Uniport Journal of Engineering and Scientific Research (UJESR)

Vol. 5, Issue 2, 2021, Page 100-111
ISSN: 2616-1192

(www.ujesr.org)

Harnessing the Properties of Nigerian Barite for Drilling Mud Utilization: Modern Progresses and Expectations

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Abstract
For Nigeria to transit from a developing nation to a developed nation, every natural resource deposit of high industrial value must be utilized. Barite is one of such natural resources with various key applications in diverse features of the modern-day industries. Energy, information and material for the making of technology have great prospect for the consumption of this precious stone (Barite). In this review article, the Nigerian localities where these deposits are found were identified and the critical properties of the barite were carefully reviewed. These properties include the essential rheological, mineralogical features suitable for drilling mud utilization. Over the years, a variety of research endeavors on this area have been conducted, which were summed up with a number of topical issues arising based on the broad review. Also, this review covers a specific interest segments on the proven and unproven estimation of reserve, chemical alteration, mineralogy of deposits, rheological properties of drilling mud utilization from the barite and its aptness for drilling activities. Furthermore, an outlook on the primary opportunities and critical practical challenges on the subject of utilization of Nigerian barite clay for drilling mud were properly discussed.

Keywords: *Drilling mud, Barite utilization, Nigeria*

Received: 15th March, 2021 *Accepted: 7th April, 2021*

1. Introduction

Nigeria depends heavily on imported products for the daily running of her economy. Apart from the petroleum industry that contributes almost 85% of her foreign exchange earnings, every other sector depends on product importation which is one of the major factors leading to the problem of dollar naira exchange rate. Despite the fact that the Nigerian economy is tactically occupied by the oil and gas sector, the latest international down fall in oil price has truncated and restricted the income from oil money for Nigerian. The fall of oil price has led to a number of economic restrictions on key oil and gas industry actors in Nigeria. Although most of the big players such as the International oil companies (IOC's) were able to withstand the hit while the local companies were badly impacted. Henceforth, there is a golden opportunity to engage in reflection and critical thinking about the way forward. For a time such as this, requires scholars to stepping forward to facilitate this opportunity that will usher in industry leaders to come together to share perspectives in view of the shocking consequence of the fall of oil price in order to bring stability the economy in harnessing and optimizing local natural resources in providing key answers to the problems available in the oil and gas industry. This would facilitate the reduction on importation of materials for oil and gas drilling operations and chat a way forward for monetary sources for the both the government, local and the IOC's. Owing to the numerous challenges facing the oil and gas industry in Nigeria, the Nigerian government moved to tackle some of these challenges by developing a blueprint and by 2010 the act was signed, titled, the Local Content Development Act. The target was to promote the utilization of Nigerian indigenous local natural resources in the oil and gas industry in order to offer a better opportunity for local participation and generate huge economic benefit to the country and solve the problems militating against the Nigerian oil and gas industry (Ayonmike and Okeke, 2015). The drilling activity in the hydrocarbon industries in the sub-Saharan African countries is one of the most critical aspects of the sector especially the Nigerian

economy. Oil and Gas drilling is so essential such that it is a critical operation used to for the authentication of the volume of hydrocarbon underneath surface and the most significant component for this business is the drilling fluid most times referred as drilling mud. "Drilling fluid" is the terminology severally utilized as the generic term for "drilling mud" for the reason that it entails all the relevant uniqueness, features, characteristics and qualities that are fundamentally calculated to match the fluid system. This is designed to match the fluid characteristics beyond its natural occurrence in subsurface formations in the course of the technical combination of formation clays and that of water.

Drilling operation is the one of most vital phases of the hydrocarbon value chain throughout the globe and more importantly that of Nigeria. Prior to the assembling of the team of engineers, geologist and economist for the calculation and subsequent development of the initial oil and gas in place is the wildcat or exploratory well drilling crew team. This aspect of the value chain is essential because it offers basic information to the investor or the host government on the volume of the hydrocarbon found beneath the earth surface before resource is invested. The drilling practice is compulsory for the verification of the quantity and quality of hydrocarbon in the subsurface reservoir and a key factor in the entire drilling operation is the drilling fluid which is most times referred to as drilling mud. Furthermore, the expression "drilling fluids" speaks about fluids with multiple components despite the fact that "drilling muds" basically represent a combination of water, clay with other additives. 78% of oil and gas field chemicals used on yearly basis are made up of drilling mud (Agwu *et al.,* 2015). Earlier before the idea of the indigenous participation in the Nigerian oil and gas industries in teams of man and material, reports have proven that most of the additives used for the drilling operation are imported. The development of the local content law was a major boost for the Government of Nigeria and the indigenous oil companies in teams of local participation in entire oil and gas value chain operation. For many years, there are several reports that indicates that key drilling operations conducted within the Niger Delta region by oil firms either home-grown and international was carried out using imported drilling mud both the additives necessary for the preparation of the fluids or before now designed drilling fluid to match the requirements for regions formation geology (Olatunde *et al.,* 2012). The estimated comparative cost of utilizing foreign materials for drilling operation in Nigeria is projected to several millions of United State dollars annually which is detrimental to the growing economy. In addition, recent report by the News Agency of Nigeria (NAN) through the Nigerian minster of solid minerals revealed that the country spends a huge sum of $300 million on importation of Barite (or Barytes) annually from Morocco, which was primarily utilized as the weighting agent for hydrocarbon drilling fluids operation for the upstream sector of the industry. Hence as the exploration for hydrocarbon bearing reservoirs is moving from the land (onshore areas) to the deep sea (offshore and deep offshore) regions, similarly is the related cost estimate of the by and large drilling operation is increasing. This is because the cost of drilling operation is as well subjected to the fluid performance; in other way round influence the technical formulation, design configuration and the safeguarding of drilling fluids essential.

The Nigerian government took a decisive measure to ensure that locally sourced materials are utilized in the oil and gas industries to support indigenous participation. This remarkable action improved the interest of entrepreneurs and researchers to venture into harnessing local sourced clays and additives for drilling mud use in the hydrocarbon companies in Nigeria. Prior to this time, several research has been conducted on the performance of locally sourced clays for the drilling mud and the result has proven that most of the clay types depending on the usage performed excellently while other like Bentonite shown high level of fluid loss during the application. Most of the other raw clays when applied show low performance properties of its fluid and loss rheological tendencies and consequently, researcher recommended the call for the boosting of the qualities of the properties through the process of beneficiation (Olatunde *et al.*,2012). Over the years the application of chemical additives for drilling fluid derived from locally sourced materials have not yielded any significant progress in teams of its property specification of global standards (Olatunde *et al.*,2012). Meeting the international standards is key for the utilization of local barite clay and considering the increasing demand for drilling mud especially barite clay for drilling as the search for hydrocarbon continues from the land, shallow water, deep water and ultra

deep water, there is a serious call for the upgrading of the local clays to match global best practice (American Petroleum Institute (API)) standard. These challenges, inadequacies and the impending trade and industry implications of the local barite reserve creates a persuasive case for further broad research in upgrading the performance and the quality of Nigerian clay deposits in meeting the foreign clay standards.

This paper seeks to review:

(a) The locally originated drilling mud properties that has been examined before now and its appropriateness for the Nigerian hydrocarbon sector drilling operation.

(b) The chronological antecedents of barite in Nigeria. The sequential order will follow the early application of Nigerian barite subsequent to the breakthrough of the Niger-Delta hydrocarbon finding within the 1958 till date, the Nigerian barite clays utilization decline and research and the current transformation of research awareness in indigenous barites.

(c) The researches based on the intellectual works in chemical analysis of barite mineral in Nigeria and some of the critical methods applied for the upgrading of the chemical composition prior to this time in corresponding with the standard of API.

Additional intellectual work that is required for the development and suitable characterization of the Nigerian barite for hydrocarbon drilling mud production.

2. The Nigerian barite

Nigeria holds abundance of solid minerals, and Barite is one of those minerals found in commercial quantity. Barites in Nigeria occur as vein infilling materials, frequently associated with lead-zinc lodes and veins in both pre-Cambrian basement and Cretaceous sedimentary rocks of the lower and middle Benue valley. The mineral occurs mostly in white, reddish-brown and clear varieties with specific gravity varying in the range of 3.5-4.4. The width of veins ranges from a few centimeters to 5.3meters. Length of veins also vary from few meters to >4500m Nigerian Geological Survey Agency under the Ministry of Mines and Steel Development (2010). Initially, the first survey work that was conducted by the Geological Survey of Nigeria in 1959 estimated the Benue valley deposits reserve at 41,000 tonnes. Based on the report of the Nigerian Mining Corporation, it was indicated that the estimated 70,000 tonnes of barite resource is deposited in the Azara area of Nassarawa State. Lately, the Nigerian Geological Survey Agency has also embarked on the assessment and estimation of recently reported deposits in Taraba States, Benue, Nassarawa, Plateau, and Cross River. The 21,123,913 metric tonnes of barite has been found in four state of Nigeria after an inferred analysis was used to estimate the resource level of viability (Nigeria Geological Survey Agency under the Ministry of Mines and Steel Development, 2010).

Barite has been discovered in commercial quantity in Nigeria in nine states. From Adamawa, Benue, Ebonyi, Cross River, Gombe, Nasarawa, Plateau, Taraba, and Zamfara state and this report is from the (Nigeria Geological Survey Agency, 2011). Table 1 presents the detailed characterization of each barites sample from the Nigerian and this work was conducted by Inyang (2013), he indicated the diverse Nigerian local governments areas Barite deposit and the standards of quality measure is based on the American Petroleum Institute (API) standard. One of the states in Nigeria identified as Barite host state is Adamawa State. The Barite occurrence in Adamawa is discovered in Demasa and Mayo-Belawa local government areas and in the form of cavity fillings and vein hosted by diverse varieties of rocks like granites, basalts, migmatites and feldspathic sandstone (Nigeria Geological Survey Agency, 2011). The specific gravity of the kind of Barite found in this state ranges from 4.0 - 4.36 and the deposit of 332,130 tonnes has been proved as the estimated reserve of barite discovered in Adamawa as reported by the (Ministry of Mines and Steel Development, 2010). Benue State is also one of the leading states where Barites are discovered to be commercial deposits and this is in the outward appearance of cavity fillings and vein, the key aspect of the occurrence has been proven to be as a result of solutions hydrothermal behaviours for the duration of the geological deformation of Santonian (Nigeria Geological Survey Agency, 2011).

Nigeria is richly endowed with profuse barite resources and if the issue of inadequate mining is properly tackled and the barite is sufficiently harnessed it will lessen the cost of importation of drilling fluid additive and other specific drilling fluids. Barite veins deposit has been found in all the six geopolitical zones of the country in large quantity. The reserve estimate of barite clay as proven reserve discovered in Nigeria is

unassumingly projected to be higher than 900 million metric tons (Aigbedion and Iyayi, 2007a,b; James *et al.*, 2008; Omole *et al.*, 2013; Bilal *et al.*,2015).Notwithstanding the huge volume of barite clay deposit found in Nigeria, the major operators of the hydrocarbon firms are yet to rest complete self-reliance on the use of indigenous supply of barite clays for drilling purposes, this is unmistakable in the sense that at present there is no indication of an account of the use of local barite clays for drilling application in Nigeria. A large amount of the overseas barites being utilized within Nigeria are over again smuggled into the country by the international oil firms (Oriji *et al.*, 2014). Foreign drilling mud importation was controlled in 2003 by the Nigeria government based on the interest for the encouragement of locally sourced clays for drill operation.

Table 1: Characterized barites sample from some Nigerian sites (Iyang *et al.*, 2013)

Sample Identity	**Specific Gravity (Mg/c^3)**	**Water soluble alkaline earth metals (mg/kg)**	**Residue greater than 75 (μm) % by wt**	**Particle less than 6 (μm) in equivalent spherical diameter (% by wt)**
Afuze	4.34	230	1.6	21
Afugo	4.44	214	2.0	22
Bundin kwaj-ali	4.33	220	1.6	21
Mayo belwa	4.16	235	2.5	28
Ntak	3.86	275	3.6	36
Obubra	3.94	290	3.4	36
P/H	3.84	298	3.7	38
Ibi	4.36	220	1.8	20
Markurdi	4.23	245	2.0	23
Mubi	3.20	245	2.0	23
Ntak	4.13	252	3.0	29
Obubra	3.94	290	3.4	36
Igara	4.54	210	1.4	19.8
Pila yandev	4.16	232	3.0	29
Ibi	4.44	210	1.8	21

3. Characterization of Nigerian barite

The Nigerian Barite is characterized to ascertain if it meets the internationally accepted specification in line with the American Petroleum Institute (API) as shown in Table 1. For Barite to be utilized as a drill mud weighty material it should meet a specific standards of say less than 1% soluble salt (250 ppm max); a specific gravity of at least 4.2; 95% pulverized barite should be accepted via 325 mesh and about 92/94 BaSO4; with a small number of iron oxide percent; Also based on the report by the Nigeria Geological Survey Agency (2011) and the Oil Company Materials Association (OCMA) has the following barite specifications prior to usage as drilling mud weighty materials operations: they specified a minimum of 4.2 Specific gravity and 250cp of Apparent viscosity; with a maximum of 3% residual wet screen analysis; Soluble alkaline earth metals of 250 mg/lit; and Residue on sieve (number 325) of 5-10% by weight (Nigeria Geological Survey Agency, 2011).

Table 1 shows the characterization of some barites sample from some Nigerian sites (Iyang *et al.*, 2013) and it is a clear indication of how most Nigerian barite have all the qualities but yet to be utilized in the oil and gas sector. Barite is discovered all over the Nigeria, specifically (in Cross River, Nasarawa States,); and why can't Nigeria become the net producer of barite and export to other nations? Although standards essential by the operating companies has been met for the locally sourced barite unlike bentonites and the others clays that requires beneficiation. Specific gravity is used to measure barite clay which is the foremost aspect to note and the Nigerian barite clay met the requirement of the international standards' specific gravity measure. However, what is lacking is the indigenous technical knowhow for processing of the natural resources.

The local government area where barite is found in Benue State includes Guma Makurdi, Ushongo, Vandeikya and Gboko. Igneous to metamorphic

rocks of Pre-Cambrian origin is the host or source rock of barite in the state and also in shale and sandstones. The Guma Barite holds a specific gravity of 3.7 to 4.4. This makes it highly attractive as the specific gravity is close the international standard. Amongst the nine states in Nigeria where Barite deposit is found in commercial value are Cross River and the host rock in this state soft and Hard rock types with vein. Sedimentary rocks are hosting the 18 barite deposited sites as identified in the state and the specific gravity of these barites is within 3.5 - 4.4. In ranges and the estimated reserves of about 8,612,880 tonnes is found in Cross River (Ministry of Mines and Steel Development, 2010).

Barite in Nasarawa state is found in sedimentary rocks such as (alluvial, siltstone, shale, sand, mudstones and limestone). The 18 veins preliminary assessment of barites proved are found in the Azara, Aloshi, Akiri, Wuse and Keana axis of Awe local government area in Nasarawa state. There is a complete exploration work that has been conducted in five of the 18 veins, while we recommend additional assessment of the left over 13 veins in order to bolster the moral of the investor and the host government (Eromosele, 2017). The specific gravity of the Nasarawa Barite is between the ranges of 3.9 - 4.4. which is highly recommended for its closeness to the specifications of the American Petroleum Institute (API) standard, on the other hand, a number of samples have been identified to have high silica content in its composition which is also consequential to low level specific gravity of about 3.6; and quartz, celestite and iron oxide are some of the few impurities linked with these variety of barite (Ministry of Mines and Steel Development, 2010). The total number of 3,243,376 tonnes is the estimated barite reserve with the standard specific gravity of 4.0 (Nigeria Geological Survey Agency, 2011). There are records that mostly Barites found in Azara, Nasarawa state come into view to have associated with very high which is as a result of chemical weathering leading key distinctive varieties of barite, specifically: Barites with siderite and ankerite as gangue and Barite with quartz and limonite as gangue, Lafia, Nasarawa state (Onwualu *et al*., 2013).

Sardauna Local Government Area which is in the extreme southeast of Taraba State is a barite producing state, exploration work conducted in different local government areas of the state proves that there is abundant barite deposit. From Yoro, Lau, Ibi to Karin-Lamido are host communities and the barites here are hosted in sandstones fine-grained and porphyritic granites. The specific gravity is good as it is very near to the required standards of 4.2. With an estimated reserve of about 8,960,000 tonnes (Nigeria Geological Survey Agency, 2011) barite in Taraba state alone. The report from the (Nigerian federal Ministry of Mines and Steel Development, 2010) indicated that faya area of plateau state hosts the best barite vein in the country and which is estimated to 500,000 tonnes reserve heap of barites. Barite in Plateau state, plateau is one of the states in Nigeria where barite is discovered in large deposit, from Yama, Angwar Kargo, Faya, Safiyo Karwa, and Gimbi are villages in the Langtang South to Wase local regions. Barite of 4.0–4.39 Specific gravity ranges is found in sandstones of the Keana Formation of Cenomanian age. Gombe state is amongst the state with huge deposit of barite in Nigeria and this resource is found in two major sites namely Gombe Hill and Liji Hill. In these locations the Gnesis/magmatite is hosting the barite in basement complex rocks with 4.09–5.3 specific gravity. Chalcopyrite, fluorite and quartz are some of the major impurities connected with the barite in this region. A total of 352,800 tonnes of barite has been estimate as the reserve from the two separate locations in Gombe state (Ministry of Mines and Steel Development, 2010). Zamfara state hold huge deposits of barite Vein, this was discovered to be as a result of barium leaching which is emanating from adjacent rocks of epigenetic hydrothermal fluids that precipitate in the vein as reported by the (Nigeria Geological Survey Agency, 2011). Some of the key host local government areas includes Yarkatsina (Gidan Saro), Bungudu, Rekebu near Chafe, Chafe (Tsafe), Dareta near Anka, Anka, Tofa forest reserve, and Gusau local government areas respectively. Ebonyi state is another state amongst the nine in Nigeria with high volume of barite deposits in Nigeria. The barite veins although not properly estimated hence it is proved that Ishiagu area of Ebonyi state barite samples is of high quality. Based on our finding we also recommend additional work to be done in Ishiagu area to increase the confidence of the investor and the host government (Onwualu *et al.*,2013)

4. Barite industrial application

It is a well-known fact that about 88% of global production of barite is used in the oil and gas industries; while 6% are consumed in chemical industries as extenders, aggregates and fillers;

another 6% is utilized by glass industries and ceramic makers. Often times the demand for barite leads to strappingly high prices in paint production. It is also very clear that companies in the business of Barite production have more opportunities in the future and this will lead to continue expansion. For the reason that several African countries are making huge effort in the search of oil and gas in the region while the world records more discoveries the demand for barites increases. As drilling operation continues the demand for drilling mud and its additives will continue to raise (Nigeria Geological Survey Agency, 2016). Barite natural occurrence is in barium sulphate mineral form and the chief properties are extremely low solubility, not being toxic, the (4.5) very high specific gravity, and it doesn't reactive physically and chemically. The extraction methods consist of underground and surface mining and this is also tag along by a straightforward physical processing technique to produce appropriately sized recommended product free from extraneous materials. Over 70% of barites produced globally are utilized as weighting agent basically for hydrocarbon exploration drilling fluids. Some of the other applications of barites in the industries for value addition comprises of the car companies, medical appliances (barium meals), rubber production, electronics firms for the use in the manufacturing of TV screen, radiation shielding, glass ceramics additives and paint production business. With this enormous application of barite and considering the huge deposit in Nigeria, the country could not keep on spending millions of dollars every year on barite importation. Nigeria imports 300 million dollars' worth of barite from Morocco annually while the mineral is quite available in Nigeria. The economic viability of the Nigerian barite clay deposit has been estimated to sum up to billions of United State dollars. Nigerian barite clay is estimated to be 65% - 70% in approximation in southern and northern parts respectively; this is reported by the Nigerian Extractive Industries and Transparency Initiative (NEITI). This report was based on the status of the Nigerian solid minerals and it showed clearly that the country is blessed with 40–50 diverse varieties of solid minerals spotted in different regions of Nigeria in large magnitude.

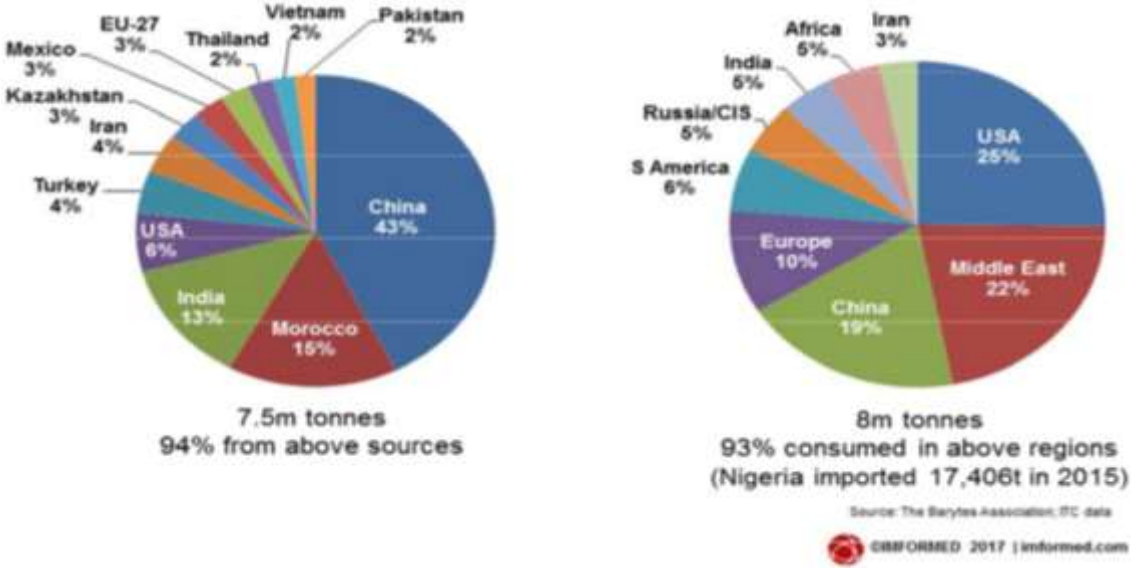

Fig. 1: World productions and consumption of barite (Industrial Mineral Forum and Research, 2017)

Figure 1 shows world productions and consumption of rate barite. Nigeria is blessed with many solid minerals, and Barite is one of those minerals found in commercial quantity. Barite is used in several industries but as earlier stated barite is mostly utilized in the oil and gas drilling operations as weighty agent for drilling mud additive. Also, in the solid industries barite applications are in several areas. Drilling an oil well can be very challenging hence the application of a drill mud is the technology that has been in use for a long time and appropriate drilling mud design helps in this operation. The role of barite cannot be over emphasized as there is no drilling mud formulation without a weighty agent in use the oil and gas industry. Owning to the fact that most high

pressure and high temperature wells are will very difficult during drill therefore there is always need for an adequate mud formulation that will contain a better weighty material, it involves a heavy fluid circulation that will pay off for high-pressure regions and zones within the well this will help in the prevention of blowout and the management of the reservoir pressure. Also, excellent drilling mud weighty material application facilitates drilling by serving as a lubricant at the same time as confining the oil and gas pressure at depth (Industrial Mineral Forum and Research, 2017). Barite Market assessment is a foundation for a comprehensive ranking on the market condition. The account contains vivid and systematic parts, supplemented with graphs, figures and tables for international and local markets situation. Also, there is a clear indication of the market predictions and forecasts for the next ten years in totality.

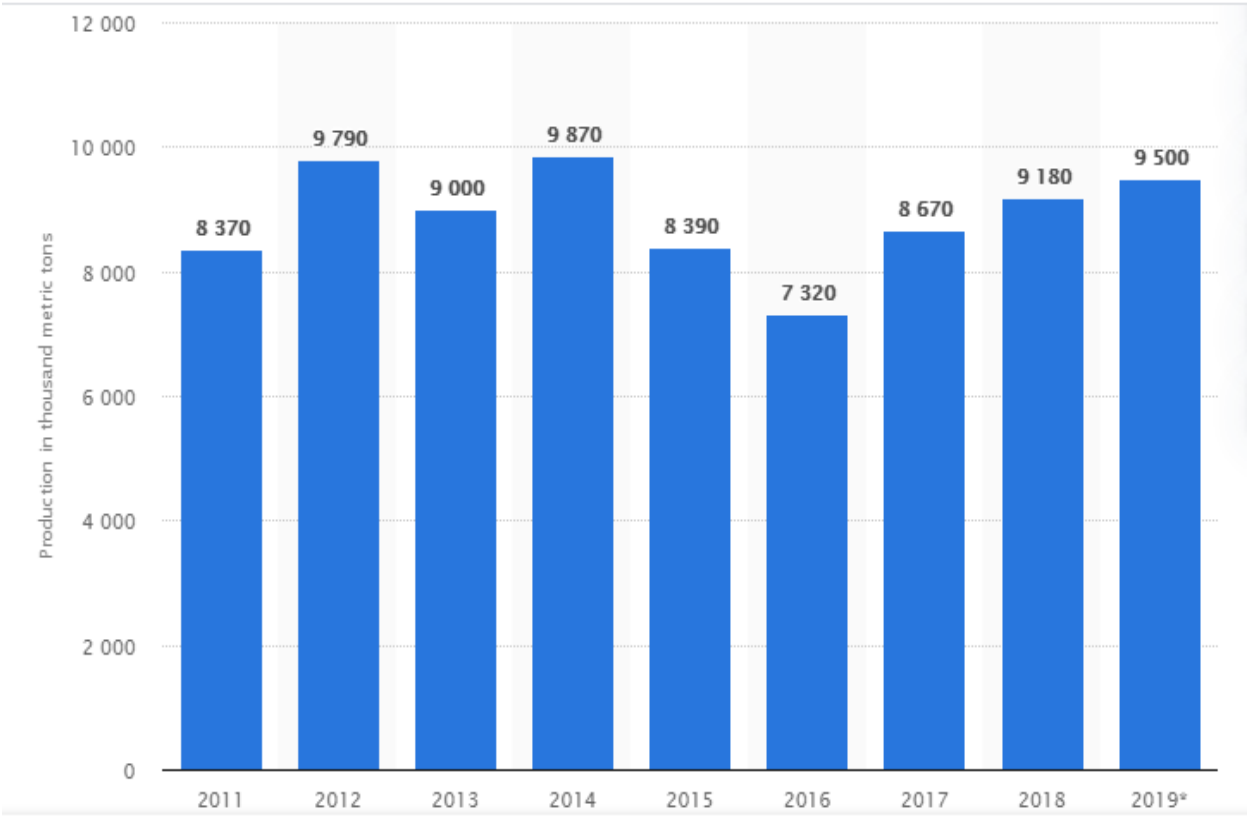

Fig. 2: Worldwide production of barite from 2011 to 2019 (Garside, 2021)

Figure 2 shows the worldwide production of barite from 2011 to 2019, there is a statistical indication of the entire global barite production from the year 2011 to 2019. In 2019, the international barite production was predicted and estimated to the total of 9.5 million metric tons, down from 9.8 million metric tons in 2012. The worldwide production of barite from 2011 to 2019 also shows that 2012, 2014 and 2019 ranked the highest years in barite production in the world, with 2019 production of 9500 million tonnes of barite produced globally (Garside, 2020). The local purchasing price of the milling companies for barites lumps was: 9,500 Naira per tonne for SG 4.0- 4.09, 10,500 Naira per tonne for SG 4.10-4.14 and 15,000 Naira per tonne for SG 4.20- 4.29.

5. Earlier research work on Nigerian barite

Table 2 shows the previous work done by some great scholars, their earlier research work done on Nigerian barite from different regions, the researcher(s) identity, the number of specific areas studied of location and experiment done in order to prove the suitability of the Nigerian barite for full industrial application. The year these research works were conducted for the records was indicated. The exploration and production of barite in Cross River to meet growing demand by international oil companies. The Tectonic Evolution of the Southern portion of the Benue Trough, each the six geopolitical zones in Nigeria were covered ranging from Cross River, Nazarawa, Ropp, Plateau Province (Plateau State), Ewekoro

(Ogun State). Barites in Nigeria occur as vein infilling materials, commonly associated with lead-zinc lodes and veins in both pre-Cambrian basement and Cretaceous sedimentary rocks of the lower and middle Benue valley. The mineral occurs mostly in white, reddish-brown and clear varieties with specific gravity varying in the range of 3.5 - 4.4. Also, the Nigerian Mining Corporation estimated the resource at 70,000 tonnes in the Azara deposit in Nassarawa State.

Table 2: Some previous research work done on Nigerian barite from different regions.

Researcher(s)	Specific areas studied of locations	Research conducted
Godwin et al. (2012)	Southern Benue Trough,	Structural styles and economic potentials of barite deposits
Ene et al. (2016)	Abakaliki Basin,	Geological & geotechnical assessment of derelict barite
Oden (2012)	Gombe state. Gombe field and Liji Hill	Field Characteristics, the Quality Issue and Some Tectonic Implications.
Edu (2006)	Taraba state. Kumar field in the Ibi, Didango field in Karim Lamido	Interim report on assessment of barite resources in Taraba State
Oden (2012)	Lessel field, Bunde, Mbato and Mbagwa. Gboko and Azara, Guma, Torkula, Kaseyo, Zanzan and Iye,	Barite Veins in the Benue Trough: Field Characteristics, the Quality Issue and Some Tectonic Implications.
Oden (2012)	Aloshi in Nasarawa State	Barite Veins Aloshi: Field Characteristics
MMSD (2010)	Zamfara state samples from Dareta, Chafe and Yarkatsina	Technical Overview in Nigeria's Minerals Development Potential.
MMSD (2010)	Faya field (Plateau state)	A heap of barites from Faya; and specific gravity for different locations
Ebunu (2017)	Benue (Guma), Zamfara (Anka), Nasarawa (Azara), Plateau (Kanam), Cross River state (Baise), Taraba (Karim Lamido)	Technical assessment of mining sites and barite quality
Ekwueme et al. (2015)	Calabar Flank, Oban Massif, Mamfe Embayment and Obudu Plateau	Chemical Composition and Industrial Quality of Barite Mineralization
Ajile (1989)	Azara, Nasarawa State	Mineralization, mining and beneficiation of barite.
Mgbemere et al. (2018)	Azara, Nasarawa State	Beneficiation of barite ore
Emmanuel (2015)	Cross River	Exploration and production of barite
Isa (2007)	Azara, Nasarawa State	Chemical oxides analysis

Based on the previous research work conducted in Nigeria on the area of the Nigerian barite we found that there is huge investment barite potential in the mining and sales within and out outside the country. While oil drilling wells operations are the key determinant factor for the demand for barites around the globe, Nigeria need to harness and optimize her barite deposit because there is no doubt that oil and gas search will continue in Nigeria and other neighbouring African countries where exploration activities are ongoing and even all through the world.

Previous works done in the area of characterization of Nigerian barite deposits was based on a regional study of the locations containing them (Table 2), furthermore, such studies have specified that the Nigerian barite clays are typically Barium element and (SO_4^{2-}). The chemical composition of a typical barite clay sample consists of 65.70% and 34.30% of Barium element and (SO_4^{2-}) respectively (Krauskopf and Beiser, 1986). Barite is mostly called 'heavy spar' due to its pure appearance in and its specific gravity (SG) of 4.5. Barites is considered and applied as a weighting agent in oil and gas drilling

owning to its chemical inertness, high density and widespread occurrence. When taking consideration into the use of barite in non-drilling oil and gas drilling we think of certain qualities such as chemical purity and color. Barite has a wide variety of industrial application ranging from industrial marine fillers, high purity grades of barite with fine and well-sorted particles, industrial paints, in brake lining/friction materials and in plastics. Barite is more often than not associated with impurities like Silicon (IV) oxide or Lead Sulphides and as a crystalline heavy material chemically composed basically of Barium Sulphate ($BaSO_4$), with 58.8% Barium. Naturally occurs as large beds or veins as a heavy gangue mineral compound in several sandstones, limestones like deposits which is insoluble in oil or water and oil chemically inert [Nigeria Geological Survey Agency under the Ministry of Mines and Steel Development (2010)]. It has been estimated that 80% to 90% of barite around the globe is applied as weighting material in the oil and gas drilling fluids formulation to hold back blow out and high formation pressures in the well (Emmanuel, 2015) also used in the pharmaceutical and paint industries. Indigenous drilling fluid additives found in Nigeria has been research and revealed be suitable in performances level as mud formulations additive when used as a weighting material, fluid loss control materials, viscosifiers and superior drilling muds borehole clean-up potentials (Al-bagoury and Steele, 2012). Higher yield stress for a mud formulation from Irvingia gabonensiswhen compared with a conventional mud hasbeen reported (Izuwa, 2015). The conventional mud was used as a control test, while different combinations of local materials were prepared, tested and the results compared with the conventional mud. In the work, it was highlighted that the biopolymer exhibited good transport ratio, an indicator for good wellbore cleaning capability of muds.

Table 3: Reserve estimates and barite SG in Nigeria (Ministry of Mines and Steel development, 2010)

State	Reserve estimate	Barite specific gravity
Adamawa	332,130 tonnes	4.0–4.36
Benue	307,657 tonnes	3.7–4.4
Cross River	8,612,880 tonnes	3.5–4.4
Ebonyi	Yet to be Determined	
Gombe	352,800 tonnes	4.09–5.3
Nasarawa	3,243, 376 tonnes	3.9–4.4
Plateau	500,000 tonnes	4.0–4.39
Taraba	8,960,000 tonnes	4.2
Zamfara	Yet to be determined	
Bauchi	Yet to be determined	
Katsina	Yet to be determined	

Table 3 shows the nine states of Nigeria barite reserve estimates and their specific gravity as reported by (Ministry of Mines and Steel development, 2010) while Zamfara, Bauchi, Katsina and Ebonyi are yet to be determined in the level of their reserves Taraba and Cross River are the states with the highest deposit of barite in Nigeria. Barites found in Taraba state have the best specific gravity of 4.2 which in most cases may not require beneficiation while the lowest forms of barite specific gravities were discovered in Benue and Nasarawa states which in the other way round will require upgrading through beneficiation process in order to meet the global accepted standards before being used in the oil and gas drilling operations. There are the pertinent issues of major concerns associated with local barites in Nigeria beyond its specific gravity such as the chemical composition of some host rocks. The impurities linked with most of these barites due to regions or areas of occurrence which is mainly at the basement/sediment boundary the typical basement rocks are phyllite, schist and gneiss. The chemical data also indicated that barite content of the host rocks decreases with increasing $Si0_2$ content. Example is the Akpet the Ba plus SO_4 content is 8.6% whilst the $Si0_2$ content is 85%; in schist from Agoi Ibiami the Ba plus $S0_4$ content is 20% whilst the $Si0_2$ content is 46% and in the gneiss at Ibogo Ba plus $S0_4$ is 15% whilst the $Si0_2$ content is about 70%. The barite and the $Si0_2$ content is 64%. A close assessment of Table 3 which shows the chemical composition of barite samples indicates that the barite occurrences in Akpet, Agoi Ibiami, Ibogo and Itu Agoi are all of high quality with Ba plus $S0_4$ content of 90% and

above. There is no indication that the composition of the host rocks has effect on the quality of the barite. The industrial quality of barite occurrences in the geological zones of Cross River State analysed in this study is higher than that of the famous and well-known Azara barite deposits studied by Ajile (1989) and Bassey (1998) (Table 3). Oden (2012) noted that in the Benue Trough the quality of barite increases with depth of the veins. He observed that in most occurrences, the quality of the material from top part of a vein (0-5m depth) is always lower than that from the deeper parts of the same vein. Hence, it is most likely that as mining gets deeper better-quality barite can be obtained in this area.

6. Conclusions

There are at present over 200 barite mining location sites in Nigeria that have been identified. This review work has been prepared to capture virtually most of the research work on Nigerian barite as it relates to drilling operation in the Nigerian oil and gas industry. Overall, the following areas were summarized from literature:

1. The chemical composition of the barite ores shows that they are of high industrial quality and suitable for use as weighting agent in drilling mud.
2. This paper has therefore established the fact that Nigeria local barite can be utilized in the industry for oil and gas drilling activities. Also established is the fitness of this local barite for drilling mud formulation and how it compares to mud formulated from foreign barite.
3. The known estimates of barite reserve in various regions of Nigeria and those requiring quantification have been established. All recorded research work points to a common path that Nigeria has a huge potentially exploitable reserve of barite, which are pre-dominantly in nine states. Beneficiation of these clays has brought about tremendous improvement in its quality, which is comparable to the standard drilling grade barite as recommended by API.
4. Benue Trough has been discovered as the host of several varieties of solid mineral especially barite and the occurrences barite in Nigeria is mostly dominated in nine states, such as, from Aloshi, Azara and Wuse in Nasarawa state.
5. Most of the oil and gas companies do not use the local barites directly; first they are blended with other additives before use. The Mine deposits are beneficiated to upgrade the specification with other materials to meet the API grade.
6. This literature review gives an idea about barite veins in Benue, Cross River and Nasarawa state that have been explored, yet their geochemical properties, geophysical characteristics, geotechnical has not been fully documented. Also, the reserve estimates in states such as Ebonyi, Zamfara, Kastina and Bauchi not been properly recorded.
7. We recommend based on the experience gathered from several barite mines site in Nigeria, that further research work should be conducted on the barite deposit veins all over the country because as the veins are being exploited, the quality of the mineral reduces, i.e. the specific gravity may reduce as the vein is being depleted. (Bruton et al., 2006). Government needs to fund research work on the exploration of high-grade premium barite of 4.2 Specific Gravity within Nigeria. Beneficiation process should also be made compulsory for local barite that fails to meet the international specification in order for the barite to gain popularity in the oil industry in Nigeria. We also recommend additional exploration of deposits of barite veins in Nigeria with keen interest in the Benue Trough its neighbouring state of Nasarawa and that the documentation of all discovered barite site and therefore support research interest in the exploration of more deposits with interest in the production and sustainable development.

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