

Geology and mineral resources of the Lower Benue Trough, Nigeria

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ABSTRACT

The Lower Benue Trough is the southern portion of the Benue Trough that is believed to have originated as a failed arm of an aulacogen at the time of the opening of the South Atlantic Oceans during the separation of the African plate and the South American plate. The geology of Lower Benue Trough is associated with the tectonic activities that were recorded during the Cenomanian. These tectonic activities produced an uplift that had a NE-SW trend. This gave way to the tectonic activities that took place in Santonian times, which resulted in the folding and uplifting of the Abakaliki Sector of the Trough and the subsidence of Anambra Platform. The latter event led to the formation of the Anambra Basin, which constituted a major depocentre of clastic sediments and deltaic sequences. The erosion of the Abakaliki uplifted and folded belts resulted in the development of a Proto-Niger Delta sequence consisting of Enugu/Nkporo, Mamu, Ajali and Nsukka Formations. This was followed by a regression that started during the Eocene and continued to the present day with the deposition of the sediments of the Tertiary Niger Delta. The Lower Benue Trough like other Sedimentary Basins in Nigeria is found to be endowed with mineral resources. Over twenty mineral resources have so far been reported in the Trough by the Geological Survey of Nigeria Agency and these include; coal, lead-zinc, barytes, limestone, clay, gypsum, phosphate, glass sand, fluorspar, salt, ironstone, uranium, sulphur, graphite, cassiterite, manganese, mica and silver.

Keywords: Benue Trough, Aulacogen, Transgression, Minerals.

INTRODUCTION

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 centered around Jos and other parts of north-central Nigeria. 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.

The Benue Trough is arbitrarily sub-divided into three portions; Lower, Middle and Upper portion (Fig. 1). No concrete line of subdivision can be drawn to demarcate the individual portions, but major localities (towns/settlements) that constitute the depocentres of the different portions have been well documented [1; 2; 3; 4 and 5].

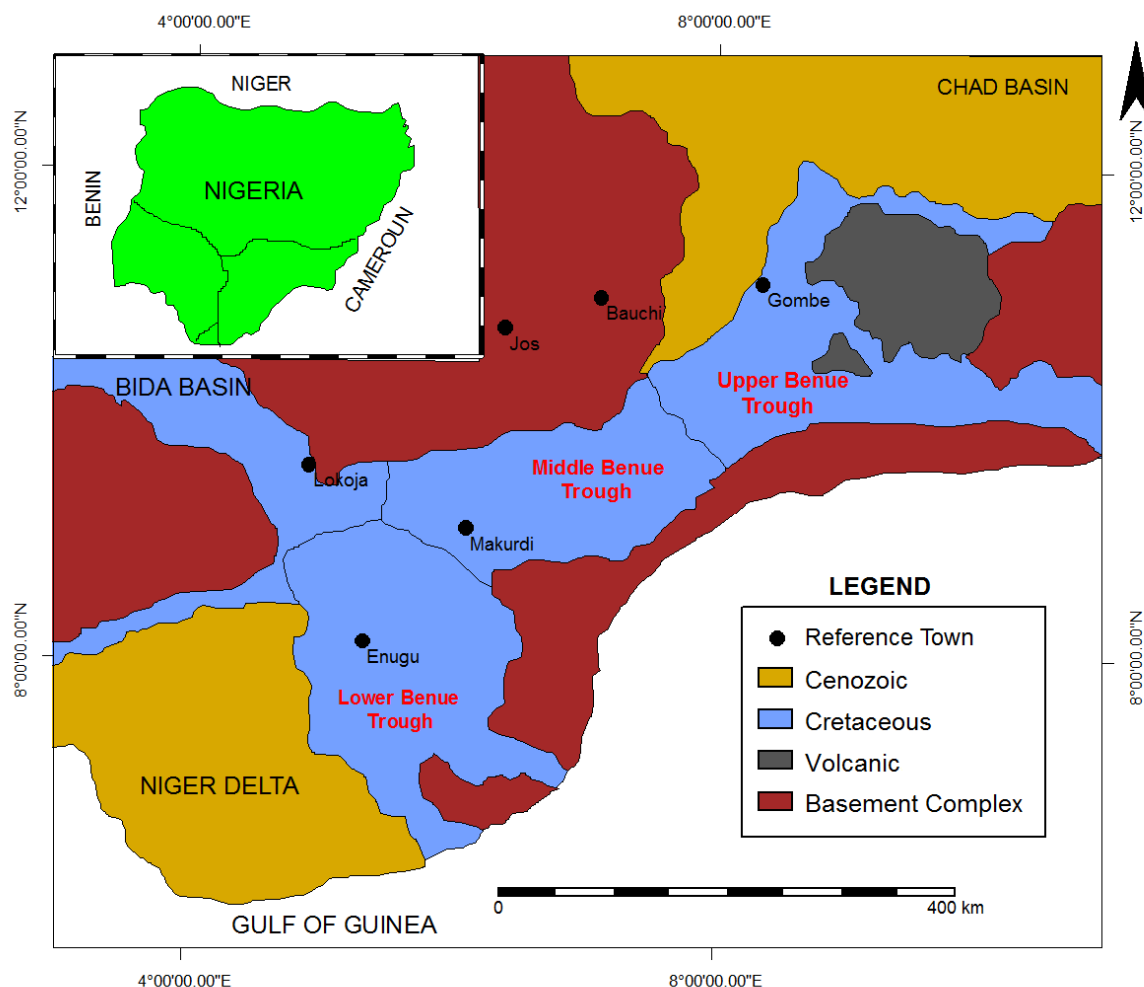


Fig. 1 Map of the Benue Trough of Nigeria modified from [4]

Nigeria as a nation is blessed with abundant solid mineral resources distributed fairly in all the States of the Federation. According to reports by the Geological Survey of Nigeria Agency, Nigeria has some 44 known major mineral deposits distributed in locations across the country and offers considerable attraction for investors. At least half of this number are found in the Lower Benue Trough which include; coal, lead-zinc, barytes, limestone, gypsum, clay, phosphate, glass sand, fluorspar, salt, ironstone, uranium, sulphur, graphite, cassiterite, manganese, mica and silver. The privatization and general reform exercises currently being undertaken by the government of Nigeria are expected to lead to an upsurge in the exploration and development of solid mineral resources in the Lower Benue Trough and in the country as a whole.

This paper therefore, attempts to update the knowledge on the structural setting, sequence stratigraphic successions and mineral resources of the Lower Benue Trough.

Stratigraphic Setting

Sedimentation in the Lower Benue Trough commenced with the marine Neocomian – Albian Asu River Group, although some pyroclastics of Aptian – Early Albian age have been scantily reported [6 and 7] (Fig. 2). The Asu River Group sediments in the Lower Benue Trough comprises predominantly of shales with localized sandstones, siltstones and limestones [8] as well as extrusive and intrusive material [9; 10; 11 and 12] of the Abakaliki Formation in the Abakaliki area and the Mfamosing Limestone in the Calabar Flank [1]. In addition, [13] described the Asu River Group as consisting of arkosic sandstones, volcanoclastics, marine shales, siltstones and limestone

which overly the Pre-Cambrian to Lower Paleozoic crystalline basement rocks. The arkosic sediments were derived principally from the extensive weathering of the basement rocks which were invaded by alkaline basaltic rocks prior to the initial rapid marine flooding of the Middle Albian times. The Asu River Group is interpreted as sediments of the first transgressive cycle into the Lower Benue Trough.

The marine Cenomanian – Turonian Nkalagu Formation (black shales, limestones and siltstones) and the interfingering regressive sandstones of the Agala and Agbani Formations (Cross River Group) rest on the Asu River Group. Although sequence of sandstones, limestones and shales with calcareous sandstones of Odukpani Formation were deposited unconformably on the Basement rocks in the Calabar Flank during the Late Albian.

The Santonian was a period of non-deposition, folding and faulting. This was followed by uplift and erosion of the sediments.

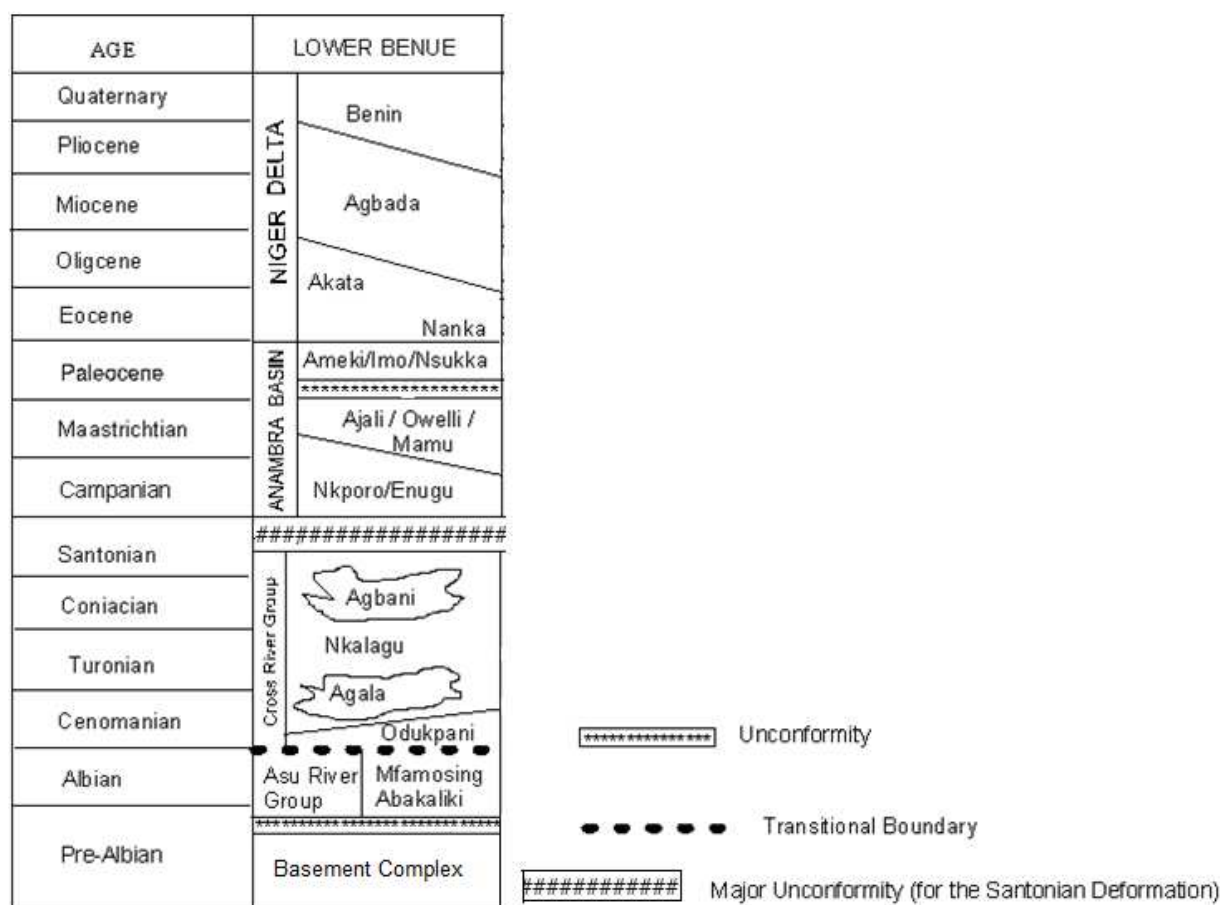


Fig. 2 Stratigraphic successions in the Lower Benue Trough of Nigeria modified from [14]

The intensive Middle–Santonian deformation and magmatism in the Benue Trough displaced the major depositional axis westward which led to the formation of the Anambra Basin. Post deformational sedimentation in the Lower Benue Trough, therefore, constitutes the Anambra Basin. Sedimentation in the Anambra Basin thus commenced with the Early Campanian – Early Maastrichtian of the Enugu and Nkporo Formations (lateral equivalents) which consist of a sequence of bluish to dark grey shale and mudstone locally with sandy shales, thin sandstones and shelly limestone beds. The shaly facies grade laterally to sandstones of the Owelli and Afikpo Formations in the Anambra Basin. The Enugu and Nkporo Formations are essentially marine sediments of the third transgressive cycle. These, in most parts of the Anambra Basin is overlain by the Lower Maastrichtian sandstones, shales, siltstones and mudstones and the inter-bedded coal seams of the deltaic Mamu Formation. The deltaic facies grade laterally into the overlying marginal marine sandstones of the Ajali and Nsukka Formations.

The marine shales of the Imo and Nsukka Formations were deposited in the Paleocene. The Nsukka Formation and the Imo Shale mark the onset of another transgression in the Anambra Basin during the Paleocene. Imo and Nsukka Formations are overlain by the tidal Nanka Sandstone of Eocene age. The Eocene Nanka Sands mark the return to regressive conditions. Nanka Formation is overlain by sandstones, shales and lignite beds of the Oligocene / Miocene Ogwashi – Asaba Formation. These Tertiary units constitute the proto- Niger Delta Eocene to Recent sequences in the subsurface. Down dip, towards the Niger Delta, the Akata Shale and the Agbada Formation constitute the Paleocene equivalents of the Anambra Basin (Fig. 2).

Mineral Resources

Geological Survey of Nigeria Agency has played an active role in the exploration for mineral deposits in Nigeria. The Lower Benue Trough like other Sedimentary Basins in Nigeria is found to be endowed with mineral resources. The mineral resources so far reported in the Trough by the Geological Survey of Nigeria Agency are discussed below.

Coal: Anambra Basin in the Lower Benue Trough is a major coal producing basin in Nigeria where intensive exploration and exploitation activities have been on since 1916 owing to the discovery of commercial coal in Udi near Enugu in 1909 by the Mineral Survey of Southern Nigeria [15]. Coal was discovered in the Mamu Formation (formerly called the ‘Lower Coal Measures’) of the Anambra Sedimentary Basin of south-eastern Nigeria [16]. Occurrence of coals in the Nsukka Formation (formerly called the ‘Upper Coal Measures’), located 4 miles north of Okaba town was later reported [17].

Mineable coal deposits in Lower Benue Trough occur at Enugu, Orukpa, Okobo, Okaba, Odokpono and Ogboyaga.

The coal deposits in the Lower Benue Trough are of medium quality, non-coking and sub-bituminous. These put together suggest that they do not possess some coking qualities suitable for coke making blends. However, the coals are suitable for electric power generation and as domestic fuel. They are also rich in resinous and waxy materials and are therefore suitable raw material for the chemical industry and also for use in the manufacture of plastics, when fractionally distilled [18]. The coals are also good producer of gas fuel, and are suitable for complete gasification using the oxygen enriched steam blast process. They can also be processed to produce automotive fuel.

Lead – Zinc: Deposits of zinc and lead minerals in the form of their ores of sphalerite and galena respectively often associated with barytes mineralization in the Cretaceous sediments of the Lower Benue Trough. The general geology of Lower Benue Trough in Abakaliki area is made up of thick sequences (500m) of slightly deformed Cretaceous sedimentary rocks made up of essentially of Albian shales, subordinate siltstones of the Asu River Group. There is also the presence of volcanic and pyroclastic materials forming elongated conical hills in the cores of the anticlinal structures. The Abakaliki lead–zinc is believed to be of hydrothermal origin emplaced at a low temperature of about 140°C and it is made up of primarily four lodes namely; Ishiagu, Enyigba, Ameri and Ameki in the Lower Benue Trough located in Ebonyi State.

Enyigba Lode: The Enyigba lode which appears to be the largest mineralized body in the Lower Benue Trough section is up to 2km in length and has a width of approximately 30km. It occurs as an open vein fillings of a series of steeply dipping N – S near vertical fault which cuts regional fold (Abakaliki anticlinorium). The lode also extends southwards into Ameri lode.

Ameri Lode: The Ameri lode which is located south of the Enyigba lode trends almost N – S which flanks the southeastern limb of the Abakaliki anticlinorium. It is also a vein/fracture infilling which appears to be a continuous extension of Enyigba.

Ameki Lode: The Ameki lode is to the southeast of the above two lodes and is bounded in the north and south by siltstone. The fracture/vein infilling displaces the siltstone border and the Abakaliki anticlinorium.

In the Abakaliki area, in particular, lead-zinc mineralization was found associated with calcareous shales and shaly limestones. The Abakaliki field is still Nigeria’s most important lead-zinc deposit.

Lead is used in the manufacture of cable coverings, pigments, storage batteries, solder, sheet lead and pipes, shot, and bearing metals. Uses of zinc include galvanizing steel plate, the manufacture of brass and other alloys, rubber vulcanizing, and the production of pigments and certain medicines and chemicals.

Barytes: Barytes occurs as vein infilling materials associated with lead–zinc lodes and veins in the both Pre-Cambrian Basement and Cretaceous Sedimentary rocks of the Lower Benue Trough. Recently the Nigerian Geological Survey Agency embarked on the evaluation of newly reported deposit in Cross River State. Barytes veins in Cross River State are hosted in both hard and soft rocks. This study divided the mineralized areas into: North comprising of Obubra, Ikom and Yala LGA and the South consisting of Biase and Yakkur LGA. Barytes are hosted more by sedimentary rocks in the north while in the south only 2 out of 18 locations are in sedimentary rocks.

The importance of barytes in the oil, paint and paper industries is well known. At the present time, Nigeria imports a considerable quantity of this mineral for use in its oil-operations. Barytes is the chief constituent of lithopone paint and it is also extensively used as an inert volume and weight filler in drilling mud, rubber, glass, paper, etc. and in the chemical industry.

Limestone: The Sedimentary limestone of Cretaceous and Tertiary ages is associated with shale, siltstone, and fine-grained sandstone in Lower Benue Trough. They are often hard, gray and shelly [19]. In all occurrences the deposition of limestone is related to the transgressive and regressive cycles in the Trough. 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 [20]. 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 was also used by the Delta Steel plant at Aladja as a fluxing agent and for making hydrated lime. Over 174 million tonnes of limestone exist in Nkalagu area in Ebonyi State and occur within the Turonian – Eze-Aku Formation. 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.

Apart from cement manufacturing, limestone is used as cut stone for building, 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.

Clay: Clay is found almost everywhere in Lower Benue Trough, though not always in sufficient quantity or of suitable quality for modern industrial purposes. Excellent clays that could be put to a variety of uses are found around Awka and Owerri. Fire-clay is found in the Late Campanian – Late Maastrichtian Lower Coal Measures of Anambra Basin at Enugu.

Clay is one of the earliest mineral substances utilized by man. It played an extremely important part in ancient civilizations, records of which were preserved in brick buildings, in monuments and in pottery, and as inscriptions upon clay tablets. Clay is still an indispensable raw material today. The present uses of clay and clay products are too numerous to list completely. In domestic life, clay is used extensively in pottery, earthenware, china, cooking ware, vases, plumbing fixtures, tiles, porcelain wares and ornaments. In building, it is used for building bricks, vitrified and enameled bricks, tiles for floors, roofs, walls and drains, sewer pipes and as an ingredient of cement. In the electrical industry, it is used for conduits, sockets, insulators and switches. It is used on a large scale in making refractory ware, such as fire bricks, furnace linings, chemical stone ware, crucibles, retorts and saggars.

Glass Sands: Large deposits of glass sands occur in the Maastrichtian False-bedded Sandstones along the escarpment near Enugu in Anambra Basin. Glass sand deposits are also found in many localities; and some of these have been investigated and found to occur in sufficiently large quantities and good quality to support bottle-making industries. Glass sands are also being exploited in Port Harcourt and Ughelli for the manufacture of sheet glass.

Gypsum: In the Lower Benue Trough, gypsum has been found as scattered crystals in Cretaceous and Tertiary clays and shales in Anambra and Imo States. No workable deposits have yet been found. Gypsum is a minor but essential ingredient of cement, in which its function is to control the setting time. Gypsum is important also as a fertilizer and for making plaster and plaster-board.

Phosphate: Phosphate is closely associated with gypsum and limestone in Lower Benue Trough. It is found in Cretaceous shales and clay in Imo State. The Geological Survey of Nigeria Agency is currently attending to evaluate the quantity of the mineral in the area. Phosphate is used for fertilizer manufacturing. Detergents, metal treatment, water treatment, pulp and paper, glass and ceramics, textiles, plastics, rubber, pharmaceuticals and cosmetics, petroleum production, toothpaste, paints, fuels, cells are end-user industries of phosphate rock. Phosphates are also used in flame retard/fire extinguisher production, food and beverage industries, dentistry, etc. It is also important to metabolism in both plants and animals.

Fluorspar: Fluorspar occurs in small quantities in the lead-zinc lodes in the Albian shales, siltstones and limestones of Asu River Group in Ishiagwu and Ogoja, but the deposits are generally too small to be of value. Fluorspar or Fluorite is a mineral composed of calcium fluoride (CaF_2), the principal fluorine-bearing mineral. The main use of fluorite has been for the production of hydrofluoric acid, an essential raw material in the manufacture of synthetic cryolite and aluminum fluoride for the aluminum industry, and in many other applications in the chemical industry. It is also employed as a standard flux used in the making of steel, in the smelting of lead ores, in ceramic industry and in the production of enamel and opal glass, and perfect crystals are used for the manufacture of apochromatic lenses.

Ironstone: Lateritic ironstone, consisting of loose angular fragments with some clayey sand, was discovered in 1952 on the high country west of Enugu. Large reserves are present, but only certain stretches of unfarmed land close to the Enugu Colliery have been investigated. Prospecting undertaken by the Geological Survey of Nigeria Agency has indicated nearly 50.8 million tonnes of ironstone in a bed from 1.5m to 9.1m thick, overlain by clayey soil ranging up to 15.2m in thickness. By screening out the sandy matrix, material with an average iron content of 43 percent can be obtained. The deposit, although of low grade, is favourably situated close to the collieries, and limestone is available a few kilometers to the east. However, because the Enugu coal does not yield coke, the conventional blast furnace cannot be used to reduce the ore to the metallic state. Ironstone is a source of iron (Fe), it is used as a component in some ceramics and also as a building material.

Salt/Brine: The folded Cretaceous rocks of the Lower Benue Trough give rise to many dilute brine springs that are the centres of village salt industries. Such springs are known to occur mainly in Abakaliki. Attempts in the past to prove the quality and quantity of the brine at depth by drilling were unsuccessful. In 1966, the Geological Survey of Nigeria analysed samples of water which it obtained during the dewatering of a 76.2m deep mine shaft at Ameri by the Nigerian Lead-Zinc Mining Company. The water was shown to have a relatively high salinity, with the highest obtained percentage of dissolved solids being 7.98 percent of the total dissolved solids in the brine was found to be composed of common salt (NaCl). No buried rock salt has been discovered in the Trough and even elsewhere in the country by the Geological Survey of Nigeria Agency.

Salt is the most familiar of all minerals and has played an important role from the beginning of man. It is used for a great variety of purposes in the chemical, metallurgical and ceramic industries, and in agriculture, medicine, and the household. Salt is so widespread in its uses that the materials made from it or requiring its use in their manufacture are continually met in everyday life. Some of its uses are the manufacture of industrial chemicals like soda, sodium bicarbonate, caustic soda, chlorine, and certain acids; the smelting and refining of ores and metals, the making of soap and dyes, the tanning of leather, the preservation of foods, the making of explosives, and the bleaching of cotton and paper.

Uranium: The Lower Benue Trough which occupies most of the eastern part of the country is filled with Cretaceous to Quaternary sediments. Most of these sediments are marine and consequently of no potential for uranium mineralization. However, uranium anomalies which may be indicative of uranium mineralization have been located by airborne spectrometric survey in some of the continental sediments, notably in the Ajali Sandstone. The anomalies in the formation occur along a belt stretching from Okigwe in the south to Angba about 150 km away in the north [5]. Uranium is used for the production of nuclear weapons and as a potential source of industrial power.

Sulphur: Native sulphur is the chief commercial source of sulphur, but pyrites and anhydrites are also mined for their sulphur content. Pyrites and marcasite, sulphides of iron, occur in the lead-zinc ores of Abakaliki and it is possible that they could be concentrated at the same time as the lead-zinc ores. Sulphur is used in chemical and fertilizer, insecticide, paper, paint, explosive, dye, rubber, oil-refining, textile, sugar, and many other industries.

Graphite: In the Lower Benue Trough the mineral is found in Obudu area of Cross River State. Graphite is used in foundry moulds, crucibles, batteries, paints, pencils, nuclear reactors and lubricants.

Cassiterite: Small amounts of cassiterite, ore of tin have been found in the Oban Hills Older Granite massif of Cross River State in the Lower Benue Trough. Tin is a widely sought metal and is used in hundreds of industrial processes throughout the world. In the form of tinplate, it is used as a protective coating for copper vessels, various metals used in the manufacture of tin cans, and similar articles. Tin is important in the production of the common alloys bronze (tin and copper), solder (tin and lead), and type metal (tin, lead, and antimony). It is also used as an alloy with titanium in the aerospace industry and as an ingredient in some insecticides. Stannic sulphide, known also as mosaic gold, is used in powdered form for bronzing articles made of plaster of paris or wood. Its compounds are used in dyeing and fire-proofing.

Manganese: Also found in the Oban Hills Older Granite massif of Cross River State is manganese. Manganese is an essential substance in refining of steel. It acts principally by removing oxygen and sulphur from the molten metal.

Mica: Small deposits of mica are known in the Oban Hills of Cross River State. Muscovite, also called white mica or common mica is used as insulating material in the manufacture of electrical apparatus, particularly vacuum tubes. Scrap mica, obtained as waste material in the manufacture of sheet mica, is used as a lubricant when mixed with oils and as a fireproofing material.

Silver: Small amounts of silver are as well present in the lead-zinc ores of galena and sphalerite respectively in Abakaliki lead-zinc field and this could probably be recovered as a by-product if the ore is mined on a sufficiently large scale. The use of silver in jewelry, tableware, and as coinage is well known. The metal is usually alloyed with small amounts of other metals to make it harder and more durable. Silver is used to coat smooth glass surfaces for mirrors by vaporization of the metal or by precipitation from a solution. Silver is also widely used in the circuitry of electrical and electronic components. Colloidal silver, dilute solutions of silver nitrate (AgNO_3), and some insoluble compounds, such as potassium, are used in medicine as antiseptics and bactericides. Argylol, a silver-protein compound, is a local antiseptic for the eyes, ears, nose, and throat.

The silver-halide salts—silver bromide, silver chloride, and silver iodide—which darken on exposure to light, are used in emulsions for photographic plates, film, and paper. The salts are soluble in sodium thiosulphate, which is the compound used in the photographic fixing process.

CONCLUSION

The Lower Benue Trough is a linear, intracratonic, graben basin, trending NE-SW. Its origin is associated with the separation of the African and South American continents in the Early Cretaceous. The Trough is characterized by an uplifted basement block, flanked by deep basin containing about 6,000 metres of sediments of various ages. These sediments are endowed with mineral deposits that could be exploited to diversify the nation's economy. For instance, Anambra Basin within the Trough contains the largest and most economically viable coal resources in Nigeria. The coal deposits in the Lower Benue Trough are non-cokable and not suitable for use in the generation of heat for the working of blast furnace for iron smelting. However, they are suitable for electric power generation and as domestic fuel. The coals are also rich in resinous and waxy materials, and are therefore, suitable raw material for the chemical industry and in the manufacture of plastics, when fractionally distilled. The shallow water sediments of the Albion around Mfamosing, contain the largest and the purest deposit of limestone in the country with 96% CaCO_3 which is being exploited for cement manufacturing. Also the largest deposits of Lead-zinc, barytes, salt, fluorspar and glass sand in Nigeria which are used for different purposes are located in various sediments within the Trough.

Without doubt, the efficient management of solid mineral industry in the Lower Benue Trough of Nigeria to ensure maximum exploration and utilization will have a considerable impact on the economic development of the country.

Good management of the industry will enhance mineral development leading to additional income per capital earnings and improved balance-of-payments position for Nigeria.

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