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Lead-Zinc-Barytes mineralization in the Benue Trough, Nigeria: Their geology, occurrences and economic prospective

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ABSTRACT

The Benue Trough of Nigeria is a sedimentary basin that extends from the Gulf of Guinea in the southwest to the Chad Basin in the northwest for about 800 km in length and 150 km in width. Lead-zinc-barytes occurs in almost the entire length of the Benue Trough. Lead-zinc-barytes mineralization in the Trough is believed to be hydrothermal in origin and is associated with brine springs. Fracturing and jointing are intense in the areas of mineralization. Lead-zinc minerals in the form of their ores of galena and sphalerite respectively and barytes mineralization are often associated with copper, quartz, iron minerals (siderite, marcasite and pyrite), gold and silver as gangue occurring in the form of veins and veinlets associated with the host sedimentary rocks in the axial zone of the Benue Trough. The mineralization occurs in form of dissemination, stockwork and narrow beds with poorly developed wall-rock silicification (alteration). The host lithologies are highly varied ranging in the Lower Benue Trough from shale to siltstone, sandstone and occasionally igneous bodies; in the Middle Benue Trough from shale to sandstone, siltstone, conglomeratic ironstone, minor limestone beds and occasionally igneous bodies; and in the Upper Benue Trough from shale to sandstone, mudstone, limestone, clay and porphyritic granites.

Keywords: Nigeria, Galena-Sphalerite-Barytes Mineralization, Hydrothermal Origin.

INTRODUCTION

Lead (Pb) is a relatively soft, malleable, blue-grey, heavy metal and is probably the earliest discovered metal that does not occur naturally in its pure state. Lead has a shiny chrome-silver lustre when it is melted into a liquid. Galena (PbS) is the principal ore mineral, usually found in association with sphalerite (ZnS) and barytes. Galena often contains inclusions of silver and is a major source of that metal.

Zinc (Zn) is a crystalline, bluish white metal that is brittle at most temperatures but becomes malleable between 100 and 150^{0}C. Above 210^{0}C, the metal becomes brittle again and can be pulverized by beating. It is principally mined as the primary sulphide sphalerite (ZnS), usually in association with galena and barytes. Sphalerite contains 67% Zn and often includes traces of simple sulphide such as Cadmium, Gallium, Germanium and Indium in solution.

Barytes, is a mineral consisting of barium sulphate. It is generally white or colourless, and is the main source of barium. Barytes occurs in a large number of depositional environments, and is deposited through a large number of processes including biogenic, hydrothermal, and evaporation, among others [1]. Barytes commonly occurs in lead-zinc veins in limestones, in hot spring deposits, and with hematite ore. It is often associated with the minerals anglesite and celestine. It has also been identified in meteorites [2].

The Benue Trough of Nigeria is arbitrarily sub-divided into three portions; Lower, Middle and Upper portion (Fig. 1) and lead-zinc-barytes mineralization occurs in almost the entire length of the Trough. Lead-zinc-barytes mineralization in the Benue Trough is associated with saline water intrusion or with fractures/shear zones and is believed to be hydrothermal in origin. There are differing views on their relationships. But there is the possibility of chemical interaction between the rising metal bearing hydrothermal fluid with the surrounding country rock in the saliferous or evaporitic zone, resulting in the deposition of Pb-Zn (galena-sphalerite) and barytes [3].

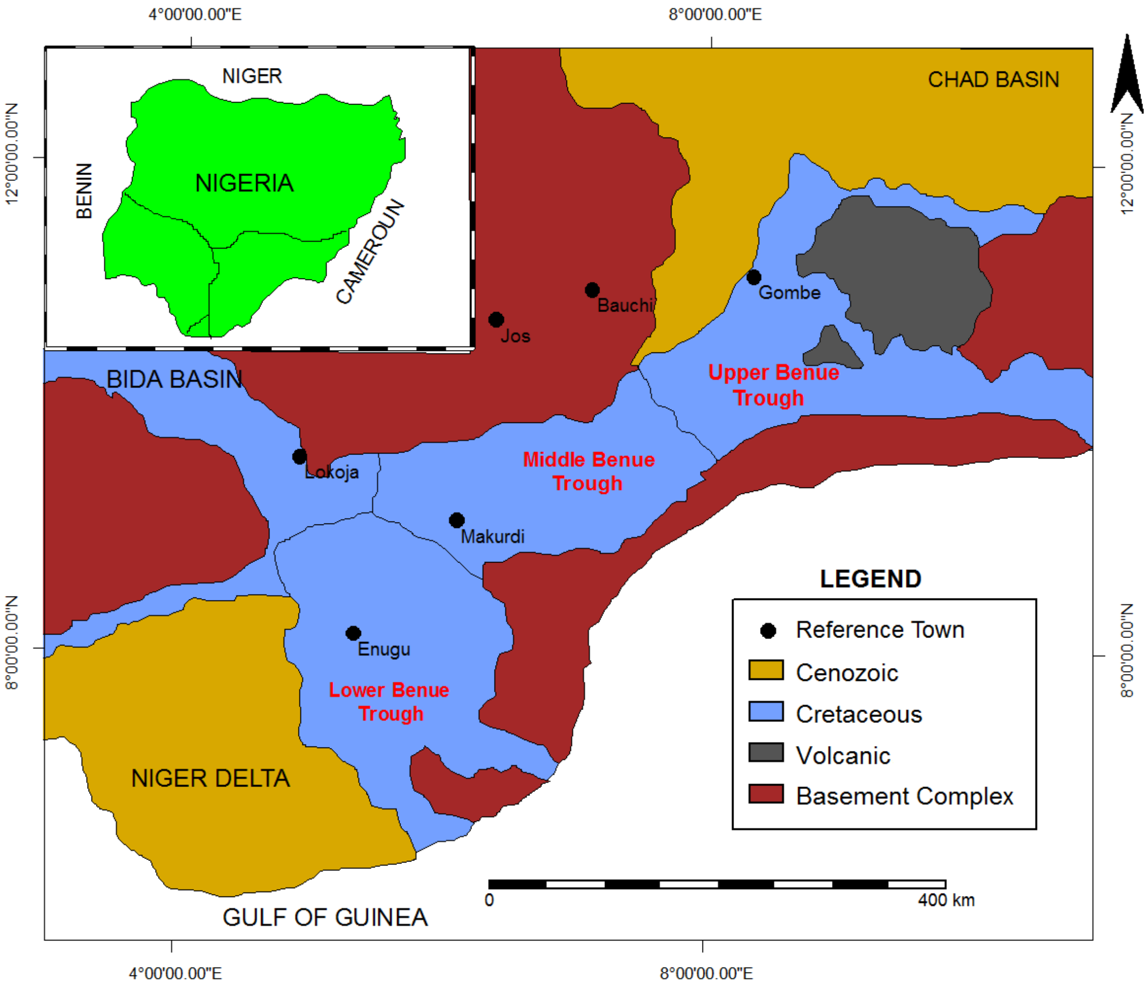

Fig. 1 Map of the Benue Trough of Nigeria [4]

Deposits of lead and zinc ores, galena and sphalerite respectively and barytes which are usually found together have long been known in the Benue Trough of Nigeria but they have only been mined in the past on a very small scale. The mining of galena and sphalerite for their metal content has been possible owing to the high cost of transport and low metal prices. The Nigerian lead-zinc-barytes field extends for about 560km in a narrow belt from Ishiagu in the Lower Benue Trough through Azara in the Middle Benue Trough to Gidan Dari in the Upper Benue Trough. Many occurrences of lead-zinc-barytes are known, such as those at Enyigba, Ameki, Ameri (near Abakaliki), Wanikande, Wanakom, Gabu and Oshina all in the Lower Benue Trough; at Keana, Aloshi, Akiri, Wuse, Akwana, Arufu, Faya, Shata, Chiata, Gbande, Gboko, Sardauna, Karim Lamido, Yoro, Lau, Wukari and Ibi in the Middle Benue Trough; and at Isimiya, Diji, Gidan Dari, Alkaleri and Gwana in the Upper Benue Trough. At least 30 lodes of lead-zinc with an aggregate length of about 6,000m have been reported in Nigerian lead-zinc field. In Abakaliki area, in particular, the Nigerian Mining Corporation has indicated proved reserves of up to 711,237 tonnes [5]. Nigerian Lead-Zinc Mining Company in 1956 gave conservative indicated reserves of 693,000 tonnes with 9.0% lead and 7.0% zinc [3]. The Abakaliki field is still Nigeria's most important lead-zinc deposit. In Azara area, the Nigerian Mining

Corporation has indicated reserves of 70,000 tonnes of barytes [5]. Azara is the best quality known deposit of barytes in Nigeria.

This paper therefore, reviews some available information on the geology, mode of occurrence and possible economic importance of lead-zinc-barytes mineralization in the Benue (Lower, Middle and Upper) Trough of Nigeria.

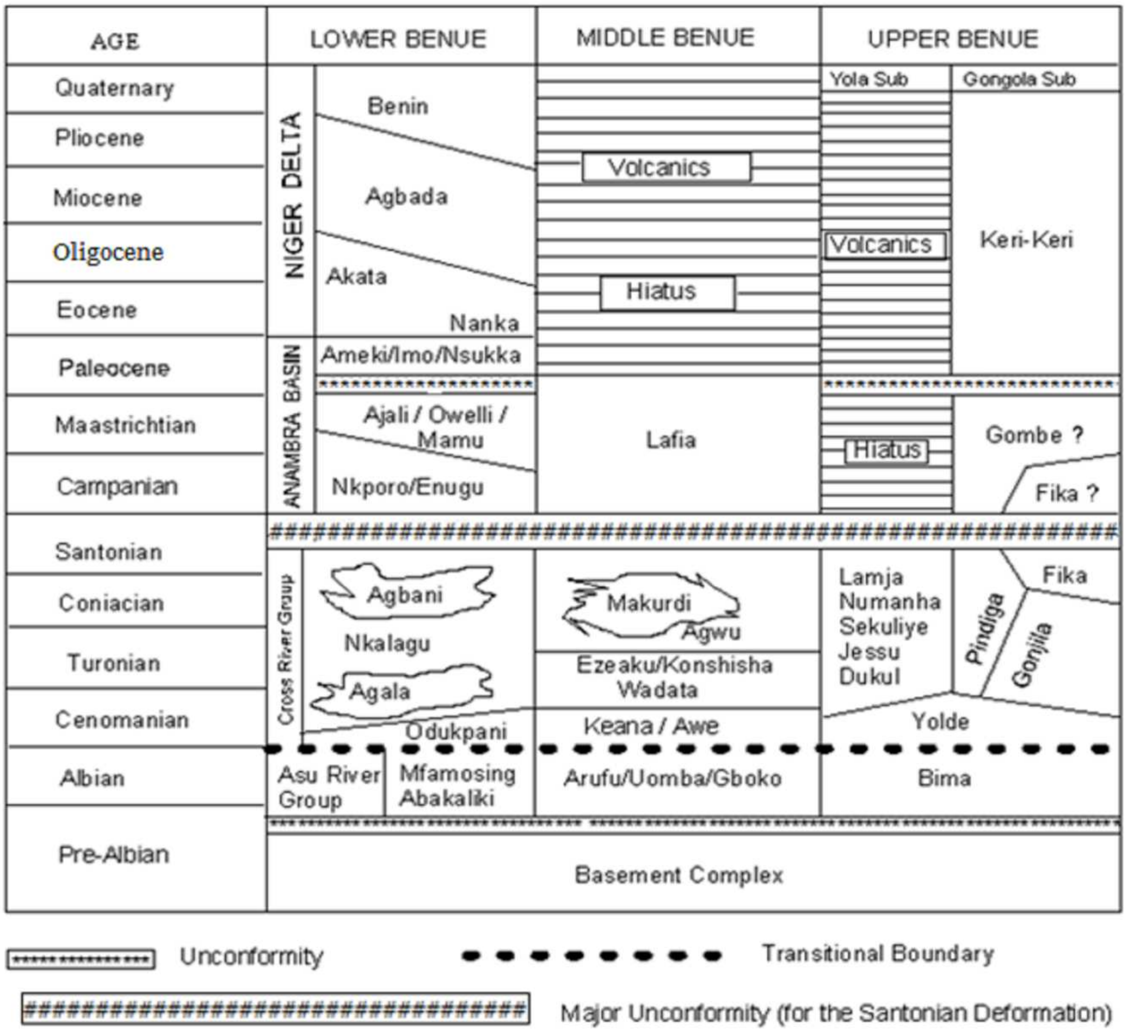

Fig. 2 Stratigraphic succession within the Benue Trough [24]

Geological Setting

The Benue Trough 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 Trough contains as much as 6,000m of Cretaceous–Tertiary sediments, including those predating the Middle Santonian which have been compressionally deformed, faulted, and uplifted in several places. Compressional folding during the Middle Santonian tectonic episode affected the whole of the Benue Trough and was quite intense, producing more than 100 anticlines and synclines [6]. The geology and stratigraphic successions in the Benue Trough have been extensively reviewed by [7-17] among others.

In the Lower Benue Trough, stratigraphic succession commenced with the marine Neocomian–Albian Asu River Group, although some pyroclastics of Aptian–Early Albian age have been sparingly reported [18 and 19] (Fig. 2). The Asu River Group sediments in the Lower Benue Trough comprises predominantly of shales with localized sandstones, siltstones and limestones [20] as well as extrusive and intrusive material [8]; [21]; [22] and [23] of the Abakaliki Formation in the Abakaliki area and the Mfamosing Limestone in the Calabar Flank [12]. 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 siltsones) 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. 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).

In the Middle Benue Trough, the sediments thickness is about 4,000m. The stratigraphic succession in this part of the Trough begins with the basal Albian Arufu, Uomba, Gboko Formations, generally referred to as the Asu River Group (Fig. 2). These are overlain by the Cenomanian Keana and Awe Formations and the Cenomanian–Early Turonian Ezeaku Formation. The Late Turonian–Early Santonian Awgu Formation lies conformably on the Ezeaku Formation. The Late Santonian–Early Cenomanian was a period of folding and uplift throughout the Benue Trough. The post-folding Campanian–Maastrichtian Lafia Formation ended the sedimentation in the Middle Benue Trough, after which widespread volcanic activities took over in the Tertiary.

The Upper part of the Trough bifurcates at its northeastern end into the Gongola and the Yola basins. In both basins, the Albian Bima Sandstone lies unconformably on the basement (Fig. 2) and is conformably overlain by the Cenomanian transitional/coastal Yolde Formation which represents the beginning of marine incursion into the Upper Benue Trough. In the Gongola basin, the lateral equivalent Gongila and Pindiga Formations lie conformably on the Yolde Formation. These Formations were deposited by the major marine incursion into the Upper Benue Trough during upper Cenomania–Turonian–Santonian periods. In the Yola basin, the Dukul, Jessu and Sekuliye Formations along with the Numanha Shale and the coal bearing Lamza Sandstone, are the upper Cenomanian–Turonian–Santonian equivalents of the Gongila and Pindiga Formations. The Upper Cenomanian–Turonian–Santonian deposits in the Yola Formation basin are lithologically and paleoenvironmentally similar to those in the Gongola basin, except the Lamza Sandstone which has a dominant marine, sandstone lithology. The Mid–Santonian was a period of folding and deformation in the whole of the Benue Trough. Post-folding sediments are represented by the continental coal-bearing Gombe Sandstone of Maastrichtian age and the Kerri-Kerri Formation of the Tertiary age.

Lead-Zinc-Barytes Mineralization in the Lower Benue Trough

In the Lower Benue Trough, lead-zinc-barytes mineralization occurs as epigenetic fracture-controlled vein deposits which are restricted to Albian–Turonian sediments (Fig. 2) but more widely distributed spatially. Detailed field studies carried out by [25] in four main areas, namely Ishiagu, Enyigba-Ameki-Ameri, Wanikande-Wanakom, and Gabu-Oshina which together constitute the four major areas of mineralization in the Lower Benue Trough revealed that in all the four areas, mineralization appears restricted to NW-SE and N-S fractures while the more common NE-SW fractures are barren. Apart from the Enyigba area, igneous bodies are found in the vicinity of the ore deposits and in the Wanikande area, barytes veins and veinlets were observed to be closely related to the intrusive bodies. The host lithologies are highly varied ranging from shale to siltstone, sandstone and occasionally igneous bodies. According to [25], the ore assemblage also varied remarkably in the areas, with lead-zinc-barytes ratios varying from approximately 3:1:0 at Ishiagu, to 2:1:0 at Enyigba, 1:0:2 at Wanikande at nearly 100% barytes at Gabu-Oshina. These show that there is a remarkable increase in barytes content from the southwest (Ishiagu) to the northeast (Gabu). Nigeria's most important lead-zinc-barytes deposit is the Abakaliki field which is made up of primarily four lodes namely Ishiagu, Enyigba, Ameki and Ameri in the Lower Benue Trough.

Lead-Zinc-Barytes Mineralization in the Middle Benue Trough

In the Middle Benue Trough, lead-zinc-barytes mineralization also occurs as epigenetic fracture-controlled vein deposits restricted to Albian–Cenomanian sediments of Asu River Group, Awe and Keana Formations (Fig. 2). The fractures occur as single linear structures or as a series irregular fractures interconnected and spaced over a considerable width and distance. The lithologies were cut by E-W and NW-SE trending mineralized veins. At Akiri, the mineralization is associated with the following gangue minerals: quartz, feldspar, hematite, calcite, and copper [26]. In Akwana and Arufu, lead-zinc-barytes mineralization is associated with the above gangue minerals and occasionally with native silver. Limestone wall rock at Akwana and Arufu is highly silicified, which appears to be related to the mineralization process as the intensity of the silicification decreases away from the vein [27]. At Azara, the veins are very rich in barytes with plenty sphalerite and with occasional cubic galena [27]. In all, about 20 veins have been mapped in Azara, and conservative estimates carried out in three rich veins, out of the 20 occurrences in this locality, indicated a reserve of up to 130,000 tonnes of contained $BaSO_4$, and for only 10m depth [3]. The host lithologies varied from shale to sandstone, siltstone, conglomeratic ironstone, minor limestone beds and occasionally igneous bodies. There are also other known occurrences of lead-zinc-barytes mineralization in the Middle Benue Trough at Aloshi, Wuse, Gbende, Sardauna, Karim Lamido, Yoro, Lau, Wukari and Ibi areas. However, Azara barytes deposit is the best known deposit of baryte in Nigeria.

Lead-Zinc-Barytes Mineralization in the Upper Benue Trough

In the Upper Benue Trough, lead-zinc-barytes mineralization is fracture-controlled vein deposits restricted to Albian–Cenomanian sediments of Bima and Yolde Formations (Fig. 2). These mineralizations are located in and around Isimiya, Diji, Gidan Dari, Alkaleri and Gwana in Bauchi State. At Isimiya, quartz veins hosted by sandstone striking N-W host the mineralization while the veins are hosted in grey shale member of the Yolde Formation at Gidan Dari. The host lithologies include; sandstone, shale, mudstone, limestone and clays.

Economic Prospective

Lead is used in building construction, lead-acid batteries for the storage of energy, ammunition (bullets and shot), weights as part of solders, fusible alloys, radiation shield, burial vault liners, ceramic glazes, cosmetics, leaded glass and crystal, paints or other protective coatings, pewter, and water lines and pipes.

Zinc is used in galvanizing steel to protect it from rust, the manufacture of brass and other alloys, rubber vulcanizing, cosmetics, plastics, rubber, ointment, sun screen creams, soaps, paints, fertilizers, batteries and the production of pigments and certain medicines and chemicals.

Barytes is used as a weighting agent for drilling fluids in oil and gas exploration to suppress high formation pressures and prevent blowouts. As a well is drilled, the bit passes through various formations, each with different characteristics. The deeper the hole, the more barytes is needed as a percentage of the total mud mix. An additional benefit of barytes is that it is non-magnetic and thus does not interfere with magnetic measurements taken in the borehole, either during logging-while-drilling or in separate drill hole logging. Other uses are in added-value applications which include filler in paint, paper, clothe and plastics, sound reduction in engine compartments, coat of automobile finishes for smoothness and corrosion resistance, friction products for automobiles and trucks, radiation-shielding cement, glass ceramics and medical applications (for example, a barium meal before a contrast CAT scan). Historically barytes was used for the production of barium hydroxide for sugar refining, and as a white pigment for textiles, paper, and paint.

CONCLUSION

Deposits of lead and zinc minerals in the form of their ores of galena and sphalerite respectively and barytes occur extensively in the Cretaceous sediments of the Benue Trough sedimentary basin of Nigeria. Pb-Zn deposits in Benue Trough are sedimentary exhalative (Sedex) type of deposit formed when metal-rich hot liquids are released into water-filled basin sediments, which results in the precipitation of ore-bearing material with basin floor sediments. Nigeria's most important lead-zinc deposit is the Abakaliki field which is made up of primarily four lodes namely Ishiagu, Enyigba, Ameki and Ameri in the Lower Benue Trough. The best known barytes deposit in Nigeria is at Azara in the Middle Benue Trough. The lead-zinc ores (galena and sphalerite) and barytes are impregnated in relatively narrow fracture zones in shale, siltstone, sandstone, limestone, mudstone, clay and occasionally igneous bodies.

There is need for further investigation of more deposits of lead-zinc-barytes in the country especially in the Benue Trough. The development and utilisation of the minerals will create job opportunities for many unemployed Nigerians. Furthermore, utilisation of Nigerian lead-zinc-barytes will have a multiplier effect on other industries.

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