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Research Paper

METALS AND SOLID MINERAL DEPOSITS IN SOUTH EAST NIGERIA IN THE ERA OF ALTERNATIVE TO CRUDE OIL AS THE NATIONS' MAJOR SOURCE OF REVENUE, ABAKALIKI AND UMUAHIA EBONYI/ABIA STATES CASE STUDIES

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Metals and solid mineral resources in the South East of Nigeria are made up of naturally occurring solid metal ores, or minerals or sedimentary deposits in forms and extents that economic extraction of the material deposit will be financially viable. At the contemporary time Nigeria's economy yearns urgently to diversify its main hold from crude oil and metals/solid minerals that can suitably provide alternative revenue to Nigeria's economy. The Nigerian economy is sustained by the crude oil/petroleum products and has been flagged deficient because of single-economy generating force. Emphasis was transferred from increase of strategies for oil and gas exploration in the Niger Delta and Nigerian sedimentary inland basins, to harnessing of opportunities for exploration for solid minerals such as gold in the alluvial and eluvial placers and primary veins in SW to NW Nigeria. Metallic minerals of galena deposits (lead ore), and sphalerite (zinc ore) are associated lead-zinc mineralization which occur in the Albian Abakaliki Shales, notably at Ishiagu and Enyigba in Ebonyi State, lead-zinc in veins at Abakaliki and Ishiagu. Economic deposits of solid minerals usually occur in tectonically disturbed areas and may be either structurally controlled or stratabound. They occur massively and sometimes in a disseminated form and may be crystalline in nature or amorphous. Exploitation or extraction Project areas comprise Abakaliki suburbs for lead-zinc deposits and salt (brine) deposits, and lead sulphide at Ohozara. Lead-Zinc localized as veins along the NE-SW Nigerian trending belt of Nigeria, with projects at Abakaliki areas, Ameri, Ameka. Also considered inevitable to the efforts on rescuing Nigeria economy from singular dependence of crude oil is the call to revamp the Iron ore in banded sedimentary formations in Awka vicinity in Anambra State, Nsude and Nsukka areas in Enugu State, Clay and kaoline industrial minerals occur in Ohiya Umuahia area which provided raw material to the famous Umuahia Ceramic Industry of the '70s to 1990's. The surplus revenue generation from crude oil drawned or buried the sustenance of clay mineral industries including the (clay) Burnt Bricks Industries at Okigwe and Awgu-Enugu sites, of the same production dates. The inevitable need for investigation for non-pure petroleum deposits such as Tarsands and Bitumen, is suggestive of the ubiquitous black shales of Nkporo-Nguzu-Eda-Abiriba-Ohafia Area (Coal

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Measure). The very extent of bitumen seepages and sediments laden with oil can be investigated in this part of South Eastern Nigeria. For the desired diversification of the national revenue, not crude oil dependent, more investigations for bitumen is inevitable in the region. The need for further coal exploration and mining as alternative source of power will to a great extent bring the Nigerian economic status to an enviable position, which will automatically extend to the Eastern States. Emphasis was laid on revitalizing the coal mining industry to provide fuel for power generation and for domestic use. More investigations are required in the Anambra Coal Basin, particularly the Enugu District. Grades of coal from bitumen to lignite still accumulate sizeable acreages of reserves. These coal sites are potential excellent thermal coals for fueling coal-fired electrical generating plants, or as back-up.

Keywords: Lead-zinc mineralization, Salt deposits, Sulfide veins, Coal deposits

INTRODUCTION

Solid mineral resources are made up of those concentrations of naturally occurring solid materials in or on the earth's crust in such forms that economic extraction of the material deposit is currently or potentially feasible. As is contemporary to our Nigerian economy there is an urgent need to diversify the main hold of the national economy from solely crude oil to inclusive of solid minerals that can suitably provide alternative revenue to Nigeria's economy. The financial status of the Nigerian economy which is sustained by the crude oil or petroleum products has been flagged deficient as much as it points to be single-economy generating force. Emphasis was transferred from increase of strategies for oil and gas exploration in the Niger Delta and Nigerian sedimentary inland basins, to harnessing of opportunities for exploration of Solid Minerals such as gold in the alluvial and eluvial placers and primary veins in SW to NW Nigeria. Economic deposits of solid minerals usually occur in tectonically disturbed areas and may be either structurally controlled or stratabound. They may occur massively or in a disseminated form and may be crystalline in nature or amorphous.

Iron ore in banded sedimentary formations in Aladja and Ajaokuta on a national basis provides a roadmap for commercial metallic ore development. Lead-Zinc localized as veins along the NE-SW Nigerian trending belt of Nigeria, with projects at Abakaliki areas, Ameri, Ameka, Also considered key to the efforts on rescuing Nigeria economy from singular dependence of crude oil is the call to revamp of the Jos and Bukuru Tin Mining with extensive availability of geological information.

Also highlighted was the necessity for enlargement of the scope of investigation for non-pure petroleum deposits such as Tarsands and Bitumen. The large extent of bitumen seepages and sediments laden with oil has been investigated in the SW Nigeria. For the desired diversification of the national revenue, not purely crude oil dependent, more investigations for bitumen were advocated for.

The Nigerian government was prompted to make further development of coal exploration and mining projects attractive, given its excellent potential as alternative source of power. Emphasis was laid on the keynote revitalizing the coal mining industry to provide fuel for power generation and for domestic use. More investigations are required in the Anambra Coal Basin, comprising and not limited to Kogi District and Benue (District of Orukpa-Ezimo), and Enugu District. The grade of coal from bitumen to lignite still accumulate significant acreages of reserves for delineation. These coal sites are considered potential excellent thermal coals for fueling coal-fired electrical generating plants. Other sites of interest include, Inyi deposit south of Enugu, Afikpo deposit south and east of Inyi, Lafia Obi deposit NE of the district requiring additional exploration, Gombe deposit east of Lafia Obi requiring more exploratory and evaluation studies, and the Asaba lignite on coastal plane south of Anambra Basin.

GEOLOGY

The study area (Figure 1) lies between latitude 6°11' N and 6°23' N and longitude 8°02' E and 8°11' E covering approximately 368.11 km^2. Some major towns within the area are Abakaliki (capital city of Ebony State), Agu-Akpu, Okposi-Umuoghara, Onyikwa and Enyigba. The area is bound in the North by Ogbaga, in the East by Ogbubara, in the South by Ndiagu and in the West by Oshiri towns, all in Ebonyi state. It is accessed through Enugu-Ogoja highway and also through Abakaliki-Afikpo highway, which link other roads as shown in Figure 1. Metallic minerals of galena deposits (lead ore), and sphalerite (zinc ore) are associated lead-zinc mineralization which occur in the Albian Abakaliki Shales (Figure 2), notably at Ishiagu and Enyigba in Ebonyi State (Ezepue, 1985).

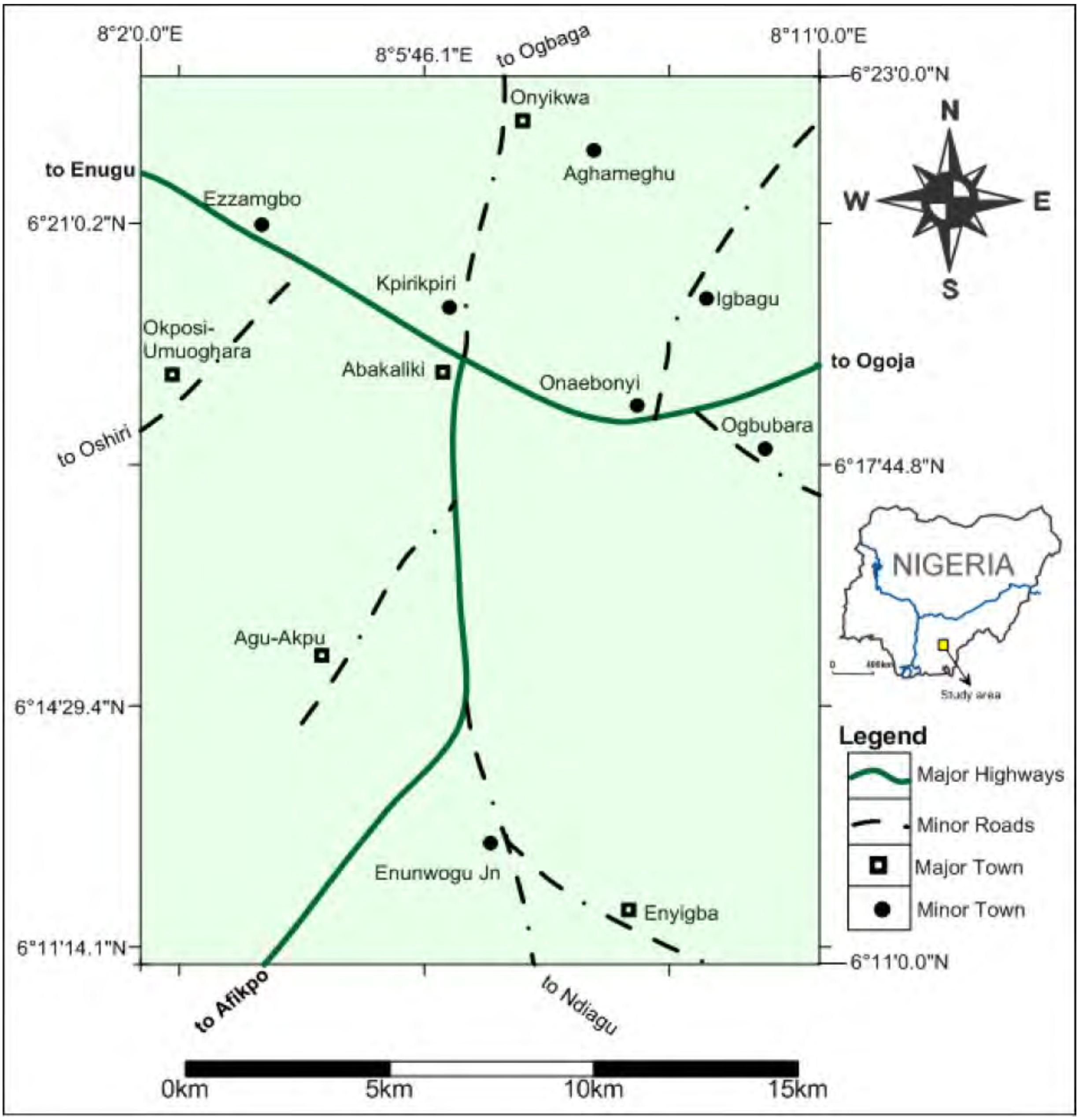
Other major cities in the South Eastern Nigeria associated with solid mineral deposits are Enugu for coal, Nkalagu, Eha-Amufu, Agwu, Nenwe, Arochukwu for limestone (Umeji, 1985), Okigwe area, Ohiya-Umuahia area for clay and kaoline deposits, which were used as bleaching agents in vegetable oils and making bricks and ceramics and were also quarried from Ogbete Enugu, and Umuahia areas for above industrial purposes.

Climate and Relief

In the tropics the climate influences weathering of minerals and disintegration of litho-materials. Abakaliki metropolis is located within the tropical savanna (wet and dry) weather. Generally, the tropical climate is characterized by at least eight months in the year having precipitation (mostly rainfall) not less than 60mm and each of the twelve months having mean temperature ranging from 18 to 27 °C in which the monthly mean temperature of the tropical savanna mostly exceeds that of other two subtypes – tropical rainforest and monsoon climate. According to Rajan (2011), the annual average temperature and precipitation of tropical savanna climate ranges from 24 °C to 27 °C and 100 mm to 150mm respectively. The wide annual precipitation variation within this climate results to four versions. The first version is characterized by distinct wet and dry seasons of virtually equal duration while the second version has seven or more months of dry seasons. The third version is an inverse of the second version while the fourth version (which is rare) features a dry season characterized by noticeable amount of precipitation and a wet season. The first and third versions are the types that occur in Southeastern (including Abakaliki metropolis), Central and Southwestern Nigeria while the second version prevails in Northern Nigeria. The Abakaliki areas fall into the tropical savanna climate, which facilitates weathering of minerals.

Relief of the study area ranges from 45 to 100 m above sea level. The highest points occur at

Figure 1: Abakaliki, Ebonyi State - Eastern Nigeria Case Study for Solid Minerals Alternative to Crude Oil as Major Revenue Generator to Nigerian Economy

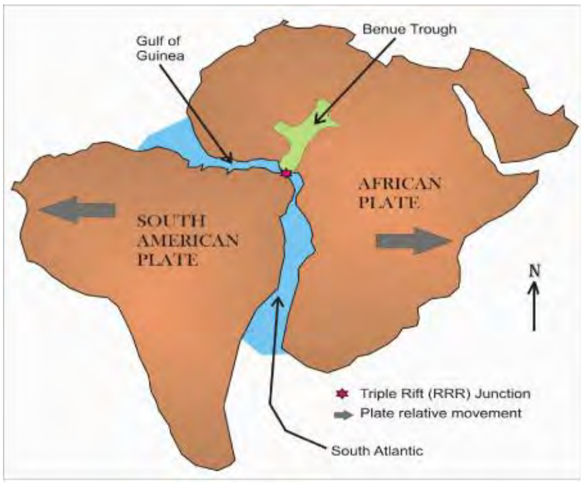


the northwestern part at Okposi-Umuoghara; the western parts are generally higher than the eastern parts.

METHODOLOGY

Basic outcrop and structural field mapping was conducted, which involved the direct physical search for solid mineral deposits, as conventional geological mapping with secondary employment of geophysical and geochemical techniques. Detailed reserve-evaluation of ore bodies to delineate the

Figure 2: Formation of the Benue Trough During the Early Cretaceous Period (Modelled After Grant, 1971)



deposits would require geophysical and geochemical surveys.

The solid minerals and host rocks will serve as raw materials to manufacturing of several products including fertilizers, paints, pharmaceuticals, and aggregates for constructions and engineering industries.

TECTONIC ORIGIN OF ABAKILIKI BASIN

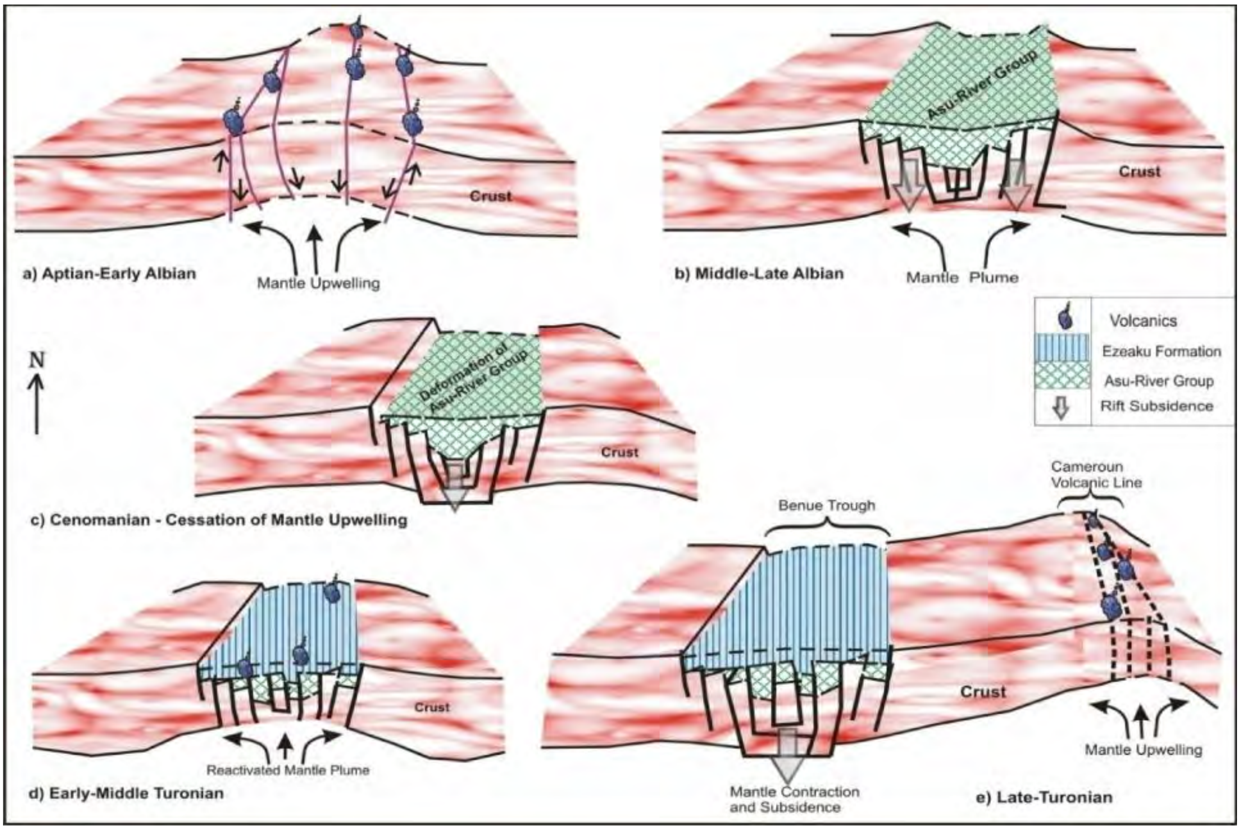
Abakiliki Basin belongs to the Lower (southern) Benue Trough. The trough itself is an approximate 800km long, 80-100 km wide and up to 5 km deep NE-SW trending intra-continental rift-like basin, which extends from Gulf of Guinea through eastern part of Nigeria to the northern part of Cameroun and formed during the Neocomian/early Gallic Epoch (early Cretaceous Period). It evolved as third failed arm of a triple rift (otherwise called RRR rift) system during separation of South American plate from African plate. This separation also gave rise to the Gulf of Guinea and South Atlantic as illustrated in Figure 3 (Burke *et al.*, 1970, 1971 and 1973; and Grant, 1971).

Olade (1975) reconstructed that the rift (Benue Trough) formed due to violent upwelling, which originated from mantle, resulting to stretching, uplift, faulting and subsidence of major crustal blocks, in Aptian – early Albian Stage (Figure 3a). The initiated faults became vent through which subsequent mantle plume (magma) migrated to the surface as volcanic eruption in early Albian Stage (Ojoh, 1990). The plume reactivated in early-middle Turonian Stage (although some authors like Uma and Lohnert, 1992 say pre-Turonian Stage) after the southern part of the trough (Lower Benue Trough) had subsided as a result of longitudinal faulting caused by the mantle upwelling (Murat, 1972) and received its first phase of sediments, the Asu-River Group, from bordering Basement Complex (Figures 3b-3d). Ojoh (1990) stated that the subsidence was spasmodic climaxing in the Turonian Stage when mantle upwelling ceased (Figure 3e).

According to Nwachukwu (1972), Wright (1976) and Ofoegbu (1983), the Benue Trough experienced another tectonic event in the Santonian Stage, which involved compression movement along the NE-SW trend of the southern part resulting to uplift and folding of Lower Benue as well as initiation of NW-SE and N-S fractures.

This folding episode is not only characterised by displacement of the depo-centres to west and east parts (corresponding to Anambra and Afikpo Basins respectively) and forming the Abakiliki Anticlinorium, but also associated with minor intermediate intrusions, Pb-Zn and fluorite-barite mineralization (Akande *et al.*, 1992). Nwachukwu (1972 and 1975) and Orajaka (1972) had attributed the mineralization to Turonian tectonic event and Albian sedimentation respectively. It is then obvious that Lower Benue Trough experienced three tectonic upheavals notably in

Figure 3: Models Showing the Tectonic Evolution of Benue Trough (Modelled After Olade, 1975 and Ojoh, 1990)



Aptian/pre-Albian, Turonian and Santonian Stages, which were all characterised by volcanic eruptions/intrusions that gave rise to igneous rocks of various types that in all cases intruded the host sedimentary rocks. In other words, Lower Benue Trough (Abakiliki Basin) contains both sedimentary protolitic rocks as well as igneous rocks. Consequent to these tectonic events, the relative ages of rocks (sedimentary, igneous and metamorphic) within this basin cannot strictly concur to 'the principle of horizontality' and/or 'cross-cutting relationship'. This means that within Abakaliki Basin, not all lithostratigraphic units are older than those overlying them and not all igneous bodies are in contact with the older host rock(s). However, Obiora (2002) showed that the igneous rocks outcrop in four major districts namely Southwest of Gboko, Ejekwe-Wanikande, Abakiliki and Okigwe-Ishiagu. He observed that for each of the igneous outcrops, the Asu-River Group is a major host rock as shown in Table 1.

Uzuakpunwa (1974) observed that Asu-River Group overlies Abakaliki pyroclastics which was probably ejected under subaerial shallow marine conditions in Aptian to early Albian Stage. He also stated that lithologically, Asu-River Group is composed of 3 km thick micaceous sandstones, mudstone, sandy shales and limestone intercalated with lava flows, dykes and sill of Cenomanian age. Authors like Nwachukwu (1972), Orajaka (1972) and Ojoh (1990) opined that Asu-River Group was deposited in marine environment by the Albian transgression, (which according to Tijani *et al.* (1996) is the cause of saline groundwater condition rampant in Lower Benue area), and is mostly composed of shales and sandstone facies with associated volcanic intrusions/pyroclastics. The works by Murat (1972) and Petters (1991) reveal that Asu-River Group is made up of Abakaliki Shales, pyroclastics/intrusions with interbedded sandstone/siltstone deposited in marine/shelf environment during the Albian Stage. They also discovered that the Lower Benue Trough is marked by three major unconformity (most likely, corresponding to the three tectonic events earlier stated) in Pre-Albian, Cenomanian and Santonian Stage respectively.

The implication of the above discussion on origin and existence of Asu-River Group rock units is that Asu-River Group sediments were deposited in multiple episodes which probably had non-uniform sediment influx in all parts of the depo-centres (Benue Trough) and spatiotemporal interspaces caused by intrusions. Also, tectonic events must have contributed immensely to re-organising the initial stratigraphic sequence of Asu-River Group (sediments and igneous rocks). Hence, it is possible to find Abakiliki Shales that are highly indurated (or regionally metamorphosed) in contact with those intruded by igneous rocks or Abakiliki pyroclastics in contact with slate or mudstone.

PETROGENESIS AND STRATIGRAPHY OF ASU-RIVER GROUP

Abakaliki metropolis is underlain by the Asu-River Group, which is the oldest stratigraphic unit within the Lower Benue Trough and occupying the core of Abakiliki Anticlinorium (Figure 3). Different authors who have studied the rock from different locations reported their observations as follows:

Obiora (2002), Obiora and Umeji (2004) and Obiora and Charan (2010) reported that Asu-River Group consists of low-grade regionally metamorphosed calcareous/silty shales of late Aptian to Albian Stage that were intruded by igneous rocks which according to Akande and Erdtmann (1998) formed from sediments that

Table 1: Distribution and Ages of the Igneous Rocks in the Lower Benue Trough (Compiled by Obiora, 2002)

District	Form/Type of Igneous Rocks	No of Outcrops	Age of Igneous Rocks	References (for Age)	Host Rocks
South west of Gboko	Subvolcanic intrusions – phonotephrites, phonolites and trachytes	Up to 40	86 Ma (Foyum monzo-syenite)	Umeji (2000)	Slate from shales of Albian Asu-River and Turonian Eze-Aku Groups
			61 Ma (Abata syenite)		
			59 Ma (Agyra syenite)		
Ejekwe-Wanikande	Non-fragmental igneous rocks- alkali dioritic rks, microgabbros/dolerites, nepheline syenite, basalt sills, trachytes and phonolites	More than 70	105 and 104 Ma (Wanikande syenite)	Snelling (1965) and Benkhelil (1986)	Mostly in the slate from the Asu-River Group and less commonly in those from the Eze-Aku Group
			94 Ma (basaltic sill, valley of Anyim River) 88.9 Ma (Olivine microgabbro, Ameka		
	Pyroclastics-tuffs and lapilli; tuffs of basaltic to trachybasaltic compositions		80.7 Ma (basic rock, Workum hills)	Benkhelil (1986)	
Abakiliki	Pyroclastics-tuffs and lapilli, tuffs of basaltic to trachybasaltic compositions and rare basalt	Up to 10	Not available		Slates from shales of the Asu-River Group
Okigwe-Ishiagu	Dolerite sills, alkali dioritic plutons, agglomeratic pyroclastics	Less than 10	87 Ma (Leru dolerite), 74 and 76 Ma (Eziator diorites)	Umeji (2000)	Slates from the Asu-River Group, less commonly in the Eze-Aku Group

were rapidly deposited over Paleozoic gneisses, schists and migmatites of Basement complex in shallow marine and brackish water environment.

RESULTS AND ANALYSIS

Metallic Minerals

Metallic minerals of galena deposits (lead ore), and sphalerite (zinc ore) are associated lead-zinc mineralization which occur in the Albian Abakaliki Shales (Figure 2), notably at Ishiagu and Enyigba in Ebonyi State, in agreement with (Ezepue, 1985). Barytes, the major ore of barium is found in the lead-zinc mineralization association in veins within the Abakaliki area of Lower Benue Trough. Other minerals associated with lead-zinc mineralization include chalcopyrite and marcasite, flourites, barites, and quartz. Secondary mineralization includes malachite, azurite,limonite, pyromorphite, and local silver.

Other areas of occurrence in the South East Zone, Nigeria include, Ameke and Ameri in Abia State, as deposits of lead and zinc lodes. Some intrusive rocks are associated with the mineralization. Exploitation of the ores at Ishiagu is essentially by communities by manual labour. The intrusive rocks and baked shales are additional resource broken down and sold for the building industry.

Lead is used in making cable coverings, pigments, solder, storage battery, sheet lead, pipes, paint, and ceramics. Zinc is used for batteries, and combined with other metals in alloys.

Iron stone deposits occur at Nsude southwest of Enugu, measuring between 1 m and 8 m in thickness. It overlies the Ajali Formation, and conceived to be derived from the lateritized beds of the overlain Nsukka Formation. Local communities smelted the ironstones into metal iron. Nigerian Geological Survey Agency (NGSA) reported occurrence of 50,000 tonnes in a bed of about 1.5 m to 9 m thick overlain by clayey soil overburden.

Industrial Minerals

Limestone has been in extensively occurrence at Nkalagu, which provided raw material for the Niger Cement Company. Limestone deposits also occurred in Eha-Amufu, Agwu, Nenwe, Arochukwu areas (Umeji, 1985). It is a unit of Eze-Aku Group of sediments.

Clay and Kaoline deposits are found extensively in the South East Zone of Nigeria, comprising Enugu areas, Okigwe areas, Owerri and Umuahia areas. They are used for manufacture of pottery, tiles, refractory bricks, vitrified bricks, sanitary wares, sewer pipes. Red clays are used by natives for painting mud walls, while beneficiated clays were used in pre-civil war decades as substitute for drilling mud in the petroleum industry.

Contemporary exploration or drilling activities in petroleum industry have been influenced by appetite for imported bentonite. However, Nigerian State Governments, Local Governments and private entrepreneurs can go back to local production of commercial quantities of beneficiated clays, and NNPC should then champion the advertizing and use of Nigeria-manufactured clays in-place of wallowing importation of trillion tonnes of foreign Bentonite.

Clays are also used as bleaching agents in vegetable oils and making bricks and ceramics Clays were quarried from Ogbete or Enugu areas, and Umuahia areas for various industrial purposes. Barytes - common ore of barium associated with lead-zinc mineralization in Abakaliki areas Lower Benue Trough, is also largely utilized in drilling muds. Tremendous amount of revenue can be generated from clays and barytes via the over petroleum exploration companies operating in Nigeria.

Glass Sand is another earth material involving sieving out appropriate grade from river sands in Abakpa, Eha Alumona in Enugu State, Beneficiation materials from the Benin Formation found abundantly in Obinze, Uratta, and Mgbirichi in Imo State.

Energy Minerals

Coal

Other major cities in the South Eastern Zone of Nigeria associated with varying capacities of solid mineral deposits are Enugu for coal.

Coal is sub-bituminous black, non-coking mineral, of Cretaceous age. The mineral is

Figure 4: Lithostratigraphic Map of Lower Benue Trough Showing Location of the Study Area (Redrawn After Reyment, 1965; Short and Stauble, 1967; Murat, 1972; and Offodile, 1976)

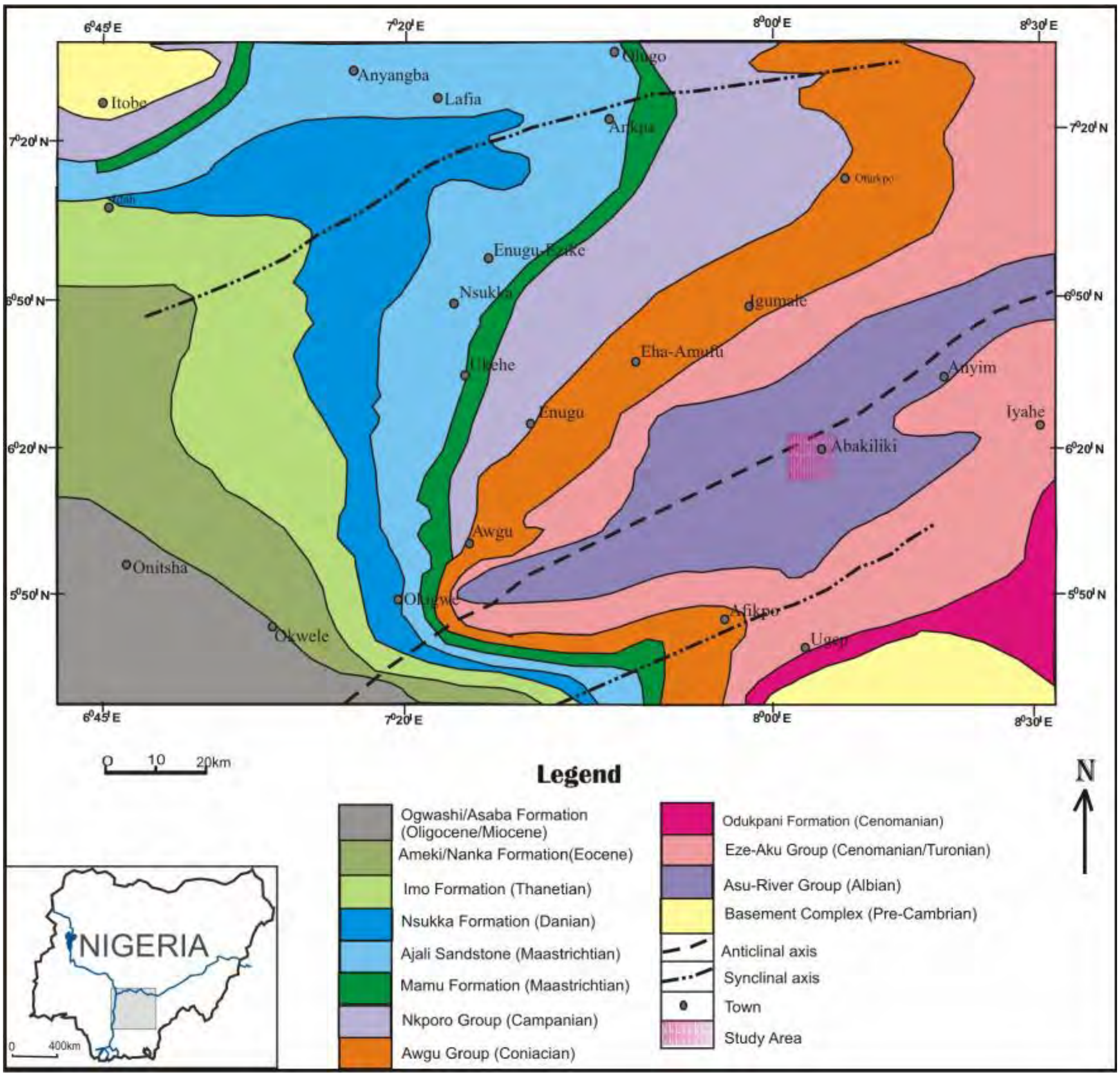


Figure 5: (a) Enyigba Massive Baked-Shale; (b) Exposed Ferroginized Shale (sh = shale, re = regolith)

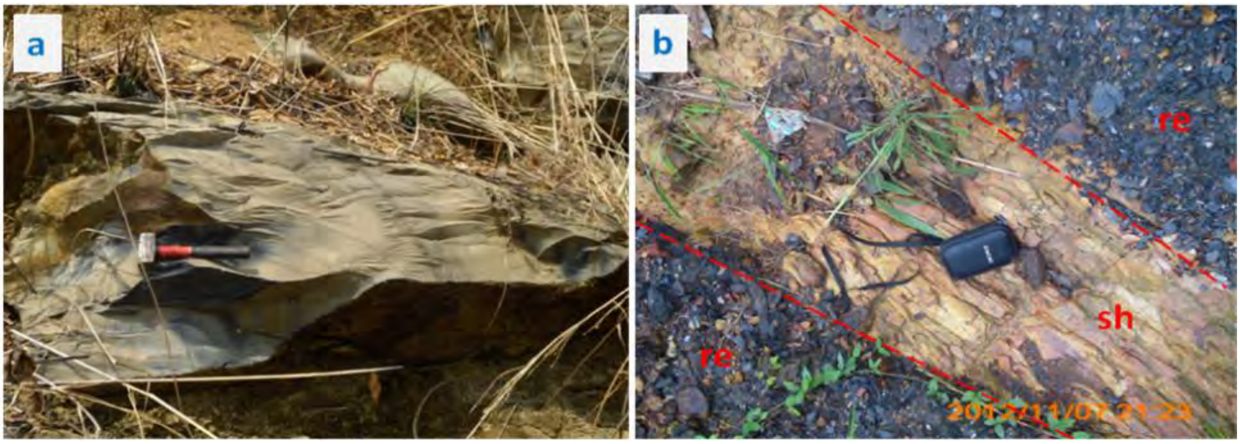


Figure 6: (a) Agu-Akpu Baked-Shale (b) Darker Shale Exposed at Agu-Akpu Quarry Site

Figure 7: (a) Ezzamgbo Tilted Shale Beds 4.6 (b) Fold Limb Observed at Ezzamgbo Outcrop

located at Enugu, Ukano, Okpatu, Ezimo, all north of Enugu, while Udi, and Inyi south of Enugu.

The Enugu coal was put at estimated reserve of 43 million tones, and mined by adit drilling because of thick overburden. It used to majorly provide fuel for the Railway Corporation in the past half of century, until the advent of fossil fuel and natural gas powered train engines. It was also used in powering the hydrothermal station at Oji River 45 km SW of Enugu, and also provided fuel for the kiln at the Niger Cement Factory Nkalagu. Production has ceased in all the mines due to more efficient powering oil and gas sources.

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