The Nigerian Mining and Geosciences Society (NMGS) succeeded in 1977, the Nigerian Mining, Geological and Metallurgical Society (NMGMS) which was founded on 15 January, 1961, and officially inaugurated on 17 December, 1962. Among its objectives, are the advancement of the study and practice of mining, geological sciences and metallurgy, and the promotion of the acquisition and dissemination of scientific contributions and knowledge in the relevant fields. The Society also ensures the protection of the ethics of the respective professions, and has statutory representation in the Council of Nigerian Mining Engineers and Geoscientists (COMEG) enacted into law by the Federal Republic of Nigeria Decree No. 40 of 1990. The categories of membership are Student, Graduate, Corporate, Fellow, Institutional, Affiliate and Honorary Member/Fellow, and the current strength of ca. 3500 includes Nigerian and foreign professionals and practitioners working or have worked within the country.

This multi-disciplinary publication was initiated in 1963, and to 1965 titled the Journal of the Nigerian Mining Geological and Metallurgical Society. Its current title, Journal of Mining and Geology adopted from the edition for 1966, was modified between 1982 and 1987, as the Nigerian Journal of Mining and Geology. The production of the Journal is normally biannual (2 issues per volume) in March and September; and from Volume 35 No.1 1999, has being under the aegis of the Petroleum Technology Development Fund (PTDF). The publication has international contributorship, circulation and citation. All contacts including correspondence on advertisement and back numbers, should be directed to the Editor-in-Chief.

Volume 47  Number 1  March 2011
Journal of Mining and Geology

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INTRODUCTION

Mineral resources are the major sources of raw materials in several manufacturing industries such as iron and steel, tin smelting, glass, chalk, fertilizer, cosmetics and construction to mention a few. The Geological Survey of Nigeria has played an active role in the exploration for these mineral deposits, which go back to 80 years. An important parameter in determining the importance of mineral resources in Nigerian economy and national development is the usefulness of these minerals in the manufacturing industry and their place in international trade. The metallic mineral deposits such as gold and tin for example, have high unit values and are marketed internationally. On the other hand, non-metallic minerals (industrial) have high place values and rarely enter international markets.

The degree of industrialization of a nation is directly related to the level of utilization of its mineral resources. Fortunately, the Nigerian government has recently focused its attention on the development of solid mineral whose production has been declining over the years. Since the materialization in any area is influenced by its geology, it will be appropriate at this point to review the geology of southwestern Nigeria.
GEOLOGICAL ENVIRONMENT OF MINERAL RESOURCES

Southwestern Nigeria in this presentation covers, Lagos, Ogun, Oyo, Osun, Ondo and Ekiti States. However, where necessary allusion is made to neighboring states of Kwara and Kogi. The southern part of the region, which is bounded by the Atlantic Ocean, and constitutes about 25% of the total area, is covered by sedimentary rocks of the Nigerian sector of the Dahomey (Benin) basin. The remaining 75% is underlain by crystalline rocks of the Precambrian basement Complex of Nigeria.

Basement Complex
The basement complex consist of four broad groups of rocks as follows:

(i) Gneiss-migmatite-quartzite complex
(ii) Schist belts
(iii) ‘Pan-African granites (Older Granites) and associated granitic rocks
(iv) Minor felsic and mafic Intrusives

Gneiss-migmatite-quartzite complex
This group of rocks constitute more than 70% of the basement complex. It is made up essentially of high grade metamorphic rocks, which comprise schists, gneisses, migmatites, marbles and quartzites of Precambrian age (over 2 billion years). The gneisses and migmatites are so intimately associated that they are hardly separable on the field. They are ubiquitous and form the bulk of the rocks in the group. A characteristic feature of these rocks is a display of banding of varying width, at least in part. The migmatite is a mixed rock composed mainly of a gneissic host and intruded granitic and pegmatitic rocks.

Both the quartzite and the marbles occur as relatively minor concordant layers within the gneiss-migmatite units. Because the quartzites are resistant to weathering and erosion, they tend to stand out, sometimes as prominent hills and ridges within the basement complex in places such as Ibadan, Iseyin and Ife areas.

All the rock types in the gneiss-migmatite complex are sources of construction materials for roads, building, bridges, dams, airport, etc. The marbles can also provide valuable raw materials for chemical industry.

Schist belts
The schist belts consist of approximately N-S trending, narrow zones of low to medium grade metamorphic rocks of mainly sedimentary and minor igneous origin which were deposited previously on the pre-existing gneiss - migmatite - quartzite basement. The rocks of the schist belts are also described as ‘Younger Metasediment’, composed of phyllite, schist, quartzite, amphibolite and flaggy gneiss of Paleoproterozoic age (about 2 billion years). Associated with the schist belts in several localities, are talc-bearing schist, which are considered to be remnants of mafic ultramatic complexes. Economic minerals associated with the rocks of the schist belts are gold in flesha area and talc in Apomu, Iregun and Iseyin districts.

Pan-African granites (Older Granites)
These granites occur as intrusive bodies of various dimensions in the pre-existing basement rocks, i.e. the gneiss - migmatite - quartzite units and the schist belts. They are widely distributed in southern Nigeria and are found in all the states of the region except Lagos, which is entirely covered by sedimentary rocks. They consist of a suite of porphyritic and non-porphyritic granite rocks of different textures. However, the medium to coarse - grained porphyritic variety is more common. One of the striking features of the Older Granites is their occurrences as picturesque inselbergs that is, prominent hills rising sharply above their surrounding plains. Such granite hills occurs as Olumo rock in Abeokuta, as Idanre Hills in Idanre, Ikere Hills in Ikere, etc.

In some places, a bluish - green rock, known, as charnockite, and minor syenite are associated with the Pan African granites. The charnockite features prominently in Akure and Ekiti areas while the syenites are found mainly in Shaki area.

The Older Granite and associated rocks are sources of construction materials, particularly rock aggregates and powder, used for making roads, building, bridges, dams etc. Both the granites and the charnockites are used for making polished stones.

Minor felsic and mafic Intrusives
These consist of concordant and discordant dykes, veins and irregular bodies of pegmatite, aplite, quartz, dolerite, gabbro, pyroxenite and serpentine. They
The sedimentary rocks of southwestern Nigeria extend from the Nigeria/Benin boundary in the west of Makurdi, Otta and Iganam in the east. The stratigraphical relationship between these rock units is discussed below.

Abeokuta Group is the oldest, and it consists of sands and intercalations of argillaceous sediments, which lie unconformably on the crystalline basement. The group, which was formerly known as Abeokuta Formation, has been recently sub-divided into three formations (Onatsola and Adegoke, 1981), namely:

(a) Ise Formation, which overlies the basement complex and consists of pre-drift sediments of grits and siltstones and over-lain by coarse to medium grained, loose sands interbedded mostly with kaolinitic clays;

(b) Afowo Formation, which consists of transitional to marine sands and sandstone with variable but thick interbedded shales and siltstone. The shale to sand ratio increases upwards with the sediment becoming highly fossiliferous. The entire sequence represents paralic sedimentation; and

(c) Aaromii Formation that is the youngest of the stratigraphic sequence and is composed of shales and siltstones with interbeds of limestone and sands. It is richly fossiliferous.

Overlying the Abeokuta Group is the Ewekoro Formation, comprising of grayish, white and greenish limestone, sandy at the base. Microfossil study of the limestone shows that the sediments were deposited in a shallow marine environment. It is Paleocene in age. Akinbo, Oshosun, Ilaro and Benin Formations in turn overlie Ewekoro Formation successively. Akinbo Formation consists of fissile and well-laminated shales. It is the western equivalent of Imo Formation in eastern Nigeria. Its age is lower Eocene. Oshosun Formation is Eocene in age and is characterized by a dull, red siliceous sandy mudstone with sandy pockets. There are inclusions of phosphorite and glauconitic material in the lower part of the formation and the upper part is made up of medium to coarse-grained silty sandstone.

Ilaro Formation is made up of both marine and continental yellowish massive and poorly consolidated sandstones, which are fine to medium grained and poorly sorted. Fossils are rare because of its continental character. It is Eocene in age.

Benin Formation, also known as Coastal Plain Sands, is the youngest unit and consists of soft, very poorly consolidated pebbly sands, lacking in fossils. It is Eocene to Recent in age.

MINERAL RESOURCES OF SOUTHWESTERN NIGERIA

It is pertinent to state at the beginning that it is customary for geologist to distinguish between mineral resources and mineral reserves.

The term resource refers to hypothetical and speculative undiscovered, sub economic mineral deposits or an undiscovered deposits of unknown economics (Peters, 1981). Reserves on the other hand, are concentrations of usable mineral or energy commodity which can be economically and legally extracted at the time of evaluation. The scope of this study embraces both resources and reserves. The mineral resources of Southwestern Nigeria can be classified into metallic, non-metallic (industrial) and energy minerals. The metallic minerals include gold and tantalite – columbite, while the non-metallic minerals comprise limestone, marble, talc, feldspar, mica, sillimanite, gemstones, bitumen, clays, phosphate, silica sand, gypsum, yellow ochre, coal laterite and gravel, and rocks for construction materials and polished stones. It is clear from the foregoing that Southwestern Nigeria is more endowed with non-metallic minerals, some of which are currently being exploited in different places.

Gold

Gold occurs in Ilesa area and is associated with the younger metasediments (schist belts). Nodular deposits are located at Iggunmodi, Iperindo and Ilbodi. Other occurrences are found at Ilawe, Iloko, Ifira and Idosa. These deposits are of two types, namely, primary and alluvial gold deposits. The primary deposits consist...
essentially of tiny auriferous quartz veins and stringers which have invaded sheared zones in granite gneiss at Iperindo and in amphibolites at Itagunmodi and Ile-ibobi. The alluvial gold deposits are derived from the erosion of primary deposits in the country rocks and the concentration of the eroded gold in the channels of tributaries of Rivers Osun and Ogun in Ilesa district (Adekoya 1978). The primary deposits are persistent and low grade while the alluvial deposits are richer and more widespread. The latter thus constitutes the main source of gold exploited in Ilesa area. Both old and current river channels, as well as flood plains in the gold bearing area are still a good source of alluvial gold.

Annual reports of the Department of Mines (1922–1980) show that almost 90% of Nigeria’s total gold production of 12,000 kg since 1914 has been from alluvial deposits derived from primary gold mineralization in the western part of the basement rocks, where the schist belts are best developed. Gold reserve in the Ilesa area is now estimated at 170,000 Troy ounces. The total gold reserve over an area of 94.6 hectares in the Itagunmodi area is 186 kg (6,000 Troy ounces). Primary gold in the Itagunmodi and Iperindo areas have grades varying from 5.3 grammes / tonne to 62.2 grammes/tonne with an average of 20.2 grammes/tonne. Investigations to establish occurrences of gold in Ibadan and Apomu are still in progress. Gold is used for monetary purposes in which it is kept as bullion, in reserve; to stabilize paper money and ease settlement of international trade balances. It is also used as ornaments in jewellery due to its softness (hardness is 2.5–3.0).

It is pertinent to mention that gold also occur in Isalu-Okojum area of Kwara State, which is located north of Ilesa district. The metasediments with which the gold is associated are actually a northern continuation of the Ilesa schist belt.

Tantalite–Columbite–Cassiterite

These three minerals are commonly associated together in granitic rocks including pegmatites. Both columbite and tantalite occur together as end-members of the columbite–tantalite isomorphous series. Columbite, when it is pure, is iron–niobium oxide (FeNb₂O₆) and tantalite is iron tantalum oxide (FeTa₂O₆). Since both substances are naturally associated, any occurrence of the mineral would contain a certain proportion of the two end–members. The ratio of columbite to tantalite in samples will vary depending on the ratio of niobium (Nb) and tantalum (Ta) in them. Because Ta attracts a higher price than Nb at present, the miners are more interested in tantalite or Ta-rich samples.

The columbite–tantalite mineral occurs in the Older Granite pegmatites which are found predominantly at Ofiki, Igbogbo, Ile-ife and Shaki in Upper Ogun area, Oyo state at Olugbaya, Olodo, Lamolo and Wofun Ayana Church in Ibadan area, Oyo State; at Awo, Ede, Ode-omu, Ile-Odan, Ile-Ife etc. in Osun State, at Iperindo, Aramoko and Oye in Ondo state, and at Mamu area of Iperindo in Ogun State. The pegmatites as mentioned earlier are complex pegmatites because they contain exotic minerals such as the columbite–tantalite, tourmaline and beryl in addition to the common pegmatite minerals (quartz, mica and feldspar). However, it would appear that not all the pegmatites are columbite/tantalite-bearing. Tantalite has been won by illegal miners from Ofiki, Ile-ife, Igbogbo, Wofun Ayana Church and Awo. Recently, the itinerant miners have shifted to Oyo, Kwara state, where tantalite is currently being mined illegally.

Cassiterite occurs in the older granite, pegmatite at Iperindo, Ekiti State. The deposit was extensively mined during the colonial era and it would appear that the richer ores have been depleted.

There are yet no figures to indicate the reserves of tantalum and columbite available in Southwestern Nigeria. There are no local markets for columbite mineral concentrates at present and production is mainly geared towards export.

Sulphides

A variety of sulphide minerals including pyrite, pyrrhotite, pentlandite, bornite and chalcocite occur in small amounts in the gabbro-intrusions and the metavolcanics of Ilesa schist belt (Baloge 1970; Elueze 1981). They commonly occur in association with chromite, nickel and cobalt. Although most of these occurrences are only of mineralogical importance, however, they may be indicative of petrological environments favourable for economic mineralization. Nickel is an alloy metal and is chiefly used in production of nickel steel and nickel cast iron. Cobalt is used for the manufacture of carbid, magnet steel and stainless steels. Chromium is also an alloy metal and a refractory.
Iron occurs as medium to coarse grained magnetite quartzite at Ajase, Iponrin, Gbede Oke and Otonokun in Ogbomoso district (Arcelloni and Maranzana, 1965; Adekoya and Oladeji, 1986). The magnetite quartzite exists in narrow (< 1 - 3m wide) bands which vary in length from a few hundred meters to a few kilometers.

Assaying of the iron bearing quartzite yielded Fe values ranging from 34 - 41% (IPCO, 1965). Previous investigation by the Geological Survey of Nigeria indicated inferred reserves of 100,000 tons of iron in Ajase area. There is evidence in form of several old workings and smelting furnaces in Iponrin to show that these iron deposits had in precolonial times supported an iron smelting and fabrication industry that once thrived in Oyo province. Although, a previous field investigation suggests that the Ogbomoso deposits have prospect for small scale mining, it is desirable to carry out more detailed investigation of entire Ogbomoso district using modern geophysical equipment. It is hoped that more of the ferruginous quartzite buried under an overburden of thick lateritic soil will be revealed.

It is useful to mention that large iron deposits of commercial value have been found in Okene and Lokoja areas in the neighbouring Kogi State, located north of Ondo State. These deposits include:

(i) Precambrian banded iron formation (Older BIF type) of Itakpe, Ajabonoko, Chokochoke, Agboido Okudii, Ebiya-Ero and others, whose aggregate reserve are over 600 million tons of iron-ore, and

(ii) Lorraine of Minette type ironstone of Maestrichtian age which occurs in three areas namely; Agbaja, Koton Karifi and Bass-Nje and contains total iron ore reserves of over 2 billion tons.

Unfortunately, however, the Lokoja deposits are characterized by high contents of phosphorus, which is detestible to iron.

Iron, which is the backbone of industrialization, is used to manufacture plants and machinery employed in industry for producing various goods. It is also extensively used for the construction of vehicles, buildings, bridges, office equipment and furniture. Other uses include fabrication of cutlery, kitchen utensils, lamps, pressing iron, water pipes, casings etc.

Talc
Several talc occurrence have been found at the Wonu and Ladunin in Apomu area and at Asogbo, Obaluru and Iregun in Ilesa area, all in Osun State, and at Iseyin, Oyo state. Also, it occurs in Ile and Ijero-Ekiti where they are associated with the amphibolites of the schists belts (Kehinde-Philips, 1973 and Elueze, 1982). The talc bodies area part of magnesian products of alteration or metamorphism of mafic ultramafic complexes, which are associated with the schists belt. Varying percentages of talc are present in the talc bodies. For example, Wonu, Obaluru and Asogbo deposits contain 65%, 70% and 85% respectively of talc with minor or subordinate amounts of tremolite, anthophyllite and chlorite.

Chemical analysis has revealed that magnesium oxide (MgO) contents of these talc bodies vary from about 31.7% to 32.3% (Durotuye and Ije, 1991). These MgO values are comparables with those of commercial talc that range from about 26.1% to 34.5. In addition to the chemical composition, the physical properties of the talc deposits indicate that they are suitable raw materials for ceramic, paper, rubber, plastics, paints, cosmetics, pharmaceutical and fertilizer industries. However, because the western Nigeria talc deposits are generally small, their reserves being only a few thousand tons, up to several tens of thousand tons, they can only be considered for small scale exploitation.

In the neighbouring Kwara state to the north, a relatively large deposit occurs at Odogbe in Isanlu Makutu. The deposit, whose estimated reserve is put at over 250,000 tons, has suitable chemical and physical properties for industrial application in most of the industries listed earlier.

Sillimanite
Sillimanite is aluminium silicate (Al₂SiO₅), which is trimorphous with kyanite and andalusite. It is a product of high-grade metamorphism and it is highly refractory. Two occurrences have been located at Olode, near Ibadan, Oyo State and at Odo-Ilesa, Osun State, near Abeokuta, Ogun state. In both cases the sillimanite is associated with quartzites that are interbedded with a green magnetite unit. The deposits are currently being investigated by the Geological Survey of Nigeria. Sillimanite is used in the manufacture of insulators, refractories and ceramics.
Feldspar and Quartz
Feldspar and quartz are abundant in granitic rocks of Southwestern Nigeria. Potash feldspar is the most important and commercial supplies are usually derived from pegmatite dykes. Feldspar and quartz deposits occur in Osogbo, Ilero (Iregun) and Abeokuta. Also, some of the complex pegmatites mentioned above sometimes contain large crystal feldspar, commonly microcline, which can be quarried for use. Example of such pegmatites have been found around Ode Omu, Ede and Awo in Osun state and Igbelua and Iwozoko in Ekiti State.

Large deposits of microcline feldspar also occur in neighbouring Kogi State (Osara forest and Okene) and in Oka area of Edo state. Feldspar is used for glass making, in the pottery industry, ceramics, wall and floor tiles and manufacture of artificial teeth among other uses.

Marble
Marble is metamorphosed limestone. The only known marble deposit in the six states of southwestern Nigeria is that at Igbeti, Oyo State. It is interbanded with other basement complex rocks such as gneisses, quartzite and schists. The marble forms an elongate body that stretches for about 130km in the N-S direction and varies in thickness from less than 0.5km in Igbeti area in the northern part to about 1km south of Alagutan in the southern portion of the marble body. A small marble deposit that has not been investigated also occurs in Idan-Ondo state.

The Igbeti marble is dolomitic as it contains up to 21% MgO (Magnesium oxide) and 30% CaO (calcium oxide) which correspond to nearly 44% MgCO₃ (magnesium carbonate) and 55% CaCO₃ (calcium carbonate) in the deposit (Oluype et al., 1990).

About 70km east of Igbeti, another dolomitic marble deposit exists at Elebu in Kwara State. Other large marble deposit found west of the Niger are located at akura, Osasa forest and Ufo River area in Kogi state and at Igarra and Ukplia in Edo state. The deposits of Kogi and Edo states are largely calcitic, containing not less than 51% CaO that translates to over 90% CaCO₃.

Bauxite
Bauxite occurs at Orin in Ekiti State and Oyan in Oyo State. No major exploration for bauxite has been carried out yet and the reserve is not known. It is an ore of aluminium and it is also used as abrasive among others.

Molybdenum
There are reported traces of molybdenum in Iken area in Ekiti state (Makanjuola, personal communication). There is need for further investigation.

Zircon
Zircon occurs in traces in the pegmatitic intrusions within the basement rocks in Ekiti and further investigation is needed.

Limestone
Limestone is a bedded sedimentary deposit, which is made up dominantly of calcium carbonate (calcite). It occurs in the Tertiary sediments of the Nigerian sector of the Dahomey (Benin) Basin and in the Upper Cretaceous sediments of the westernmost portion of the Anambra Basin. In western Nigeria, the Tertiary limestone, known as Ewekoro limestone, forms a bed at least 16m thick and 120km long in an E-W direction. It can be traced from Yemogi valley, southeast of Ijebu Ode through Sagamu, Oida, Papa Alanti, Ibeje, Owode, Ijan-Egugua and Ijuen all in Ogun State, to the Benin Republic border. Adekoya (1982) has made a forecast reserve of over 100 billion tons within a 10 metre thickness of the limestone in the entire E-W belt.

Ewekoro limestone is overlain by a shale sequence called Akmbo Formation, and underlain by sandstone and grits of Araromi Formation (former Abeokuta Formation). The limestone dips gently underneat the Akmbo shale, extending like other formations to the Atlantic continental shelf. Currently, Ewekoro limestone is being explored by the West African Portland Cement at Sagamu and Ewekoro. On account of its large reserves and wide distribution, the Ewekoro limestone belt still offers great opportunities for exploitation in many places along the belt.

Limestone also occurs as thin lenses intercalated within Nkporo Shale of upper Cretaceous age in the Okeluse-Atiogiga district of Ondo State. The limestone lenses extend for a few hundred meters and vary in thickness from 1.5 - 1.4m in Okeluse area. A total reserve of over 7 million tons of limestone has been estimated for three occurrences located around Okeluse. (Ojo 1971; Futa Consultants, 1988).
Clay deposits of Southwestern Nigeria fall into two categories, viz. primary or residual clays and secondary or sedimentary clays. Chemical weathering or hydrothermal alteration of crystalline rocks in situ forms primary clays. Such clays are present in lateritic weathering profiles developed on the basement complex rocks, notably gneisses and granites and schists. Ther e is primary or residual clay. Notable primary fire clay deposits occur in the following localities:

(i) Ibadan and surrounding villages, Oyo, Saki, Iese, and Iretapata, Eruwa, Kishi in Oyo state,
(ii) Iwo, Ede, Awo, Illesa, Ilesa, Erin Oke, Ikere and Apomu in Osun state,
(iii) Ikere, Ado, Osi, Oyo, Ikole, Omuo, Ode, Ise, Igara Odo, etc in Ekiti State.
(iv) Ondo, Ille Ife, Ore, Oniparagadi, Oba-Akoko, Afin-Akoko, Isua-Akoko, Idoani, Ilefe, Owo, Akure, etc., in Ondo State; and
(v) Osiete, Egbada, Ora, Oke-Eri, Ipata, Innope, Ifebe, Igbo, etc. in Ogun state.

White kaolinitic clays of residual origin have been found in some localities in western Nigeria. These includes several localities around Ibadan and Akinlabi (Ado Awanluye), Oyo State; Abeokuta, Osiete, Onibode and Barnajo, Ogun State; Ara, Isan and ikere, Ekiti State, and Akure, Ondo State.

Secondary clays are associated with sedimentary deposits in sedimentary basins and drainage systems where clay materials eroded from primary sources are deposited with other sediments. These clays occur in southwestern Nigeria in the Nigerian sector of the Dahomey (Benin) Basin. They include white kaolinitic clays and material suitable for fire clay. Sedimentary kaolinitic clays occur at Sogbon (near Okitipupa), Ode Aye and Ilori, Ondo State; Elefun-Togogangan (near Ile-Ife), Orito, Ayiyetoto, Ilogun, Ijomo, Abule Ogun, Sotube (near Sagamu) and Ibonwon Imagbon (near Ijebu-Ode), Ogun State.

Majority of the sedimentary clays is fire clay suitable for brick making. A major source of such fire clays is the Akinbo Formation, a shale sequence, overlying the Ewekoro limestone. The shales form good fire clays at Itori, Ofada, Ilefe, Ifo junction and Seriki Oko in Ogun State. Greyish and brownish clays interbedded with the Benin Formation (Coastal Plain Sands) and Recent alluvium in the near coastal areas are good sources of fire clay. Such clays have been found at Epe, Ejein, Tomoba, Ikteja and Omi (Lekki area), Ebuwa Omele (ikorodu area) in Lagos State; ifoninlodo and Onise in Ogun State and Ode Aye in Ondo State. Many of the deposits have large reserves and are mined locally for pottery and crude bricks.

Phosphate

Sedimentary phosphate also called phosphorite, forms part of Eocene Oshosun Formation, which also contains shales and lignitic beds. The Oshosun beds overlie the shales of Akinbo Formation in the Nigerian sector of the Dahomey (Benin) Basin. The phosphorite, which is intercalated with the shale and clayey sandstone, outcrops along the Lagos - Abeokuta railway at Ifo junction and near Osun Osun village. Reserves of about 20,000 tons of phosphate rocks have been estimated in the Ifo junction phosphate deposit. A phosphate layer up to 1m thick also overlies the Ewekoro limestone.

Also, phosphate occurrences have been investigated at Oshosun, Senki-Oko, Akinrade, Ido and Fagbeolu. In terms of morphology, three types are recognized, namely: granular, nodular and vesicular phosphates. The nodular and vesicular types have higher P₂O₅ content (Kehinde-Philips 1974). Phosphate is a raw material for the chemical fertilizer industry. These occurrences are radio-active.

Kaolin

Kaolin deposits are widely distributed throughout Nigeria. In southwestern Nigeria, it can be found in Ede, Ilanese and Ileme among others. The reserve at Ede is estimated at 1.5 million tons, while that of Ileme
Silica Deposit

Three types of silica deposits occur in the southwest, namely loose silica sand deposits formed by sedimentary processes; quartzite, which is metamorphosed sandstone; and quartz crystal of vein or pegmatite origin. The loose silica sand include construction sand and glass sand. Construction sand, which is used extensively for building houses, making sandcrete blocks and sand filling, is found in both present and ancient flood plains and river channels. It is also found in the near-shore areas of the Atlantic ocean and lagoons (Lagos and Lekki) in Lagos, Ogun and Ondo states.

Glass sand, also called silica sand occurs extensively in southwestern Nigeria. High quality silica sands are found in Aiyetoro, Ilesa-Ife, Okitipupa, Ijero Makun-Omi, Igbookoda, Badagry and Lekki. The chemical analysis of silica sands indicates that SiO₂ content ranges from 99.01% - 99.6%. Silica sand is the major raw material for the manufacture of glassware and bottles. The deposits have been fully explored and exploitation is going on. The reserves are 16 million tons at Okitipupa, 1 million tons at Igbookoda 4 million tons at Ijero and 3 million tons at Ijebu-Ife. The deposits adequately satisfy the requirement of glass industries. Deposits have the potential of replacing the imported sands used in gravel packing.

Quartzite of varying purity, which can be used as a source of silica, are present in the basement complex of southwestern Nigeria. They are associated with either the schist belts or the gneiss - migmatisite-quartzite units. Enormous reserves of such quartzite bodies are found as prominent hills and ridges in Ilesa, Esa Oke, Erin Oke, Ijavure, Ipitu Modiri, etc., in Osun State; and in Ilesa, Ofon Abye, Erinjiyan in Ekiti State. Others are prominent hills of Iseyin and Ibadan in Oyo State.

The quartzites can be quarried and processed to produce silica for various purposes such as metallurgical, refractory, glass and chemical uses. Clean grade quartzite gravel and sand produced under close textural control are used as water filter.

Gypsum

There are occurrences of gypsum in Ogun State associated with the radioactive phosphate. Gypsum occurs in specks and traces and is used mainly in the manufacture of plaster of Paris, cement, paint and chalk.

Laterite

Laterite is a product of tropical weathering of rocks. The term is used to cover lateritic soils (commonly clayey) and iron rich crust (hardpan) present in the lateritic weathering profiles. Laterite is ubiquitous, particularly in areas underlain by the basement complex in southwestern Nigeria. Enormous quantities of laterite are available particularly in areas of deep weathering in all the states of southwestern Nigeria. Laterite can also be used with minor beneficiation for making compacted laterite blocks with or without cement or lime stabilization. This weathering product is used extensively for road and building construction.

Construction Aggregates

Available construction stones in the southwestern Nigeria fall into three categories — laterite, gravel, quartzite, rubble and crystalline rocks. Laterite gravel consists of iron concretions, which are formed as part of lateritic iron crust and are subsequently disaggregated as the laterite disintegrates in site. The lateritic concretions are particularly abundant in laterites developed on charnockites such as those of Ekiti and Ondo States. When separated from the loose soil, the lateritic gravel constitutes very durable aggregate for road works.

Quartzite rubble is made up of quartzite fragments of varying sizes, which are derived from the physical weathering of quartzite bodies within the gneiss-migmatisite unit of the basement complex. It is formed in areas where quartzite ridges are abundant such as Ibadan, Iseyin, Ikire, Ilesa, Oke Ilesi-Ijero area, etc. Such quartzite rubble is used extensively as gravel for building houses. Small quartzite boulders within the gneiss-migmatisite units are often quarried manually in many localities and used as building stones.

Laid crystalline rocks of the basement are crushed into aggregates for various construction works. Gneisses and migmatises as well as granites are the common rock types used for producing crushed stones of different sizes for constructing buildings, roads, dams, airports, bridges, etc. These rock types are abundant in all the
areas of southwestern Nigeria underlain by the basement complex.

Rock for Polished Stones
Most of the basement complex rocks are suitable for producing polished stone of varying colour tones and quality (Elueze, 1995). However, when the availability of large rock reserves for economic exploitation is considered along with the rock physical properties, the number of rock types that can support viable polishing project is reduced to a few which include gneisses, granite, charnockites and possibly, syenites.

Gneisses are widespread and constitute over 60% of the basement complex. Large gneiss outcrops occur in Ibadan, Oshogbo, Ogbomoso, Erin Oke, Ore, Ijebu-Ode, etc. The older Granites, which occur in differing textures and colours, exist as plutons of various dimensions in all the states of southwest Nigeria except Lagos. They are particularly abundant in Abeokuta area, Ogun State; Ilesa, Akure, Iju-Ishagbolu and Akoko area (Akungba, Ikare, Oka, etc), Ondo State; Ikare, Ado and Osi, Ekiti State; and Eruwa, Ibadan, Ikoyi (near Ogbomoso), Igbeti, Oyo State.

Charnockites and syenites are much less common than the older granites with which they are nevertheless associated on the field and even consanguineous. The charnockites occur as plutonic bodies, sometIimes of batholithic dimensions, in Ijebu-Ode, Ondo State and in Ikare, Ado, Oye and Osi area, Ekiti State. A notable occurrence of syenite is at Shaki, and Iseyin, Oyo State. These two rock types are good source materials for polished stones. It should be noted that the Igbeti marble could also be polished and used as floor or wall tiles, although its dolomitic property confers on it a greater value for use in the chemical industries.

Ochre
Ochre is normally a naturally occurring powder, composed essentially of iron oxide, commonly hydrated iron oxide such as limonite and goethite. It commonly exists in three varieties—yellow, brown and red ochres. Yellow ochre occurs sporadically in Sagamu and Ilesa areas. The Sagamu yellow ochre forms irregular bodies within the grits or sandstone of Abeokuta Group that outcrops in Sagamu. The mineral, which was once used for painting houses in the locality, can be applied in the manufacture of paints, linoleum, rubber, etc. In Ilesa area, yellow ochre occurs within a weathering profile derived from gneisses amphibolites. Red to brownish ochre has been observed in Igarra area, Edo State, where intense lateritic weathering of phyllite has produced variegated, banded ochreous profiles.

Gemstones

Beryl and tourmaline gemstones of semi-precious to precious quality, occur in the OldGranite pegmatities, which as earlier mentioned also contain columbite-tantalite minerals. Beryl is beryllium aluminium-silicate (Be, Al, Si, O). It exists as a marine blue variety called “aquamarine”, as a semi-precious pale blue type commonly known as “beryl” but locally called “berut” by the local miners; and as a green variety described as “emerald”.

Emerald and semi-precious beryl occur in the complex pegmatities of Ologe, Oloje and Walung-Yiyan Church in Ibadan area, Oyo State and Lamole, near Ibadan, Ogun State. Aquamarine has been reported to occur in Awode and Ede areas. Tourmaline is a complex borosilicates (boron-bearing silicate) of aluminium together with alkali metals, iron and magnesium. Three varieties of tourmaline gemstones are found in the OldGranite complex pegmatities of western Nigeria. These include the green variety (emerald or Brazilian emerald), the pinkish red variety (rubellite) and the blue type (indicolite or Brazilian spavellite). The black tourmaline (schorl), which is ubiquitous, is rarely of gem quality, but large columnar schorl appears semi-precious.

Emeraldite tends to be more common in the pegmatities of Ekiti and Ogun States. It occurs predominantly in Ijero, Ikere and Ile-Ife. On the other hand, the rubellite seems to predominate in the pegmatities of upper Ogun area, Oyo States. It has been found at Oki, Idiko-Ile, New Target and other areas in Shaki-Kishin region. The blue tourmaline is rare but it was reportedly obtained at Oto in Kwara State. The various gemstones are cut, polished and employed in making exquisite jewellery.

Tarsand/Oil Sand
Sandstone heavily impregnated with bitumen occurs in a narrow E-W belt, which extends from Igbeti to Ogun State through Ondo State to the western margin of Edo State. It is not yet explored in Ogun State which is suspected to have greater reserve than the deposit in Ondo State. The bitumen outcropping belt is over 120km long and 6km wide. Outcrops occur at Igbeti,
Yemoji; iyowin, Agbabu, Afaluko, Ajobeyande area, some localities north of Lekki Lagoon, llutitun area, Odo Aye area, Foriku, Aiyadi, Agbabu area and Ofosi. The bitumen occurs as impregnation of Upper Cretaceous arenaceous sediments with an oil saturation of 12 wt% percent (Adegoke et. al., 1980). Adegoke and his colleagues estimated an area of about 17km² around Agbabu to contain 1534 million metric tonnes of bitumen, which is to yield 1022 million barrels of heavy oil. The Ondo state sector of the bitumen belt was reckoned to contain not less than 42 billion barrels of derivable oil reserves.

Oil and Gas
The occurrence of bitumen and oil shale in the bitumen belt just discussed above is an indication that hydrocarbon accumulation occurs down dip or the Cretaceous sediments in the Dahomey (Benin) basin in western Nigerian. As a matter of fact, oil and gas are currently being exploited in the near-shore area of Ondo State.

SUMMARY AND CONCLUSIONS
A summary of all the minerals discussed in the foregoing account and their uses is presented in Table 1. The Table shows that the states of southwestern Nigeria are endowed more with non-metallic than metallic minerals. The economic deposits of gold, gemstones and marble as well as occurrences of bauxite, nickel and chromite are hosted by the Precambrian to Paleozoic Basement complex of Southwestern Nigerian while the Cretaceous sediments are host to deposits of limestones, silica sands, kaolin and oil sands as well as occurrence of radioactive phosphate and gypsum.

On the basis of available geological information, some of these minerals are reckoned to occur in very large quantities and could support viable mineral industry in different parts of the states. However, further studies are still going on in order to discover more mineral resources in southwestern Nigeria and assess the possibilities of their exploitations.

Table 1. Mineral Resources of South-western Nigeria

<table>
<thead>
<tr>
<th>MINERAL TYPE</th>
<th>LOCALITY</th>
<th>RESERVE (Ton)</th>
<th>USES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Columbite-Tantalite</td>
<td>Igbolaye, Wofun, Iyana Church, Awo, Ojo</td>
<td>-</td>
<td>Tantalum and niobium contained in this mineral are used for heat and corrosion resistant steels and alloys applied in space ships and gas turbines.</td>
</tr>
<tr>
<td>Iron Ore</td>
<td>Ajae, Ipinnin, Gbode, Oko, Otamokun, Ajinope,</td>
<td>100,000 (Ajae)</td>
<td>For steel manufacture.</td>
</tr>
<tr>
<td>Oker Blf</td>
<td>Ijabo, Agbonoko, Chokocho, Agbado, Okuda, Ebys, Ero, etc.</td>
<td>600 million</td>
<td>-</td>
</tr>
<tr>
<td>Ironstone</td>
<td>Agbaja, Koton Karifi, Bawa-Nige</td>
<td>Over 2 billion</td>
<td>-</td>
</tr>
<tr>
<td>Alkali and Primary</td>
<td>Iperindo, Ilagenmok, Ilawara, Iboke</td>
<td>-</td>
<td>For ornaments, monetary purposes, most of it being used as bullion in reserve for notes issued, dentistry, etc.</td>
</tr>
<tr>
<td>Marble</td>
<td>Igbeti</td>
<td>&gt;40 million</td>
<td>For fluxing stone in steel making, for soil replenishment and acidity correction, for glass and paint making, for use in paper mills, for sugar refining, for construction materials such as terrazzo, plasterboard, etc.</td>
</tr>
<tr>
<td>Dolomitic</td>
<td>Elebu</td>
<td>150,000</td>
<td>NO</td>
</tr>
<tr>
<td>Limestones</td>
<td>Fossiliferous</td>
<td></td>
<td></td>
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<tr>
<td>------------</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Okolua</td>
<td>7 million</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Okolua</td>
<td>7 million</td>
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<table>
<thead>
<tr>
<th>Clay</th>
<th>Fire Clay</th>
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</thead>
<tbody>
<tr>
<td>Ita-dam, Saki, Ijesha, Ijesha</td>
<td>For making bricks, tiles, and refractories.</td>
</tr>
<tr>
<td>Ojodu</td>
<td>&gt;2.5 million</td>
</tr>
<tr>
<td>Ijebu-Ode</td>
<td>5 million</td>
</tr>
<tr>
<td>Ijebu-Ode</td>
<td>Large</td>
</tr>
<tr>
<td>Osogbo</td>
<td>ND</td>
</tr>
<tr>
<td>Elefun Taro</td>
<td>ND</td>
</tr>
<tr>
<td>Akintola (Ife Awo)</td>
<td>3.5 million</td>
</tr>
<tr>
<td>Ilu-odo</td>
<td>ND</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Kaolin</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ijebu-Ode, Ilesa, Odo-aje, Ifon, Abula, Oge, Ife</td>
<td>For making clays for use as filters, extenders and carriers in paints, rubber, plastics, textiles, and paper industries; for making drugs, etc.</td>
</tr>
<tr>
<td>7 million</td>
<td>4 million</td>
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<tr>
<td>7 million</td>
<td>7 million</td>
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<td>7 million</td>
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<td>ND</td>
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<table>
<thead>
<tr>
<th>Phosphates</th>
<th>Phosphorite</th>
</tr>
</thead>
<tbody>
<tr>
<td>20,000</td>
<td>For making fertilizers, matches, and chemicals.</td>
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<table>
<thead>
<tr>
<th>Bitumen</th>
<th>Semi-Solid Hydrocarbon</th>
</tr>
</thead>
<tbody>
<tr>
<td>1534 (Agbadu)</td>
<td>As a source of heavy oil which can be cracked to make other products such as diesel, fuel oil, kerosene, pitch, and motor spirit; can also be a source of sulphur, ammonia, phenol, Ni and V.</td>
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</tbody>
</table>

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<thead>
<tr>
<th>Ochre</th>
<th>Primary Yellow Ochre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ilesa</td>
<td>ND</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Secondary Yellow Ochre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sagamu</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Feldspar Pegmatite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ijero</td>
</tr>
<tr>
<td>Ebo</td>
</tr>
<tr>
<td>Awo</td>
</tr>
<tr>
<td>Ode Omu</td>
</tr>
</tbody>
</table>
| Gemstones | Olode, Olojoro, Wolfswano Church, Lamote, Awode Lome, Ile-Ife, Ikerre, Obiara, Ishan, Ijeora, New Target, Ondo. | ND | For making polished ornamental stones. |}

| Construction Stones | Lateritic soil and hardpan | Present in all states of the southwestern. | ND | -dito- |}

| Rocks for polishing | Granites, Complex area; Charnockite, abundant in Ondo and Ekiti, Syenite States; Syenite at Saki. | Large | Polished stones used as floor and wall tiles, statues and other embellishment. |}

| Oil and Gas | Liquid and Gaseous | Near shore area of Ondo state | ND | Used to produce fuel, and chemicals for various domestic and industrial uses. |}

| Gypsum | Sedimentary | Ososun, Abule Onew | ND | Manufacture of cement, paint, chalk, plasters. |}
REFERENCES


