grains of calcite and dolomite that often make up marble mass are crystalline and have a definite rhombohedra cleavage. They are mostly twinned; both the cleavage and the twinning of each grain are independent as relating to other grains. The texture is usually about the same in all directions, though in some marbles an elongation of grains in one direction has been noted. Based on hand specimen, the texture of the marbles in Obajana area ranges from medium to very coarse.

Compressive Strength

The strength of the tested samples from pit 1 show 13.84 MPa, while pits 2 and 3 are higher due to the presence of increased traces of iron and magnesium oxides compared to pit 1. The value ranges between 92.5 - 93.6 MPa with the aid of flex compressive machine. Strength of a material is the measure of its capacity to resist stresses of any kinds. It depends partly on the rift in the rock and on the cleavage and hardness of the grains and partly on the state of aggregation, including the degree of cohesion interlocking of grains and nature of cementing material, if such is present.

Geochemical Classification of Obajana Marble

Thirty samples were collected from Obajana marble deposit from three (3) different pits and analyzed for their chemical compositions using X-ray fluorescence technique. The results are presented in Tables 1, 2 and 3

Table 1: Geochemical data from Obajana Pit 1

SAMPLE ID	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	SO_3
P1 S1	0.17	0.06	0.12	53.33	0.19	0.03	0.00	0.07
P1 S2	1.39	0.37	0.21	52.29	0.18	0.06	0.00	0.11
P1 S3	0.41	0.14	0.13	53.44	0.09	0.04	0.00	0.05
P1 S4	0.73	0.18	0.15	52.86	0.05	0.03	0.00	0.04
P1 S5	2.14	0.42	0.24	52.16	0.00	0.06	0.00	0.02
P1 S6	0.31	0.06	0.11	53.99	0.00	0.01	0.00	0.00
P1 S7	1.28	0.46	0.28	53.45	0.15	0.06	0.00	0.19
P1 S8	2.18	0.99	0.84	50.69	0.20	0.02	0.00	0.02
P1 S9	3.38	0.74	0.27	51.22	0.30	0.15	0.00	0.05
P1 S10	3.18	1.07	0.91	50.03	0.38	0.12	0.00	0.01
Average	1.52	0.45	0.33	52.35	0.19	0.06	0.00	0.06

Table 2: Geochemical Data from Obajana Pit 2

SAMPLE ID	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	SO_3
P2 S1	3.13	0.38	0.18	51.87	0.41	0.05	0.11	0.11
P2 S2	4.39	0.38	0.22	50.80	0.51	0.07	0.07	0.13
P2 S3	4.86	0.86	0.38	50.11	1.08	0.20	0.03	0.38
P2 S4	4.68	0.57	0.35	49.92	1.13	0.14	0.02	0.31
P2 S5	3.86	0.50	0.26	51.32	0.88	0.11	0.04	0.24
P2 S6	5.16	0.78	0.33	49.92	0.61	0.12	0.06	0.16
P2 S7	7.21	1.10	0.44	48.57	1.24	0.16	0.01	0.33
P2 S8	6.39	1.16	0.45	48.31	1.57	0.21	0.06	0.30
P2 S9	4.63	1.10	0.52	48.79	1.63	0.22	0.05	0.41
P2 S10	5.13	1.30	0.65	43.7	1.61	0.28	0.02	0.38
Average	4.94	0.81	0.38	49.34	1.07	0.16	0.05	0.28

Table 3: Geochemical Data from Obajana Pit 3

SAMPLE ID	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	SO_3
P3 S1	3.23	0.45	0.20	51.84	0.39	0.10	0.10	0.14
P3 S2	3.46	0.51	0.25	51.82	0.41	0.10	0.09	0.14
P3 S3	3.22	0.17	0.12	52.93	0.09	0.02	0.13	0.00
P3 S4	4.32	0.27	0.13	52.21	0.06	0.01	0.13	0.01
P3 S5	3.53	0.50	0.22	51.84	0.66	0.07	0.10	0.10
P3 S6	6.20	2.07	0.36	49.39	0.21	0.07	0.11	0.01
P3 S7	3.55	0.66	0.21	51.75	0.82	0.06	0.10	0.07
P3 S8	4.60	0.57	0.26	50.17	0.86	0.08	0.12	0.14
P3 S9	1.57	0.44	0.22	51.69	1.19	0.08	0.08	0.14
P3 S10	3.45	0.36	0.21	51.36	0.90	0.09	0.07	0.16
Average	3.71	0.6	0.22	51.5	0.56	0.07	0.10	0.09

The chemical data is marked by low SiO_2, Al_2O_3, MgO and high values of CaO. The (pit 1) results reveals lower SiO_2 (0.17 - 3.39 wt.% with average of 1.52 wt.%), Al_2O_3 (0.06 - 1.07 wt.% with average of 0.45 wt.%), MgO (0.0 - 0.38 wt.%, average = 0.19 wt.%), Fe_2O_3 (0.11 - 0.91 wt.% and average of 0.33 wt.%), K_2O (0.01 - 15 wt.% with average of 0.06 wt.%), high CaO (50.04 - 53.99 wt.%, average 52.35 wt.%) compared to pits 2 and 3, and zero Na_2O (0.00%). In this pit, sample P1S6 contain the highest CaO. Pit 2 analysis is marked by higher SiO_2 (3.13 - 7.21 wt.% and averaged 4.94 wt. %), Al_2O_3 (0.38 - 1.30 wt.% with average of 0.81 wt.%), Fe_2O_3 (0.18 - 0.65 wt.%, average = 0.38 wt.%), MgO (0.41 - 1.63 wt.%, average of 1.07 wt.%), K_2O (0.05 - 0.28 wt.%, average of 0.16 wt.%), Na_2O (0.01 - 0.11 wt.%, with an average of 0.05 wt.%), SO_3 (0.11 - 0.41 wt.%, averaged 0.28 wt.%), with lower CaO (43.79 - 51.87 wt.%, averaged 49.34 wt.%), compared to pit 1 and pit 3. In this pit, sample P2S8 and P2S7 have the highest silica content even compare to all other samples from other pits. Presence of increased magnesium oxide results in traces of brownish colour in the sample.

Also, pit 3 is marked by Fe_2O_3 (0.12 - 0.36 wt.%, averaged 0.22 wt.%), Na_2O (0.07 - 0.13 wt.%, averaged 0.10 wt.%) and this impacted the pinkish colouration, the SiO_2 (1.57 - 6.20 wt.%, with an average of 3.71 wt.%) which is second highest, particularly P3S8 from this pit compared to Pit 2 while when compared with pit 1 is the highest. MgO (0.09 - 1.19 wt.%, with average of 0.56 wt.%), this is lower compared with pit 2 but higher compared to pit 3. Pit 3 is lower in Al_2O_3 (0.17 – 2.07 wt.%, with average equals 0.60 wt.%) compared to pit 2 but higher than in pit 1. It is lower in Fe_2O_3 (0.12 - 0.36 wt.%, with average of 0.22 wt.%) compared to both pits 1 and 2. K_2O (0.01 - 0.10 wt.%, and average of 0.07 wt.%), SO_3 (0.00 - 0.16 wt.%, averaged 0.09 wt.%), and high CaO (49.39 - 52.93 wt.%, with an average value of 51.50 wt.%) compared to pit 2 but lower than in pit 1.

Mineralogical Composition of Obajana Marble

Observation of Mineral Sections under Microscope

Three (3) representative samples, one from each pit were selected and subjected to petrographic study; they are P1S8, P2S7 and P3S4. Where P is pit and S means sample.

Under plane polarized light (PPL), sample P1S8 is colourless, low relief, anhedral in shape, cleavage type was rhombohedral, not fracture nor altered, have some inclusions of opaque minerals. While when observed Hence, the samples are calcite marble. Table 4 presents the modal percentages of the mineralogical composition of the samples as observed under optical microscope.

Table 4: The Summary of Modal Analysis under Microscope, Magnification: X10

Samples Percentage	Modal Composition	
P1S8	Calcite	95
	Opaque mineral	5
P2S7	Calcite	85
	Opaque mineral	15
P3S4	Calcite	98
	Opaque mineral	2

Economic Applications of Obajana Marble

Marble finds useful applications in different spheres of an economy. According to Scott and Durham (1984), marble has high economic values classified into six broad categories namely: metallurgical, chemical, environmental, construction, refractory and agriculture, and each of these groups require a specification for their usefulness. Thus, Obajana marble can be useful in the following ways:

Metallurgical Lime Production

The requirements for metallurgical lime (steel flux) in blast furnaces; CaMgO is required with silica (SiO_2) less than 5 % but more than 2 %, Al_2O_3 less than 2 %, MgO under cross polarized light (XPL) has interference bluish - pink of high relief on rotation of stage. Birefringence is 3rd Order and simple and lamellar twining, the extinction is symmetrical. Opaque minerals were observed to be the dark coloured grains as inclusion in the slide under plane and cross polarize light and it is possibly iron oxide. Similar attributes were also observed in samples P2S7 and P3S4. Hence, the samples are calcite marble. Table 4 presents the modal percentages of the mineralogical composition of the samples as observed under optical microscope.

less than 4 %, P_2O_5 not more than a trace, that is 0.005 ppm to 0.006 ppm. While for steel flux (open hearth) Calcium carbonate content preferably not less than 96 % of lower grades are occasionally accepted. So, pits 2 and 3 are good raw materials for this production, the Obajana marble meets this specification $CaCO_3 > 96$ % which means it can be used for both open hearth and blast furnaces in steel fluxes. Most of the lime produced from marble is used as steel flux. In steel manufacturing, lime acts as a flux use in removing of phosphorous, silica and sulphur, as calcium phosphates, silicates and sulphides in the slag which is tapped off as molten metal.

Paints and Fillers

In the production of paints and fillers in the industries, it is required that calcium carbonate content should exceed 96 % but magnesia lime stones containing as much as 8% magnesium oxide are occasionally tolerated. The $MgCO_3$ content generally is 1 %. Other maxima include Fe_2O_3 (0.25 wt. %), SiO_2 (2.0 wt.%) and SO_3 (0.1 wt.%). In the manufacturing of quicklime for pulp and paper, the Calcium carbonate ($CaCO_3$) contents must be more than 96 % for most manufacturers. In the paper industry, high calcium marble is required as it is suitable for making soda pulp and sulfate pulp. The marble can be reacted with sulfur dioxide to produce cooking liquor. This acidic liquor is then used to digest the constituents of the wood chips except cellulose. The Obajana marble in general meets these specifications for both uses as fillers in paper and in the manufacturing of paints with $CaCO_3$ content of > 96 % and MgO of less than 1.1 wt.% (Ofulume, 1991).

Lubricants

Samples from pits 2 and 3 are very good for the manufacturing of lubricants (greases). Calcium oxide not less than 72.6 %, magnesium oxide not more than 1 %, maximum silica plus iron plus alumina, 1.5 %, maximum carbon dioxide (at point of manufacture) 1 %.

Beet-Sugar

In the manufacturing of beet-sugar, the silica (SiO_2) content not more than 2 %. Magnesia not more than 4% is required. At some plants ferric oxide (Fe_2O_3) must not exceed 0.5 %. The high calcium limes when finely powdered can be employed in refining beet and cane sugar by carbonization. The pure marble from Obajana would not impart a sour taste to sugar. Since carbon-dioxide as well as lime is required in beet sugar refining, the raw marble may be burned at the refinery. The lime precipitates impurities from the juices/syrup from impure solutions. Obajana marble meets these specifications and thus can be useful in the beet sugar manufacturing.

Glass Manufacturing

In glass manufacturing Ferric oxide (Fe_2O_3) not more than 0.05, preferably not more than 0.02 % for colourless glass, rock having up to 0.1 % Fe_2O_3 is sometimes accepted for coloured container glass. Calcium carbonate ($CaCO_3$) should exceed 96 % in case of marble, or 96 % calcium-magnesium carbonate in case of dolomite. Amounts of silica, alumina, magnesia etc., must not vary from shipment to shipment. Samples from pit 2 and pit 3 fairly meets these specifications, thus can be used in glass manufacturing.

Portland Cement Production

The raw marble from pits 1, 2 and 3 can be used in Portland cement production, the major requirements are Magnesium oxide (MgO) not more than 3 %, preferably not more than 2 %. Total alkalis not more than 0.5 %. Minimum calcium carbonate ($CaCO_3$) content varies from plant to plant depending upon availability of other raw materials, but generally is more than 82 %. Obajana marble meets these specification thus it is suitable for the production of Portland cement.

Environmental Uses

Absence of cobalt, mercury and lead in marble is a major advantage for its water treatment / softening applications. Obajana marble has none of these earlier mention elements either in trace or minor amounts. So, their lime products will be useful in sewage treatment, neutralization of acid water, silica and phosphate removal from sewage effluents. These specifications are quite similar to that for water softening and purification. If well processed, the Obajana marble lime products should be useful in sewage water treatments.

Construction

The requirements for concrete aggregate, ballast, road metal and road base is that the concrete should be low in alkalis and free from surface organic matter. Presence of opaline silica is highly undesirable in concrete aggregate especially pit 2 deposit that composed up to 7 % silica content. Other aggregate suitability is based chiefly on durability, particularly toughness and of low porosity, CaO and MgO of about 70 % and CO_2 < 50% (American Society fr Testing and Materials (ASTM), 1976). In terms of fitness, it must leave little or no residue; compressive strength of > 20MPa, tensile strength > 2Mpa and shear strength > 7MPa. Obajana marble meets these specifications and could as well be used as road stabilizers, aggregates with the exception of pit 2, ornamental stones and building blocks.

Agricultural Uses

The marble also function as a neutralizer of acids and soil enhancer, the requirements are pH > 8 with low grittiness and Obajana marble (pH=8.3) meets this requirements and thus is useful as soil ameliorants and nutrients status enhancer.

Conclusion

The field work reveal the Obajana area falls within the central Nigerian basement rocks of the Lokoja – Jakura schist belts. The country rocks found within the study area include mica-quartz schist, quartzite, granite-gneiss and pegmatite. Physical tests conducted show satisfactory properties especially good strength and bulk specific gravity values corresponding to the requirements of dimension stones and construction industries. Also, determination of the physical characteristics of the marble using well established standards and specifications, combined with mineralogical and chemical data support the utilization of the marble as feedstock in cement production, iron and fluxes ingredient, fillers in paints and paper making, as extenders and chemical additives in glass making and carbonate based chemicals. The marble is also suitable for water softening, acid water neutralization and reduction of bacterial load in municipal water treatment.

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