

1.0 INTRODUCTION

Geology, the study of rocks, minerals and the physical make-up of the solid earth, determines the environment and natural resources and, thence also, the industrial potentials and wealth of a nation. After climate, geological factors exert, perhaps, the greatest impact on economic activities, since soils, water supply and vegetation are, to a large extent, influenced by the nature of the underlying bedrock.

The vast ocean margin that borders Nigeria to the south; the intricate drainage systems that sculpture the physical landscape; the mountainous eastern frontiers; and the wind-swept northern hinterland, with the great plains on the Saharan fringe, are all part of the surface geological features that bestow upon Nigeria its unique physical attributes.

It could, perhaps, perplex the ordinary mind that, whereas Nigeria exhibits bewildering cultural diversity, the landscape is a continuum in a seamless physical web that unites the physical entity termed Nigeria, regardless of political differences which are mere human artefact.

For example, the Niger-Benue drainage system, which has, over the long geological period of 55 million years, supplied sediments from the Nigerian hinterland for the construction of the petroleum-rich Niger Delta on the coast, has demonstrated the long-term impact of unifying geological processes in a nation with divergent human interests. Economic self-sufficiency is also feasible in Nigeria, where the diversity of rocks and mineral wealth, combined with cheap sources of renewable and non-renewable energy, create an enormous industrial potential.

1.1 DEFINITION OF GEOLOGY

Geology is the science comprising the study of solid Earth, the rocks of which it is composed, and the processes by which they change. Geology can also refer generally to the study of the solid features of any celestial body (such as the geology of the Moon or Mars).

Geology gives insight into the history of the Earth by providing the primary evidence for plate tectonics, the evolutionary history of life, and past climates. In modern times, geology is commercially important for mineral and hydrocarbon exploration / exploitation as well as for evaluating water resources. It is publicly important for the prediction and understanding of natural hazards, the remediation of environmental problems and for providing insights into past climate change. Geology also plays a role in geotechnical engineering and is a major academic discipline.

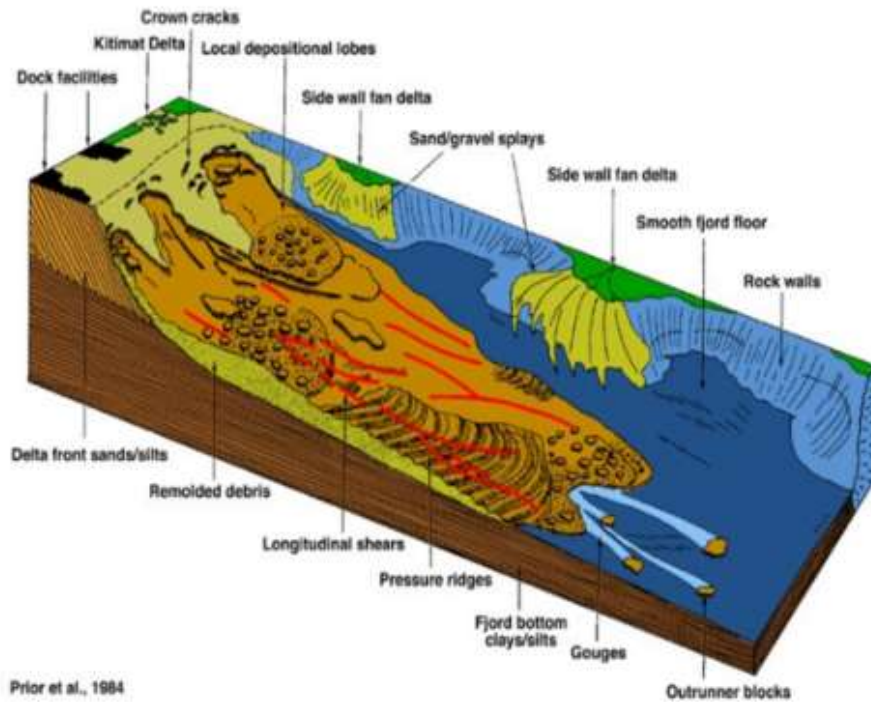
1.2 TYPES OF GEOLOGY

1.2.1 GEOLOGIC TIME

Geological time put in a diagram called a [geological clock](#), showing the relative lengths of the [eons](#) of the Earth's history.

The geologic time scale encompasses the history of the Earth. It is bracketed at the old end by the dates of the earliest [solar system](#) material at 4.567 [Ga](#), (gigaannum: billion years ago) and the age of the Earth at 4.54 Ga at the beginning of the informally recognized [Hadeaneon](#). At the young end of the scale, it is bracketed by the present day in the [Holocene epoch](#).

GEOLOGY OF NIGERIA



Prior et al., 1984

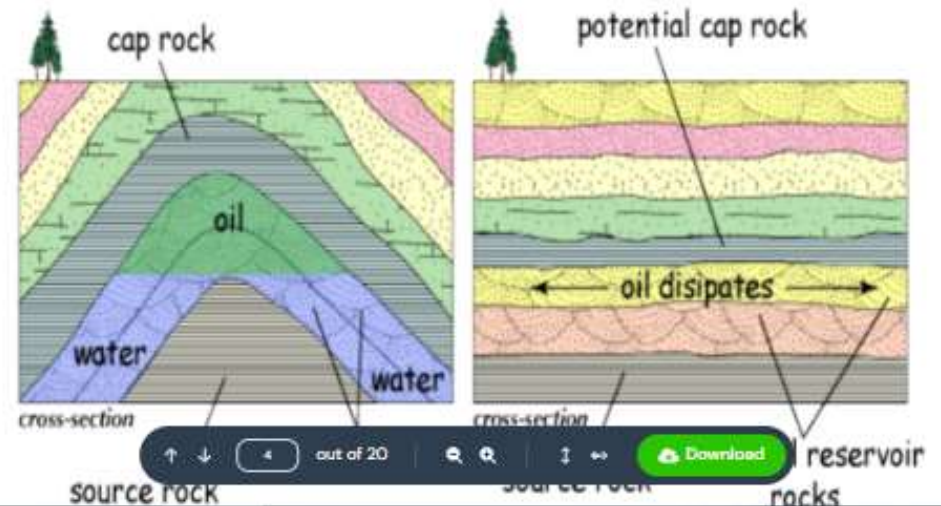
2.1 ROCK TYPES

The three major rock types - igneous, metamorphic and sedimentary - abound in Nigeria. Igneous and metamorphic rocks constitute the Precambrian basement complex which is the oldest, crystalline, solid physical foundation of the country. Sedimentary rocks fill up the basins which are vast depressions between basement landmass. The Basement Complex and the sedimentary basins are equally dispersed in Nigeria, with basement most extensive in

Northern Nigeria; less so in the south-western part of the country; and least along the eastern margin.

The sedimentary basins occupy the central x-shaped area in the country; they underlie all of southern Nigeria; and are also found in the northwest in Sokoto, and in Borno State and the entire Lake Chad in the north-east. Igneous and volcanic rocks occur mainly on the Jos Plateau, where they are the sources of mineral deposits such as tin, columbite, tantalite, wolframite, monazite and gemstones. Gold, molybdenite, and non-metallic minerals such as marble, feldspars and talc are among the mineral deposits in the Basement Complex.

Apart from oil and natural gas, groundwater and a host of industrial minerals such as barites, lime-stone and clay, the older sedimentary rocks are mineralised with lead and zinc. Coal and lignite occur extensively in the southern and middle Benue Trough, with the lignite belt extending into Delta State. Bitumen or tar occurs in Cretaceous sediments extending from Ogun to Ondo State. Lateritic superficial deposits are ubiquitous in Nigeria.



2.2 BASEMENT COMPLEX

Basement complex rocks are subdivided into migmatite-gneiss complexes; the older metasediments; the younger metasediments; the older granites; and the younger granite alkaline ring complexes and volcanic rocks. The migmatite-gneiss complex is the commonest rock type in the Nigerian Basement complex. It comprises two main types of gneisses: the biotite-gneiss and the banded gneiss. Very widespread, the biotitic gneisses are normally fine-grained with strong foliation caused by the parallel arrangement of alternating dark and light minerals.

The banded gneisses show alternating light-coloured and dark bands and exhibit intricate folding of their bands. The migmatite gneiss complex is the oldest basement rock, and is believed to be of sedimentary origin but was later profoundly altered into metamorphic and granite conditions. The older meta-sediments were also among the earliest rocks to form on the Nigerian Basement Complex. Initially of sedimentary origin, with a more extensive distribution, the older meta-sediments underwent prolonged, repeated metamorphism; and now occur as quartzites (ancient sand-stones), marble (ancient limestone's), and other calcareous and relics of highly altered clayey sediments and igneous rocks.

Most parts of the Basement complex are underlain by belts of roughly north-south trending, slightly metamorphosed ancient Pre-Cambrian sedimentary and volcanic rocks known as the younger meta-sediments. The major rock types are ancient shaly rocks which are now referred to as quartz-biotite-muscovite schist. These change laterally into coarse-grained feldspar-bearing micaceous schists. Schists with graphite, phyllites and chlorite are common.

Ferruginous quartzites and tale schists also occur. The younger metasediments contain most of the gold deposits in Nigeria in the northwest around Maru and Anka, and at Zuru; near Kaduna, and also at Ilesha in southwestern Nigeria.

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Older granites are widespread throughout the Basement Complex and occur as large circular masses within the schists and the older migmatitegneiss complexes. The older granites vary extensively in composition. The younger granite complexes in Nigeria are found mainly on the Jos Plateau, forming a distinctive group of intrusive and volcanic rocks that are bounded by ring dykes or ring faults. Other occurrences approximate a north-south belt towards the middle Benue in the south where the ages are younger and towards Niger Republic in the north where the younger granites are older. There is enormous variety in the granite composition of these rocks.

2.3 SEDIMENTARY BASINS

Nigeria is underlain by seven major sedimentary basins, viz: (from the oldest), the Calabar Flank, the Benue Trough, the Chad Basin, SE Iullemmeden (Sokoto) Basin, the Dahomey Basin, and the Niger Delta Basin. Sedimentary successions in these basins are of middle Mesozoic to Recent age. Older sedimentary deposits were not preserved, probably because during the Paleozoic - early Mesozoic, what is now Nigeria was a broad regional basement uplift, with no major basin subsidence for sediment accumulation. Nigerian basins are broadly divisible into coastal Calabar Flank, Niger Delta, Dahomey Basin and interior basins (Benue Trough, Chad Basin, Nupe Basin, SE Iullemmeden Basin). However, the sedimentary successions in these basins are broadly divisible into:

- (1) Basal continental sandstones, siltstones, and mudstones;
- (2) Middle marine shales and limestone's interceded with sandstones and siltstones;
- (3) Upper sandstone sequence that is continental or paralic.

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Although a tripartite subdivision is also applicable to the Niger Delta, this sequence has been growing seaward with lower marine shales grading through thick ancient coastal sandstones and shales, into an upper continental sequence. The middle ancient coastal sediments are oil-

and shales, into an upper continental sequence. The middle ancient coastal sediments are oil- and gas-bearing.

2.4 THE CALABAR FLANK

The Calabar Flank sedimentary basin that extends from the southern margin of this is Oban Basement complex to the boundary with the e Niger Delta. Here, sudden sediment thickening e demarcates the Niger Delta Basin that formed as the latest of a series of basins in the Benue Trough, diagonally crossing Nigeria from the southwest to ire the northwest.

A northwest-southern trending basement structure underlie the Calabar Flank and defines the Itu High and the Ikang Trough, thus relating the Calabar Flank to the South Atlantic Cretaceous marginal basins with similar horst-and-graben structures in Angola and Gabon. The sedimentary succession on the Calabar Flank is mostly of Cretaceous age, comprising an ancient river-borne sandstone, the Awi Formation; and the overlying marine Odukpani Group of Albian to Late Cretaceous age.

The Odukpani Group comprises the Mfamosing Limestone, the Ekenkpon Shale and the New Netim Marl, which are all exposed near the Odukpani local government area headquarters. This is uncomfortably covered by the Nkporo Shale. Tertiary marine shales and regressive sandstones overlie the Cretaceous succession. The total sediment thickness in the surfaces of the Calabar Flank is over 3500m.

2.5 THE BENUE TROUGH

The Benue Trough originated from Early Cretaceous rifling of the central West African basement uplift. It forms a regional structure which is exposed from the northern frame of the Niger Delta and runs north-eastwards for about 1000km to underneath Lake Chad, where it

terminates. Regionally, the Benue Trough is part of an Early Cretaceous rift complex known as the West and Central African Rift System.

Tectonic phases and basin development on the Benue: o Troughs are divisible into:

- (1) An Early Cretaceous rift phase with fluvial and lacustrine deposits;
- (2) Late Early to Middle Cretaceous phase of rapid basin subsidence and initiation of marine transgression in all rift segments, characterised by submarine gravity flows with megaslumps and turbidites;
- (3) Prolonged shelf and deep basin deposition especially in the southern part (Abakiliki Rift) under predominantly oxygen-deficient bottom conditions,
- (4) Tectonism, involving deformation and a- magnetism and the formation of lead-zinc deposits from circulating hot brines,
- (5) Late Cretaceous post-deformation subsidence with westward displacement of depocentres, especially in the Anambra Basin, where extensive coal forming swamps developed. Although several sub-basins or depocentres have been identified in the Benue

thick.

2.7 SE LULLEMMEDEN BASIN

Marine Late Cretaceous - Palaeocene beds in the SE lullemmeden Basin are well exposed into the Sokoto region, in Niger and extending into Mali. Two cycles of deposition constitute the Late Cretaceous - Palaeocene marine sequence in SE lullemmeden Basin. The Rime cycle of Late Cretaceous age comprises the Taloka Formation (50m of brown, laminated, parallel, bedded, carbonaceous, fine-grained sandstone, siltstones and mudstones), overlain by the Dukamaje Formation (10m of basal bone bed, gypsiferous, fissile, gray lower and upper shales and middle marl). The Palaeocene Sokoto cycle comprises the Wurno Formation (20m of soft, tabular mudstone, muddy siltstones, and fine-grained sandstones at the base which grades upward into the Dange shale (10m thick), and the Kalambaina Formation (12m of nodular, marly limestone which becomes shaly at the top). The Gwandu Formation above is a ferruginous sandstone of continental origin.

2.8 DAHOMEY BASIN

This is an arcuate coastal basin, the onshore parts of which underlie the coastal plains of southwest Nigeria, Benin and Togo. A faulted basement high, the Okitipupa Basement Ridge

Trough on geophysical (gravity) evidence, structurally and in terms of sediments three segments, the Lower, the Middle and the Upper Benue Trough, have been recognised.

2.6 THE SOUTHERN CHAD BASIN

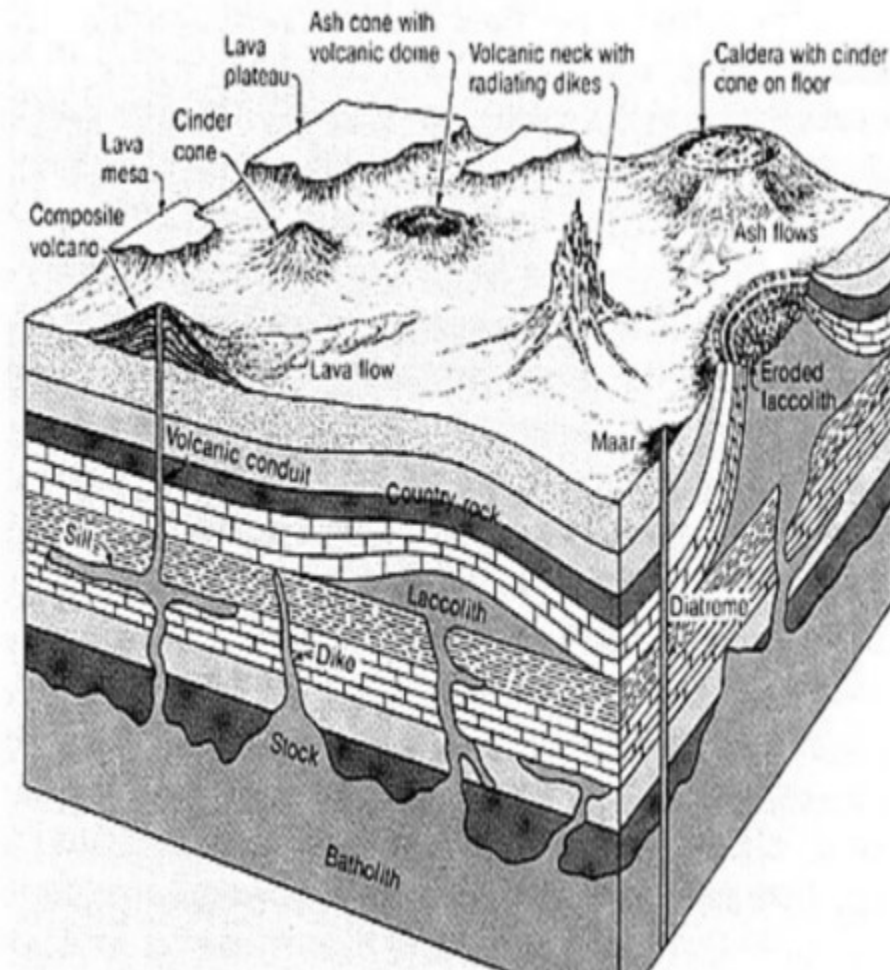
This is poorly exposed in Nigeria and merges with the Upper Benue Trough. A subsurface basement high, the Zambuk Ridge, separates the Southern Chad Basin from the Upper Benue. The Bima sandstone is the oldest sedimentary deposit in the Chad Basin. A Middle Cretaceous shale-limestone succession, subdivided into the Gongola Formation at the base and the Fika Shale at the top, constitutes the marine and transitional deposits which extend from the Upper Benue into the Southern Chad Basin. The Tertiary Chad Formation is very

separated the Dahomey Embayment from the Benue Trough until the late cretaceous subsidence and marine transgression united both basins. From available subsurface stratigraphic information, it is apparent that some of the basement blocks underlie the Dahomey Embayment are displaced towards the NNE-SSW basin axis as well as towards the offshore.

At the base of the sedimentary succession is the bitumen- bearing sand of enormous economic potentials. Shallow boreholes have penetrated continuous Late Cretaceous marine shales which are correlated with the Nkporo Shale Formation. Nearer the coast and offshore, the marine beds are older. Lower Tertiary marine units (Palaeocene Ewekoro Limestone Formation and the Eocene phosphatic Oshosun Formation) are exposed in quarries at Shagamu and Ewekoro in Ogun State, and at Onigbolo and Tabligbo in neighbouring Benin Republic. Although the younger Tertiary strata exposed along the coast are non-marine, marine Miocene deposits (Ijebu Formation, Afowo Beds) are known in the offshore subsurface.

2.8 NIGER DELTA

In its sedimentary succession, the Niger Delta comprises a lower marine unit, the Akata Group; a middle coastal unit, the Agbada Group; and an upper continental sequence, the Benin Group. Each of these units represents an enormous geologic age span, because of the advancement of the Niger Delta ocean ward. Ancient marine shales in the Niger Delta provide excellent source rocks for petroleum, whereas the sands are the reservoirs where oil and gas accumulation took place; trapping is mostly along faults.



3.1 COAL AND LIGNITE

Like other parts of the world, coal is the oldest commercial fuel, dating in Nigeria from 1916 when 24,000 tons were produced. Production peaked at near one million tons in 1959, before declining to the present insignificant level. This is due to the reduction in the demand for coal arising from dieselisation of rail transportation, and switching from coal to gas for thermal power generation.

Nevertheless, Nigeria's coal reserves are large, over 2 billion metric tonnes, of which 650 million tonnes are proven. If fully revitalised, the coal industry could fetch up to 5 billion Naira in export earnings. Coal production is from the Cretaceous Anambra Basin which extends to Dekina in the northern part of the basin in Benue State and to Okigwe in the south. The coal in this basin is sub-bituminous and occurs principally at two levels, the lower coal measures (Mamu Formation) and the upper coal measures (Nsukka Formation).

From north to south, the reserves from seams over one meter thick, are (in million tonnes); Ogboyoga (100), Okaba (70), Orukpa (60), Ezimo (50), and Enugu (50) (FRN, 1987). Coal

seams also occur at Gombe in Gombe State. Mine production capacities after full rehabilitation and privatisation could attain the following levels: Onyeama and Okpara (150,000-400,000 tonnes/year), Owukpa (2,500 tonnes/year) and Okaba (15,000-300,000 tonnes/ year). Nigerian subbituminous coal has a high calorific value (5,000-6,000 cal/g or 5500-6500 airdried), low ash and low sulfur contents, with good storage characteristics (Afonja, 1979).

In the Lafia-Obi area of Nassarawa State, good quality cooking coal has been discovered which is suitable for use in the iron and steel industry. If utilised, the Lafia-Obi coal would save the country the high cost of importing cookable coal. Since the Nigerian Coal

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Corporation has lost nearly all its traditional customers, notably railways and power authority, a recent drive to market its coal overseas offered some hope of recovery.

European buyers in Italy and the United Kingdom have started importing Nigerian coal,

because its low sulfur content is environmentally acceptable. As already noted, Nigeria has the largest lignite deposit in Africa, with reserves of about 50 million tonnes. The Nigerian lignite belt, of mid-Tertiary age, extends from Oriu in the south-east, through Urnuezeala, Umuahia, Nnewi, Oba, in a 20 to 40km - wide belt across the Niger, to Ogwashi, Asaba, Mgbiigliba and Adiase-Uti in Delta State. It has not yet been exploited.

CHAPTER FOUR

4.1 NON-METALLIC MINERAL AND INDUSTRIAL MATERIALS

Crushed rock, gravel, sand and clay are ubiquitous building materials widely used for rural and urban dwellings, and in the construction industry for civil engineering works such as roads, buildings, bridges and dams. The Basement Complex furnishes a rich source of crushed rock which is augmented with basalt, dolerite and limestone in some places. Laterite is a common building and road-surfacing material. River gravel of various sizes are widely available as aggregates and building material, especially in Akwa Ibom and Cross River states.

Sand of glass-making quality has been found and assayed in many parts of the country (Odukwe, 1981). In Port Harcourt, the Trans-Amadi sands contain over 99 per cent Silicon oxide (SiO₂) and at Ughelli, another clean coastal plain, sand deposit assays 97 per cent Silicon oxide (SiO₂). Both sands are used for the manufacture of bottles and window glass. The West African Glass Company at Aba utilises a local sand deposit. Many other glass sand deposits are known especially along the coast. Reserves are inexhaustible since full industrial

use has hardly begun.

Clays of various kinds and grades abound throughout Nigeria's sedimentary basins and on the basement. Nigeria has a rich traditional pottery industry that dates from the Stone Age. In all parts of the country, native pottery is a vibrant traditional art form and an established cottage industry for earthen wares. Modern industrial uses of clay for ceramics and bricks obtain throughout the country. Ceramic works at Abeokuta (Ogun State), Ikorodu (Lagos State), Okigwe (Imo State), Umuahia (Abia State) and Suleja in Niger State produce glazed wares from local kaolin. Refractory clays for refractory bricks have been proven at Onibode near Abeokuta where the refractoriness is very high at about 1,750°C.

In Enugu, beneath the coal seams, are vast deposits of other fire clays, with reserves of about 130 million tonnes. Other major clay deposits occur in Akwa Ibom (Etinan, Itu, Onna, Uyo); Anambra State at Ozubulu (3.5 million tonnes) and Ukpok (4.2 million tonnes); Edo/Delta

States at Igoriakhi (over 14.0 million tonnes); Imo/Abia States (over 2.0 million tonnes) at Igbere and Ogbuebule; Kaduna State (over 5.3 million tonnes) at Miraba- Rido and Kaohia; Katsina State (3.4 million tonnes) at Kankara; Ogun State (over 2.0 million tonnes) at Oke-Eri and Illefun Hill; large deposits in Ondo State; over 18 million tonnes in Plateau State at Nafuta, Worrom, Major Porter and Sabon Gida; and, in Sokoto State 2.0 million tonnes of pisolitic clays occur at Girl, and clay bricks are made at Wurno (RMRDC, 1989). Bentonitic clays, which are used for drilling mud, were first produced in Bende in Abia State in 1961-62.

Recent investigations by the Nigerian Mining Corporation, aimed at locally sourcing the enormous amount of bentonite imported into the country by the petroleum industry, established the existence of bentonitic clay reserves of over 700 million tonnes in the country, with the largest single deposit at Afuze in Edo State holding 70-80 million tonnes. Limestone and gypsum, the principal raw materials for cement manufacture, are very essential for a rapidly growing nation like Nigeria.

And, indeed, cement is in very high demand in the country. While limestones abound in Nigeria more than in any other West African country, gypsum and other salts have not been found in commercial quantity. The nearest potential source of gypsum for Nigeria could be Mali Republic, where millions of tonnes of mineable salts occur at Agorgott. As for clinker

(processed limestone for cement), Nigeria could export this material to Cameroun, which at present obtains its clinker from Europe.

Seven out of the eight cement factories in Nigeria are sited close to limestone deposits, except the plant at Okpilla in Edo State, which uses marble. The cement factory at D'Onigholo in Benin Republic is jointly owned by Benin (52 per cent) and Nigeria (46 per cent); It is

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located on the Ewekoro limestone deposit which extends from Ogun State in Nigeria to as far as Ghana. Other cement factories in Nigeria are located at Ashaka, Yandev, Nkalagu, Shagamu, Okpilla, Ewekoro, Sokoto and Calabar.

The limestone at Mfamosing, near Calabar, is the largest and the purest deposit in Nigeria. It is about 50m thick, at the quarry site. West of Calabar, another carbonate body occurs in the subsurface that is 450m thick. The Calabar flank is the main carbonate province in Nigeria, with well-developed tropical karsts and caves (Reijers and Potters, 1987). The Mfamosing

limestone has over 97 per cent limestone (CaCO_3).

It is used by the Delta Steel plant at Aladja as a fluxing agent and for making hydrated lime. Marble is found in the Basement Complex and is quarried at Jankura near Lokoja, at Ubo near Okene, and at Okpilla. The Jankura marble is utilised as decorative marble by the Nigerian Marble Industries. Dolomitic marble deposits are exploited at Igbeji in Oyo State and at Kwakuti in Niger State. Other deposits are at Elehu in Kwara State, Kobe in Benue State, Muro Hill in Plateau State, and at Burum and Taka Lafia in the Federal Capital Territory.

Feldspar, a mineral that is used locally in the ceramic and glass industries, occurs abundantly in the Basement Complex. Economic deposits are found in the granitic intrusive in the basement and especially in pegmatite's where potash feldspar is the commercial type. Important sources of feldspar rich pegmatite's occur in Kwara and Kogi States and also extensively around Osogbo in Osun State. Near Oshogbo, potash feldspars attain lengths of 0.9m, but around Ijero in Ekiti state, gigantic crystals are up to 1.2m long.

Feldspar-rich pegmatites are common in the Qwozan area of Borno State and in parts of Adamawa/Taraba states. Although rock salt has not been found in Nigeria, highly saline brines in the Benue Trough provide potential local sources of salt except, of course, the open

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ocean and there are as yet no Salinas on the Nigerian coast. But along the Benue Trough brines, salt springs, salt ponds and shallow subsurface brine pools are commonly associated with lead-zinc deposits.

Salt concentrations are up to 1.5 per cent in the Ikom area and 8.6 per cent at Okpoma in Cross River State, where the richest occur. At Uburu-Okposi in Abia State, the salt concentration is up to 5 per cent and 5 - 6 per cent at Ameri. near Abakaliki. Further north, in Nassarawa State (Keana, Awe) and in Taraba and Adamawa States, there are other brine

fields. Geophysical investigations by the Geological Survey of Nigeria and other organisations aimed at locating salt domes in the Benue Trough, have so far not found any.

Therefore, the establishment of local, modern and large-scale salt industry in Nigeria is still a dream not realised. However, at Okpoma, Ikom, Uburu, Okposi, and Abakaliki and in the Keana/Awe areas, the local people have established a long tradition of winning salt from their brines.

Among the metallurgical and refractory minerals needed for the reduction of ores from their metallic state and for making resistant materials for high temperature metallurgical furnace, which will be required by the local metallurgical industries (e.g. iron steel plant), only fluorspar and graphite seem to have commercial prospects in Nigeria.

The lead-zinc lodes in the Benue Trough carry small amounts of fluorspar which also occur in tin veins in the younger granites. Impure graphite is known in the younger metasediments near Birnin Gwari in Kaduna State, Taraba and Adamawa States, at Hayna (Ningi) in Bauchi State and in the Obudu area of Cross River State.

Other refractory minerals, such as sillimanite and kyanite, occur in the Birnin Qwari schists, while sillimanite is found in the vicinity of Ibadan. Other industrial and manufacturing

materials such as mica, talc, asbestos and barytes also occur in the country. There is a mica deposit around Egbe in Kwara and Kogi States which was mined in the past.

The crystal size of Nigerian mica is often not large enough to be economic. Low grade talc occurs in schists near Ibadan (Oyo State), Ilesha (Osun State), Abuchi in Niger State, Zonkwa in Kaduna State and at Isanlu in Kwara State. Asbestos exists at Shemi in Kaduna State, and a large deposit occurs at Chafe in Sokoto State.

Barytes, major weight filler for drilling mud, occurs in veins, up to 1.8m thick in association with lead- zinc deposits in Cross River, Benue, Plateau, Taraba and Adamawa States. Major baryte occurrences in Nigeria are at Lefin in Cross River State, at Alosi, Akuri, Wuse, Azara

CONCLUSION

and Gbane in Plateau State. Keana in Nassarawa State and at Ibi and Durngel in Taraba and Adamawa States.

At Azara, good quality baryte reserves of about 70,000 tonnes have been proven by the Nigerian Mining Corporation. Finally, the Nigerian basement also holds some prospects for gemstones. In Nassarawa, Plateau and Kaduna States, aquamarine, emerald, sapphire, ruby, topaz, tourmaline, zircon and almandine have been won from pegmatites.

Geologically, Nigeria comprises crystalline basement rocks and sedimentary basins, almost in equal proportions. The ages of the basement rocks span Precambrian to early Palaeozoic, having been consolidated during the Pan-African. The sedimentary basins are of Cretaceous to Recent age. While road construction and maintenance are comparatively cheaper on basement terrain, the sedimentary basins present enormous difficulties and lead to high construction costs, the situation being more challenging in the Niger Delta. However, the geology of Nigeria provides a unique source of petroleum and mineral wealth, and unparalleled opportunities for rapid economic development.

