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Geology and Occurrences of Limestone and Marble in Nigeria

Felix Bamidele Fatoye[1*] and Yomi Barnabas Gideon[2]
1.Department of Mineral Resources Engineering, Kogi State Polytechnic, P. M. B. 1101, Lokoja, Nigeria.
2.Department of Earth Sciences, Kogi State University, P. M. B. 1008, Anyigba, Nigeria.
*E-mail: feliztoye@yahoo.com

Abstract
Limestone occurs only in the sedimentary basins in Nigeria. It occurs mainly in the Benue Trough (Lower, Middle and Upper), Sokoto, Dahomey and Borno (Chad) Basins. Limestone-forming environments (shallow coastal marine conditions), appear to have occurred several times in the geological history of the basins. However, the limestone deposits of the Benue Trough (Lower, Middle and Upper), appear to contain the largest and most economically viable limestone resources in the country. Nearly all the limestone deposits in the country are used for the manufacture of cement. Marble, a metamorphosed limestone occurs within the migmatite-gneiss-schist-quartzite complex as relicts of sedimentary carbonate rocks. These are Upper Proterozoic schist belt metasediments which are normally marked by a general absence of carbonates. Such marble deposits appear to be limited to the western portions of the south and central parts of the country. Several of these marble deposits are currently being exploited for cement (Ukpilla and Obajana) and decorative stone (Jakura, Kwakuti and Igbetti) with some production of ground rock for industrial use. Limestone and marble are among the few industrial minerals and rocks that have been utilized to any great extent in the country. This article summarizes the information available on the country's limestone and marble deposits (the geology, occurrences, characteristics, reserves, production and quality). Recommendations are proposed for developing the limestone and marble industry to make a positive contribution to the national economy.
Keywords: Nigeria, Sedimentary, Precambrian, Calcite, Dolomite, Carbonate Rocks.

1.0 Introduction

Limestone is a sedimentary rock composed largely of mineral calcite ($CaCO_3$), formed by either organic or inorganic processes (Serra, 2006). Marble is a metamorphic rock composed essentially of calcite ($CaCO_3$), dolomite [$CaMg(CO_3)_2$], or a combination of the two, with a fine- to coarse-grained crystalline texture (Serra, 2006). Marble is a metamorphosed limestone. Limestone and marble are carbonate rocks, dominated by the mineral calcite ($CaCO_3$).

Nigeria is endowed with large deposits of limestone and marble located in all parts of the country. The limestone at Mfamosing, near Calabar, is the largest and the purest deposit in Nigeria. It is about 50 metres thick at the quarry site. West of Calabar, another carbonate body occurs in the subsurface that is 450 metres thick. The Calabar Flank is the main carbonate province in Nigeria with well-developed tropical karsts and caves (Reiljer and Nwajide, 1998). Limestone and marble, the principal raw materials for cement manufacture, are very essential for a rapidly growing nation like Nigeria. These industrial rocks can be said to be already in extensive use in Nigeria. They are used mostly for one purpose – the production of building and constructional materials. Several cement factories have been built by government and even individuals to utilize the limestone and marble deposits in their respective areas. The output of cement from these companies is quite high, though grossly insufficient to cope with the high demand caused by the appreciable rise in domestic construction. The effect of this insufficiency has been cushioned by the establishment of two cement factories by Dangote Cement Company Plc., one is located at Obajana in Kogi State which is the largest cement company in Africa and the third largest in the world with production of 10.25 million tonnes at the rate of about 1000 trucks per day and the other factory at Ibeshe in Ogun State with 6 million tonnes per annum capacity.

Limestone and marble are extremely valuable industrial rock raw materials. Construction and cement manufacturing industries are principal consumers. They are also used in the production of chemicals, fertilizer, abrasives, industrial fillers, ceramics, etc.

Considerable information on the limestone and marble occurrences and resources in Nigeria has accumulated over the years. This article attempts to summarize all available information on the limestone and marble deposits in Nigeria.

2.0 Geological Setting

The geology of Nigeria is made up of three major litho-petrological components, namely, the Basement Complex, Younger Granites, and Sedimentary Basins. The Basement Complex, which is Precambrian in age, is made up of the Migmatite-Gneiss Complex, the Schist Belts and the Older Granites. The Younger Granites comprise several Jurassic magmatic ring complexes. They are structurally and petrologically distinct from the Older Granites. The Sedimentary Basins, containing sediment fill of Cretaceous to Tertiary ages, comprise the

Niger Delta, the Benue Trough, the Chad Basin, the Sokoto Basin, the Mid-Niger (Bida/Nupe) Basin and the Dahomey Basin.

Limestone and marble occur throughout Nigeria in both Basement rocks and in the Sedimentary Basins (Figure 1). The Cement Plants in the country are located near quarries of suitable limestone or marble deposits. Limestone, marble and dolomite in Nigeria may be conveniently grouped into three classes on the basis of geological age, as follows: the Precambrian marble, the Cretaceous limestone, and the Tertiary limestone.

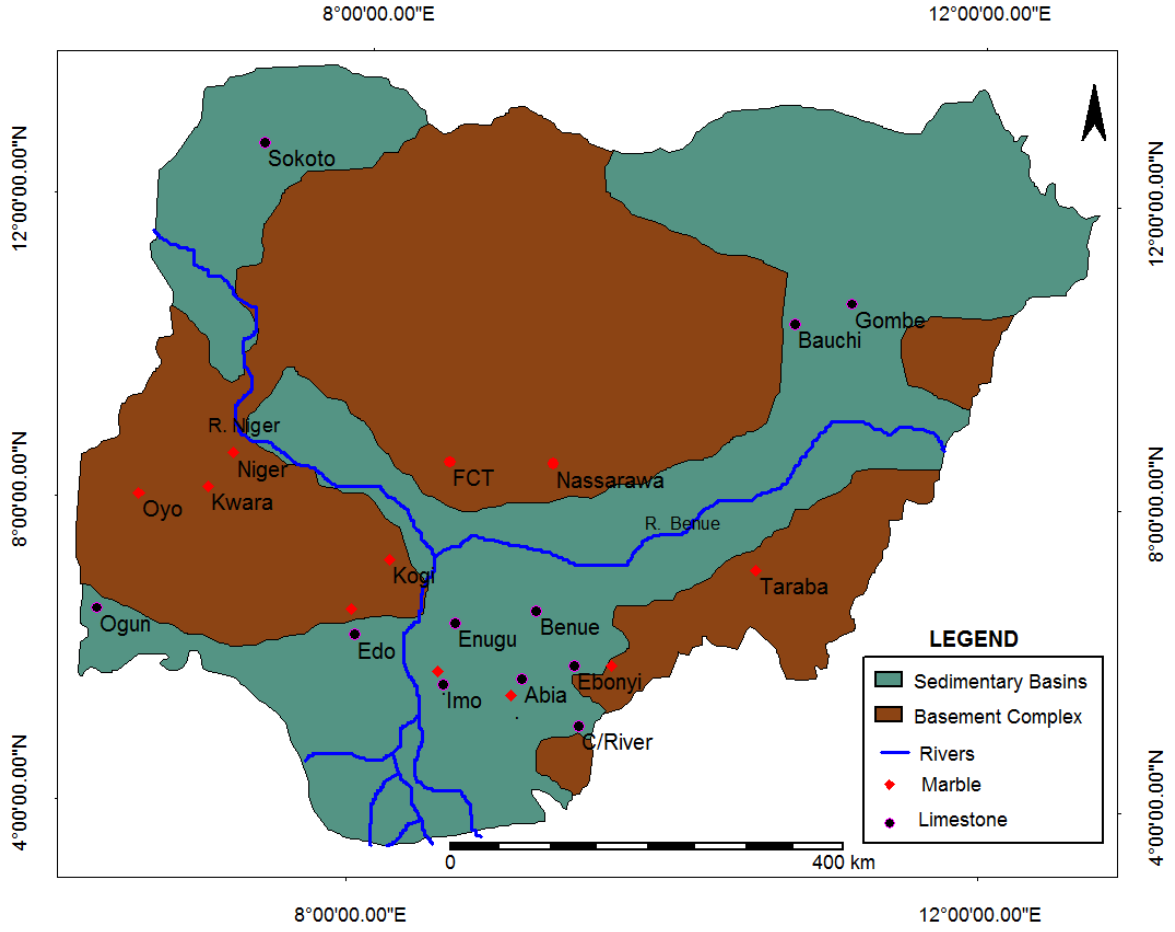

Figure 1. Geological map of Nigeria showing limestone and marble occurrences.

The Precambrian limestone, which has been re-crystallized to form marble, is confined within the schist belts of the western half of Nigeria west of longitude 8^0E. They are white and grayish when relatively pure. They contain variable amounts of mica, calcilicates and sometimes, small inclusions of gneiss, pegmatite and quartz as well as reaction products. These deposits are being used mainly for paladina crushed stone aggregate, and lime (Jakura marble) (FMIC, 1999). The Ukpilla deposit in Edo State is presently being used for the manufacture of cement and calcium carbonate. Other marble deposits are Igbetti and Alaguntan, Oyo State; Ekinrin – Adde, Itobe, Ubo River and Okoloke in Kogi State, etc. Five major marble deposits are currently being exploited in the schist belt area have an estimated reserve of about 150 million tonnes. The lensoidal shape of these deposits suggests that many more occurrences may yet be discovered in the schist belts.

The Sedimentary limestone of Cretaceous and Tertiary ages is associated with shale, siltstone, and fine-grained sandstone. They are often hard, gray and shelly (Abatan, *et al.*, 1993). The Cretaceous varieties occur in a wide belt of territory which, extends from Calabar in the south-east, through Agila, Igumale and Yandev in the central Nigeria to Ashaka and Gombe in the northeast of the country.

The Tertiary beds sometimes contain limestone and inter-bedded marbles. Total estimated resources of these varieties are about 200 million tonnes. They occur in Shagamu, Ewekoro, Ibeshe and Sokoto where they

are being exploited for cement manufacture (RMRDC, 2001).

Most of the deposits being exploited by the cement industry have varied compositions, which range from about 81% calcite ($CaCO_3$) in Sokoto to about 96% calcite ($CaCO_3$) in Mfamosing. Dolomite [$CaMg(CO_3)_2$] values range from about 0.5% in the Mfamosing limestone to about 4.6% in the Ukpilla marble (Abatan *et al.,* 1993). Except in a few cases, the contents of phosphates, sulphur and iron are in trace amounts only.

3.0 Limestone and Marble Formation

Limestone is formed either by direct crystallization from water (usually seawater) or by accumulation of shell and shell fragments.

All limestone forms from the precipitation of calcium carbonate from water. Calcium carbonate leaves solutions in many ways and each way produces a different kind of limestone. All the different ways can be classified into two major groups: either with or without the aid of a living organism (that is, either by organic or inorganic processes).

Most limestone is formed with the help of living organisms. Many marine organisms extract calcium carbonate from seawater to make shells or bones. Mussels, clams, oysters, and corals do this. So too do microscopic organisms such as foraminifera. When the organisms die their shells and bones settle to the seafloor and accumulate there. Wave action may break the shells and bones into smaller fragments, forming a carbonate sand or mud. Over millions of years, these sediments of shells, sand, and mud may harden into limestone. Coquina is a type of limestone containing large fragments of shell and coral. Chalk is a type of limestone formed of shells of microscopic animals.

Limestone can also be formed without the aid of living organisms. If water containing calcium carbonate is evaporated, the calcium carbonate is left behind and will crystalize out of solution. For example, at Mammoth Hot Springs in Yellowstone National Park, hot water containing calcium carbonate emerges from deep underground. As the hot water evaporates and cools, it can no longer hold all of the calcium carbonate dissolved in it and some of it crystallizes out, forming limestone terraces. Limestone formed from springs is called travertine. Calcium carbonate also precipitates in shallow tropical seas and lagoons where high temperatures cause seawater to evaporate. Such limestone is called oolite.

Marble is a form of limestone transformed through the heat and pressure of metamorphism into a dense, variously coloured, crystallized rock.

4.0 Physical and Chemical Properties

The principal component of limestone is the mineral calcite, but limestone frequently also contains the minerals dolomite [$CaMg(CO_3)_2$] and aragonite ($CaCO_3$). Pure calcite, dolomite, and aragonite are clear or white. However, with impurities, they can take on a variety of colours. Consequently, limestone is commonly light coloured; usually it is tan or gray. However, limestone has been found in almost every colour. The colour of limestone is due to impurities such as sand, clay, iron oxides and hydroxides, and organic materials. Colourful streaks in marble are the result of impurities such as quartz or dolomite in the original limestone, which result in the formation of minerals such as forsterite (or serpentine). If the limestone contains other materials such as sand and clay, the calcite will react with them to produce minerals such as tremolite, epidote, diopside, and grossular garnet.

The strength of limestone and marble is the measure of its capacity to resist stresses and it depends on the rift, hardness of grains, state of aggregation and degree of cohesion and interlocking of grains etc. The crushing strength of Nigerian limestone and marble varies between 8,000 and 27,000 psi (563 to 1,899 kg/cm^2). The average specific gravity of Nigerian limestone and marble varies from 2.70 to 2.86.

The surface of marble crumbles readily when exposed to a moist, acid atmosphere, but marble is durable in a dry atmosphere and when protected from rain. The purest form of marble is statuary marble, which is white with visible crystalline structure. The distinctive luster of statuary marble is caused by light penetrating a short distance into the stone and then being reflected from the surfaces of inner crystals.

When a drop of dilute hydrochloric acid is placed on a piece of limestone, the acid reacts with the calcite and forms bubbles of carbon dioxide. Calcite ($CaCO_3$) of which marble is composed is highly susceptible to attack by acid agents. Marble is readily dissolved by acids, even very dilute acid. However, dolomite marble is much more resistant to acid attack than calcite marble.

5.0 Limestone and Marble Occurrences in Nigeria

Extensive deposits of limestone and marble exist throughout the country. They provide the necessary raw materials for the country's cement factories. A few of them are currently being exploited and only these will be reviewed (Tables 1 & 2). Most of the limestone deposits are high in quality, generally containing over 80%

$CaCO_3$ (RMRDC, 2001).

Table 1: Locations of Limestone Deposits in Nigeria.

State	Locations	Estimated Reserve (Million Tonnes)
Ogun	Ewekoro Shagamu Ibeshe	35 10 -
Cross River	Mfamosing, Odukpani, Obubra, Ugep, Ikot Ana, Ago, Ibami.	30 - -
Benue	Yandev Igumale Ogbologuta Adiga, Tokura.	70 110 10.16 -
Ebonyi	Nkalagu Afikpo, Ntezi, Ikwo.	174 -
Enugu	Nkanu Odomoke Ngbo	110 54 2
Sokoto	Kalambaina Dange, Shuni, Wamakko	101.6 -
Gombe	Ashaka	-
Bauchi	Pindiga, Kanawa, Deba- Habe.	-
Edo	Akoko-Edo Owan, Etsako.	10 -
Imo	Umu-Obon Okigwe	101 -
Abia	Ohafia, Arochukwu.	-
Nassarawa	Awe	-

Table 2: Marble Deposits in Nigeria.

State	Location	Estimated Reserve (Million Tonnes)	Remarks
Kogi	Jakura, Ekinrin-Adde, Itobe, Ubo River, Okoloke	N/A	Being exploited.
FCT	Burum, Takalafia, Takusara, Kusaki, Kenada, Ele	7.0	Already investigated and is being exploited.
Oyo	Igbetti, Alaguntan	Large	Commercial exploitation.
Niger	Kwakuti	2.5	Commercial exploitation.
Kwara	Elebu Bugum, Oreke, Owa-Kajola, Babanloma, Eleja, Oke Oyan, Ibare/Oja/Agunjin	5 2.6	Not quantified.
Edo	Ukpilla, Akoko-Edo, Etsako, Igara, Ate	N/A	Dolomite and marble.
Nassarawa	Muro Hills, Ugya,	N/A	To be fully investigated.
Imo	Okigwe	N/A	Further investigation required.
Ebonyi	Afikpo, Abakaliki, Ohaozara, Ezza north and south	20	Being exploited.
Abia	Ohafia	N/A	Need for more investigation.
Taraba	Jalingo	N/A	Need for more investigation.
Ekiti	Ijero	N/A	Need for more investigation

The shallow water sediments of the Albian around Mfamosing, contain the largest and the purest deposit in Nigeria. It is about 50 metres thick, at the quarry site. The first Middle Albian transgression ended

about the Cenomanian, marking its shorelines with the deposition of the limestones of the Odukpani Formation, at the Calabar Flank, in the southeast. The Calabar Flank is the main carbonate province in Nigeria, with well-developed tropical karsts and caves (Reijer and Nwajide, 1998). The Mfamosing limestone has over 96 percent calcite ($CaCO_3$). Reserves in this area exceed 30 million tonnes. The Calabar Cement Company (CALCEMCO) was using the limestone for cement alone. It is also used by the Delta Steel plant at Aladja as a fluxing agent and for making hydrated lime. Dangote Cement Company has just proposed a 6 million tonnes per annum cement plant in Calabar to work on the deposit.

Over 174 million tonnes of limestone exist in Nkalagu area in Ebonyi State and occur within the Turonian – Eze-Aku Formation (Odukwe, 1985). There are six major limestone beds varying in thickness from 3 – 10 metres each. The Nigerian Cement Company (NIGERCEM) was the sole worker of this deposit for cement manufacture and was the first indigenous manufacturer of cement in Nigeria.

About 35 million tonnes of limestone have been proved in Ewekoro presently being quarried by the West African Portland Cement Company. Between Ewekoro and the Benin (formerly Dahomey) border an additional 100 million tonnes is reported to exist. The deposit is wholly used for cement manufacture.

Another 10 million tonnes of limestone have also been proved in Shagamu presently being worked on by Lafarge Cement WAPCO Nig. Plc. for cement manufacture.

The limestone deposit at Ibeshe in Ogun State covers a large area and it is very rich in $CaCO_3$. Dangote Cement Company has just established a cement factory with 6 million tonnes per annum capacity there at Ibeshe that is quarrying the limestone for cement manufacture.

In the Benue Trough are the Asu River Group sediments of the Albian age around Yandev. Within these sediments are three limestone beds with thickness totaling about 40 metres (Adekeye and Akande, 2002). Total reserves in this area exceed 70 million tonnes. The Benue Cement Company now Dangote Cement Company plc works this deposit, again for cement manufacture with capacity of 4 million tonnes per annum.

The limestone deposit at Ashaka in Gombe State covers a large area and it is mainly used by Ashaka Cement Company for cement manufacture. Prior to this, the Nigerian Mining Corporation quarried the limestone for the use of the super-phosphate Fertilizer Company based in Kaduna.

The Maastrichtian – Kalambaina Formation in Sokoto contains thick limestone beds. These limestone beds extend from Dange and Shuni Belt down to Wamakko and Kalambaina, and these are quarried by the Northern Nigerian Cement Company solely for cement production. The reserves in the area exceed 101.6 million tonnes. Sokoto Limestone has 81% $CaCO_3$ (RMRDC, 2001).

Recently large discoveries of limestone deposits were made near Awe in Nassarawa State and proposals for investment in cement production using these limestone deposits have been solicited from both the Federal and the State governments. Most of the limestone deposits are high in quantity, generally containing over 80% $CaCO_3$ (Obaje, 2009).

Limestone deposits suitable for cement manufacture also occur at Ikot Ana, Odukpani, Obubra, Ugep, Ago and Ibami in Cross River State; Ogbologuta, Igumale, Adiga, Tokura and Akahana-Jangerigeri in Benue State; Nkanu, Odomoke and Ngbo in Enugu State; Akoko-Edo, Owan and Etsako in Edo State; Umu-Obon and Okigwe in Imo State; Afikpo, Ntezi and Ikwo in Ebonyi State; Ohafia and Arochukwu in Abia State; Pindiga in Gombe State and Kanawa, and Deba Habe in Bauchi State.

Jakura marble about 40km northwest of Lokoja the Kogi State capital has been worked mainly for decorative purposes, by Jakura Marble Company. It is a body of pure marble in the Basement Complex. Due to its granular size, extent and purity it also has a potential value in the cement and steel industries. And so a cement company, Dangote Cement Company has been built at Obajana village that is currently working on the deposit located about 7.5km from the factory. At 10.25 million tonnes per annum, Obajana Cement Plant is the largest cement factory in Sub – Sahara.

Ukpilla marble deposit in Edo State is pure calcium carbonate in the Basement Complex. It has probably resulted from the metamorphism of an existing bed of sedimentary limestone. The Bendel Cement Company then was using the marble in its cement plant.

Marble deposits are also found at Kwakuti in Niger State; Burum, Takalafia, Takusara, Kusaki, Kenada and Ele in FCT; Itobe, Ekinrin-Adde, Ubo River and Okoloke in Kogi State; Muro Hills, Ugya and Awe in Nassarawa State; Elebu, Bugum, Oreke, Owa-Kajola, Babanloma, Eleja, Oke Oyan and Ibare/Oja/Agunjin in Kwara State; Igbetti and Alaguntan in Oyo State; Ukpilla, Akoko-Edo, Etsako, Igara and Atteh in Edo State; Afikpo, Abakaliki, Ohaozara, Ezza north and south in Ebonyi State; Ohafia in Abia State; Jalingo in Taraba State and Okigwe in Imo State. All of these deposits, with the exception of the Muro Hills and Ubo River deposits, have been shown to be dolomitic, that is, they contain higher proportions of magnesium to calcium than the ordinary marbles, which renders them unsuitable for making cement (GSN, 1987). However, some of the deposits, such as those at Kwakuti and Igbetti are being mined for other purposes such as decorative.

5.1 Cement Factories In Nigeria

Cement factories in Nigeria are sited close to limestone deposits, except the plants at Okpilla in Edo State and Obajana in Kogi State, which use marble. Other cement factories in Nigeria are located at Ashaka (Gombe State), Yandev (Benue State), Nkalagu (Ebonyi State), Shagamu (Ogun State), Ewekoro (Ogun State), Sokoto (Sokoto State), Calabar (Cross River State) and Ibeshe (Ogun State).

Limestone deposits in different parts of Nigeria are in excess of 2 billion metric tonnes. The country till date imports cement because of the dearth of cement factories to meet domestic demand. Annual demand for Portland cement is about 17 million metric tonnes while domestic production stands at below 12 million metric tonnes. Although the effect of this insufficiency has been cushioned by the establishment of two cement factories by Dangote Cement Company Plc; one is located at Obajana in Kogi State which is the largest cement company in Africa and the third largest in the world with production of 10.25 million tonnes at the rate of about 1000 trucks per day and the other factory located at Ibeshe in Ogun State with 6 million tonnes per annum capacity.

6.0 Industrial Applications

Limestone is used as cut stone for building. Limestone is widely used as crushed stone, or aggregate, for general building purposes, roadbeds and railway lines. Finely crushed limestone is also used as filler in industrial products such as asphalt, rubber, paint, plastic, and fertilizers. When heated, the calcium carbonate in limestone decomposes to lime, or calcium oxide, and is important as a flux in smelting copper and lead ores and in making iron and steel. Lime is a key ingredient in the manufacture of cement and concrete. It also used in the production of asbestos, glass and ceramics.

Major industries in Nigeria utilizing granulated limestone include; National Fertilizer Company of Nigeria, Onne, Port Harcourt; Fertilizer and Chemical Company, Kurmi-Mashi, Kaduna; and Morris Nigeria Limited, Minna. Those utilizing lime include; Delta Steel Company, Aladja; Ajaokuta Steel Company, Ajaokuta; and all Water Treatment Plants in the country.

The uses of marble are too numerous. It is used in building, sculpture, monuments, and as dimension stones. The uses also include; paint making, tooth paste, detergents, soaps, pharmaceuticals, cosmetics, chewing gum, sweets, water treatment, soil treatment, ceramics making, asbestos making, industrial adhesives, paper conversion, livestock concentrate, chemical fillers (rubber and plastic products) and steel and iron refinery.

7.0 Conclusion

Limestone and marble are very important industrial raw materials. The supplies of these materials are far less than the demand. Also the supply of processed or granulated limestone and marble to relevant end-users has not met demand.

To meet the demand, there is need for further investigation of various deposits so as to group them according to grades and specific industrial uses for which they are most suited.

Through maximum exploration and exploitation, Nigeria can earn more foreign exchange to complement her earnings. Also the development and utilization of limestone and marble will create job opportunities for many unemployed Nigerians. Furthermore, utilization of Nigerian limestone and marble will have a multiplier effect on other industries.

There is ample investment opportunity in limestone and marble development and processing in Nigeria.

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