FEASIBILITY ANALYSIS OF COMMERCIAL BARITE PRODUCTION IN NASARAWA STATE, NIGERIA

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By

EZE, CHUKWUKA KENNEDY

Supervised by

Professor David Ogbe

African University of Science and Technology
www.aust.edu.ng

P.M.B 681, Garki, Abuja F.C.T
Nigeria

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A THESIS APPROVED BY THE PETROLEUM ENGINEERING DEPARTMENT

RECOMMENDED: ……………………………....

Supervisor, Prof. David Ogbe

……………………………....

Committee Member, Dr. Alpheus Igbokoyi

……………………………....

Head, Department of Petroleum Engineering

APPROVED: …………………………………........

Chief Academic Officer

…………………………………........

Date

ABSTRACT

Nigeria is blessed with mineral resources but unfortunately many have been poorly exploited. This has resulted to spending huge sums of money to import these minerals rather than taking advantage of available local natural resources. Among such minerals is barite, a mineral in abundance and an important raw material used in the oil and gas industry as a weighting agent in drilling for crude oil. Due to its high specific gravity value, barite helps to counteract pressure from the subsurface formation during drilling. However, most of the barites currently used in Nigeria is imported because the resource has not been produced on a commercial scale to meet demand. Also, some of the locally processed barites have specific gravity lower than the petroleum industry accepted standard because of a lot of impurities associated with the barite ores. The primary objective of this study is to examine the value chain of barite minerals in Nigeria. A detailed analysis of barite resources in Nasarawa State, Nigeria is also presented.

Barites in Nasarawa State occur in form of veins with vein depth projected to be 20metres. The inferred resources in the state is 3.2 million metric tons with specific gravity in the range of 3.9 and 4.4, which is within the specifications of the American Petroleum Institute (API) required for drilling operations.

An economic analysis was carried out to evaluate the viability of commercial production of barite in Nasarawa State to meet the demands of the oil and gas industry. Historical production from artisanal miners was scaled up to simulate the commercial production of barites in Nasarawa. The annual rig count was used to infer the volume of barite consumed in Nigeria by the oil and gas industry. Projected production along with price, royalty and mineral tax were the input data fed into the economic model. The results of the economic analysis indicated a payback period of about 4years with an Internal Rate of Return of 28% and a Net Present Value of $1.36 million USD using a 10% discount rate. The major finding of this study is that investment in barite exploration and production in Nasarawa State is a wise economic decision.

Keywords: Barite exploration and production, Barite resources, Nasarawa State, Specific Gravity, Internal Rate of Return, Payback Period

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Finally, a deep appreciation and immense gratitude to my family for their support, inspiration, and encouragement all the way.

DEDICATION

I dedicate this work to God Almighty for granting me the knowledge and wisdom to carry out this research work.

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CHAPTER 1
INTRODUCTION

1.1 INTRODUCTION AND BACKGROUND

Barite is the primary, naturally occurring mineral type of barium. It can occur in a variety of colors including yellow, brown, white, blue, gray, or even colorless, typically has a vitreous to pearly luster. It is characterized by several unique properties with its primary distinctive property being its specific gravity. It is chemically and physically unreactive, inexpensive, non-lethal, has great radiation-protecting, great sound-stunning and low oil adsorption. The significant range of the mineral hardness is from 2.5 to 3.5. (King, 2013)

Most of the barite mined is used as a weighting agent in the formulation of drilling mud in the oil and gas industry. Barite builds up the hydrostatic pressure of the drilling mud enabling it to hold back intrusion of formation fluids from high-pressure zones experienced during drilling. The delicateness of the mineral additionally keeps it from having detrimental effect on drilling tools during drilling and empowers it to serve as a lubricant. The American Petroleum Institute (API) has established standards for the use of barite in drilling mud. Most barite must be ground to a small uniform size (as required by API standard) before being used as a weighting agent in drilling mud. The specific gravity (SG) is the most vital characteristic of barite used in drilling mud and the API specification called for a minimum SG of 4.2.

Because of concerns about dwindling reserves of 4.2-SG barite, the API issued a new edition of API Specification 13A (i.e., Specification for Drilling Fluids Materials, effective August 1, 2010) permitting the use of 4.1-SG barite in drilling mud. Aside from the SG property, a 4.1-SG barite is like 4.2-SG barite in the new edition of the API specifications. They require that the barite be finely ground so that at least 97% of the material, by weight, can pass through a 200-Tyler mesh [75-micrometer (μm)] screen, and that no more than 30%, by weight, can be less than 6 μm, effective diameter, which is measured using sedimentation techniques. It is also required that the ground barite may contain no more than 250 ppm water-soluble alkaline earth metals such as calcium (American Petroleum Institute, 2010, p. 13–23, 83–96).

Within the barite industry, the term “grade” increasingly refers to barite of differing SG, as opposed to indicating purity as is common with many other mineral commodities. Usually, barites of higher grade (i.e., higher SG) are desired; however, it is important to note that the presence of certain impurities can also raise the SG of lower purity material. (McRae, 2015)

Barite deposits in Nigeria are spread across the Cretaceous Benue Trough. The mineralization is structurally controlled by NW-SE, N-S and NE-SW fractures. The typical mode of occurrence is the vein and cavity deposit type commonly associated with galena, sphalerite, copper sulphide, fluorite, quartz, iron oxide as gangue minerals (Ezekwesili et al., 2018). Prominent areas of barite occurrences in Nigeria include Nasarawa, Plateau, Taraba, Benue, Cross River, Adamawa, Gombe, Ebonyi and Zamfara States. The inferred resources and proven reserves of barites are estimated to be 21 and 11 million metric tons, respectively. Economic evaluation shows that the barites in Nigeria are viable having low(SG=<3.5) to high(SG=5.3) grades. A significant part of the extensive barite resources in Nigeria is still underexploited and further exploration work is needed to boost its exploitation (Labe et al., 2018).

The petroleum industry remains the major source of income in the country. It has been reported that the barites from Nigerian soil, apart from existing in huge commercial quantities, have an impressive specific gravity within accepted API specification. Considering the importance of this mineral in drilling operations, it is obvious that the optimal production and utilization of locally produced barite will not only meet the demands of the oil and gas industry, but more importantly, create jobs and bring about growth of income per capita.

1.2 PROBLEM STATEMENT

Barite is an essential raw material in the petroleum industry used mainly as a weighting agent in drilling operations. Barite increases the hydrostatic pressure of the drilling mud in order to prevent intrusion of formation fluids from high pressure zones encountered during drilling. This important role ensures that the properties of the barite used must be monitored to guarantee safe drilling.

Nigeria is among the top oil producing countries in Africa and is richly blessed with this mineral, hence should be able to promote local content by producing enough that meets the demand of the oil and gas sector. Yet, the nation remains heavily reliant on the importation of this mineral spending a minimum of $35million annually.

Two questions then arise: What are the constraints limiting the optimal exploration and production of Nigeria’s barite resources? What is the economic viability of commercial production of barite locally?

1.3 AIM AND OBJECTIVES OF STUDY

This study is aimed at analyzing the exploration, production, supply and demand of barite resources in Nigeria with special focus on barite production from Nasawara State. Nasawara is one of the Nigerian States with vast amounts of barite resources. An investigation into the value chain of barite minerals in Nasarawa State is presented. An economic analysis is used to evaluate the viability of investment into barite exploration and production in the State.

The objectives of this study include:

- To evaluate the exploration, production, supply and demand of barite in Nigeria.
- To examine the exploration and production of barite in Nasarawa State.
- To develop an economic model for evaluating the viability of commercial-scale barite exploration and production in the state.

1.4 SCOPE OF WORK

The work will look into the barite resources, production, import and export activities in Nigeria. Data such as estimated reserves, annual rig count, barite consumption and wells drilled in Nigeria will be collected for analysis. A more detailed investigation will be done on the barite mining activities in Nasarawa State which will entail evaluating all the activities undertaken to deliver barite to the intended market by looking at the barite resources in the state, record of small-scale miners, production history and cost of operations.

1.5 ORGANIZATION OF THESIS

The thesis is divided into six chapters. Chapter 1 gives a brief introduction on the subject matter; it also states the objectives of the study. Chapter 2 presents a theoretical background of the mode of occurrence, mineralogy and geological characteristics behind vein-type barite deposits in Nigeria. The methodology used to evaluate the viability of commercial production of barite minerals in Nasarawa State is presented in Chapter 3. Chapter 4 analyzes the exploration, production, supply and demand of barite in Nigeria. In Chapter 5 is an analysis of data gathered and results derived from the economic modeling of the feasibility of commercial barite production in Nasarawa State. Chapter 6 summarizes the major findings and conclusions derived from this study and presents some recommendations for further investigation.

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CHAPTER 2
LITERATURE REVIEW

A review of related works in the published literature is presented in this Chapter to provide background information for the study; to identify related investigations; examine the data sources used by other researchers and identify gaps in the literature.

This chapter describes the features of barite such as mode of occurrences, geochemistry and mineralogy. Geological characteristics behind vein-type deposits in Nigeria, major source of barite mineralization in Nigeria, artisanal mining and environmental considerations are also discussed.

2.1 DEFINITION AND MODE OF BARITE OCCURRENCE

Barite($BaSO4$) is the most frequently occurring and abundant barium ore mineral, containing 58.8% Ba or 65.7% BaO and 34.3% SO_3 in its pure form. By way of occurrence, commercial deposits of barite can be geologically divided into three main categories: vein and cavity fillings, bedded deposits and residual ones. The mineral is usually incorporated with quartz, chert, calcite, dolomite, pyrite, galena and sphalerite. Barite can exist in three configurations viz: stratiform or bedded, residual and in veins (Nigerian Geological Survey Agency, 2009).

2.1.1 Vein and Cavity Filling Deposits

Veins are mineral deposits that develop when a pre- existing fracture or fissure is filled with new mineral material within the host rock. Mineral deposition is usually carried out by circulating hot aqueous liquids. Many economically important ore deposits are of vein type. It is believed that vein deposits form when hot aqueous solutions conveying various elements move through fissures in rock, applying pressure on the fissure walls. Hot, rising water from the cooling of igneous plutons can deposit minerals through the crust.

As water heated by hot magma rises, there is a drop in the temperature and pressure of the environment and minerals exsolute and crystallize. Meteoric ground water may also trickle down through the earth's crust, dissolving surface minerals and gaining heat from the geothermal gradient or from nearby igneous intrusions. Dissolved substances can precipitate and crystallize at greater depth along the walls of the fissures and cavities through which the water flows. Barites and related minerals occur along faults, joints, bedding planes, solution channels and various sink structures in this type of deposit. Deposits in solution channels and sink structures are most frequent in limestones. Host rocks are usually Precambrian to Tertiary in age. Grade of barite minerals contrast from area to area and within deposits. Deposits ordinarily have sharp contact with wall rocks. Veins are usually dissipated and unpredictable and extend in width from a couple of centimeters to a couple of several centimeters and in length from a couple to many meters. Most vein deposits shaped as new mineral species are accelerated onto wall rocks which themselves stay unaltered. In such cases, mineral deposits fill the first break or crevice in the host rock; however, it doesn't stretch out into the host rock itself. The demarcation between host rock wall and deposited vein minerals along these lines remains obviously outlined. (Labe et al., 2018)

Vein deposits of this nature are a sort of hydrothermal deposit considering the fact that the mineral species which create the veins were precipitated by hot waters. In any case, occasionally the prior wall rock which contains the vein experiences modification. Bits of the host rock may either break down and be transported away or else respond chemically with the flowing volatile liquids or the recently shaped mineral species.

Hydrothermal deposits are grouped according to the depth and temperature at which they formed. At great depths and high temperatures are hypothermal deposits; mesothermal deposits are found at intermediate depths and temperatures; and epithermal deposits at the shallowest depths and relatively low temperatures (Geology Inc., 2014).

2.1.2 Residual Deposits

Residual deposits of barites are formed from accumulation of material derived by weathering from both vein, replacement, cavity fillings and bedded barite deposits. Because of its insolubility, barite often occurs in residual clay deposits resulting from the weathering of limestone and dolomite. Most of the residual barite is white and translucent to opaque and occurs in fibrous or dense fine-grained masses. It also occurs as subhedral to anhedral crystals. Most deposits contain cherts, jasperoid and drusy quartz with some amount of pyrite, galena and sphalerite. Bedded deposits are those formed by the precipitation of barites at or near the sea floor of sedimentary basins. (Labe et al., 2018)

2.1.3 Bedded Deposits

These include those deposits in which barites occur as principal minerals or cementing agents in stratiform bodies in layered sequence of rocks. The term also include stratabound and stratiform deposits. Generally, the most commercially valuable and sought of all types of barite because they tend to be of high grade and individual deposits have large tonnages. Bedded deposits occur in sequences of sedimentary rocks characterized by abundant chert and black siliceous shale and siltstone. They have wide age range from Precambrian to Tertiary but are

especially in rocks of mid-Paleozoic age. Individual beds are massive to laminated and fine grained and contain between 50% and 95% barites. Bed thickness varies between some few centimeters to 30m and a bed may extend for up to several hectares. (Labe et al., 2018)
They are typically described as syngenetic, epigenetic or both. They occur in diverse host rock sequences that most commonly contain chert, argillite, shale and or limestone but might also be composed of dolomite, slate, sandstone, quartzite. They may exhibit primary depositional and diagenetic features such as graded or crossbedding, rhythmic layering, large scale interbedding of shale and barite. Most occur in rocks of mid-Paleozoic age and they may occur as essentially monomineralic deposits. (Labe et al., 2018)

In Nigeria, most barite deposits are the veins, fissures, and cavity filling types. The veins and cavities are hosted by a variety of rocks from shale, mudstones, siltstones, sandstone, and limestone through porphyritic granite to gneisses and migmatite.

2.2 GEOCHEMISTRY

Barium exists in the geologic condition principally as the divalent cation Ba^{2+}. This particle is bigger than most other divalent cations and consequently, barium is not easily harboured in common rock forming minerals. During fractional crystallization of silicate magmas, barium becomes concentrated in the residual silicate liquid. It is also concentrated in silicate liquids produced by partial melting. The barium content of average upper continental crust is estimated to be 0.0624 weight percent (Rudnick and Gao, 2003). Granitic rockss commonly have to some degree higher barium content than average continental crust, and basaltic rocks ordinarily have to some degree lower barium content. The scope of barium content of shales ranges around a similar range as the barium content of granitic rocks. Barium substitutes extensively for the nearly-as-large Pb^{2+} and Sr^{2+} cations in minerals that contain these elements, and less extensively for the somewhat smaller Ca^{2+} and K^{+} ions; substitution for K^{+} requires a coupled substitution to maintain charge balance. In common igneous rocks, barium is present as a trace or minor element in potassium feldspar and mica where it substitutes for K^{+}. In common sedimentary rocks and hydrothermal deposits, barium exists for the most part in barite or organic matter. The presence of trace amounts of barite in many sedimentary rocks mirrors the fact that sulfate (SO_4^{2-}) is the stable form of sulfur in most Earth-surface environments and the formation constant for barite (barium sulfate, $BaSO_4$) is quite large. Although barite is highly stable in oxidizing (sulfate-stable) environments, it tends to be gradually broken up in reducing hydrogen sulfide (H_2S) stable environments. This attribute has significant ramifications for the formation of barite deposits and for environmental aspects of barite mining. (Johnson et al., 2017)

2.3 MINERALOGY

Barite is typically white or colorless. Crystals tend to be tabular and have habits that reflect the orthorhombic symmetry of the barite lattice. Fibrous, nodular, and massive forms are also common. The mineral has a hardness of 3 to 3.5 on the Mohs scale, which is about the same hardness as copper, and it has a density of 4.48 grams per cubic centimeter (g/cm3), which is roughly twice that of common rocks. Barite has multiple good cleavages. Natural barite is relatively pure, often showing only minor substitution of barium by strontium (less than 7 percent) or lead. (Mukherjee, 2007) The relative purity is convenient from a resource perspective because commercially important properties that depend on mineral chemistry, such as density and solubility, can be expected to vary little no matter where the barite is found. Most barite deposits have low impurity levels because (a) deposits typically form as precipitates from aqueous fluids, and (b) barium partitions more strongly into the sulfate mineral than strontium, lead, and other potential impurities. Calcium replacement of barium is also restricted in natural occurrences.

Gangue minerals are often contained in barite deposits, each deposit bearing its own unique attributes and abundance. Prominent among the gangue minerals are quartz or other forms of silica (chert, jasperoid), sulfide minerals (galena, marcasite, pyrite and sphalerite), clay minerals, carbonates (calcite and siderite) and iron oxides. (Mukherjee, 2007)

Witherite is colourless. Crystals normally take the form of pseudo-hexagonal di-pyramids. Witherite possesses hardness of 3.5 on the Mohs scale and density of 4.3g/cm^3. It is distinguished from barite by the fact that it effervesces in cold acids. The mineral usually contains little amounts of strontium and calcium in place of barium. Witherite is typically found in veins inside sedimentary rocks where it is related with galena and less generally anglesite, barite and barytocalcite. It can also occur as an alteration product of barite and would itself be able to be modified to barite. Other barium minerals exist but none occur in deposits as abundant, concentrated and extensive as barite. (Reimann, 1998)

2.4 GEOLOGICAL CHARACTERISTICS BEHIND VEIN-TYPE DEPOSITS IN NIGERIA

In Nigeria, we have sedimentary basins which have been intruded by magmatic (igneous) rocks, e.g., the Lower Benue rift. During magma rising, hydrothermal fluids inject into rocks thereby leaching compounds which are composition of elements. Some of these compounds are barium compounds (e.g., barite sulphate, BaSO4) which crystallize in fissure, joints, fractures, fault lines of these rocks precipitating into barite compounds. The effects of these host rocks being baked by the intrusions allow for several mineralization within the basin. Consequently, we see the veins that protrude from these intrusions mineralizing barite, lead-zinc, galena, sphalerite, etc., as a result of the interaction between the hot magmatic fluid and the basin. Other factors such as tectonism could also be considered.

Nigeria has several sources of barite mineralization, but the Benue trough remains the major source (Figure 2.1). There are at least ten barite fields in the trough, each containing swarms of veins or concordant stratiform minerals flats of hydrothermal origin.

The Benue Trough

Benue trough is a rift basin in central West Africa that extends NNE-SSW for about 800km in length and 150km in width. The trough contains up to 6,000 m of Cretaceous–Tertiary sediments of which those predating the mid-Santonian have been compressionally folded, faulted, and uplifted in several places.

We can find two veins trends in the trough: the NW-SE trend which tends to be orthogonal to the trough axis and the N-S to NNE-SSW trends, which is younger than the former. Both vein sets are formed from tension joints reflecting different post-sedimentary deformation phases in the trough. NW-SE veins occurred more than the N-S veins almost in the proportion of 2:1. (Benkhelil, 1989)

Dips of the veins tend to be high (>80°), a condition that favours manual mining. Veins tend to display a simple block profile and their widths vary from a few centimetres to as much as 6 metres, though the most frequently occurring widths are between 50cm and 1m. The ramification of this is that $BaSO_4$ concentrations in hydrothermal fluids in the trough were most likely low amid the Cretaceous time period. In numerous veins, there is barite quality contrast between the top part and the lower portions. Higher quality barite will in general come from the lower portions. (Benkhelil, 1989)

The Benue Trough in Nigeria consists of a series of rift basins which form a part of the Central West African Rift System of the Niger, Chad, Cameroon and Sudan. (Figure 2.2) Basement fragmentation, block faulting, subsidence and rifting accompanying the opening of the South Atlantic Ocean led to the deposition and accumulation of sediments ranging between 4km to 6km in the greater Benue Trough along the 800km axis over a width of about 120km from the northern parts of the Niger Delta Basin in the South West to the fringes of the Chad Basin on the north east. The Benue Trough is subdivided into a Lower, Middle and Upper portion (Figure 2.3 and 2.4) with the Lower Benue consisting of the Abakaliki and Anambra basins and the Upper Benue made up partially of the Gongola sub basin. (Obaje et al., 2006)

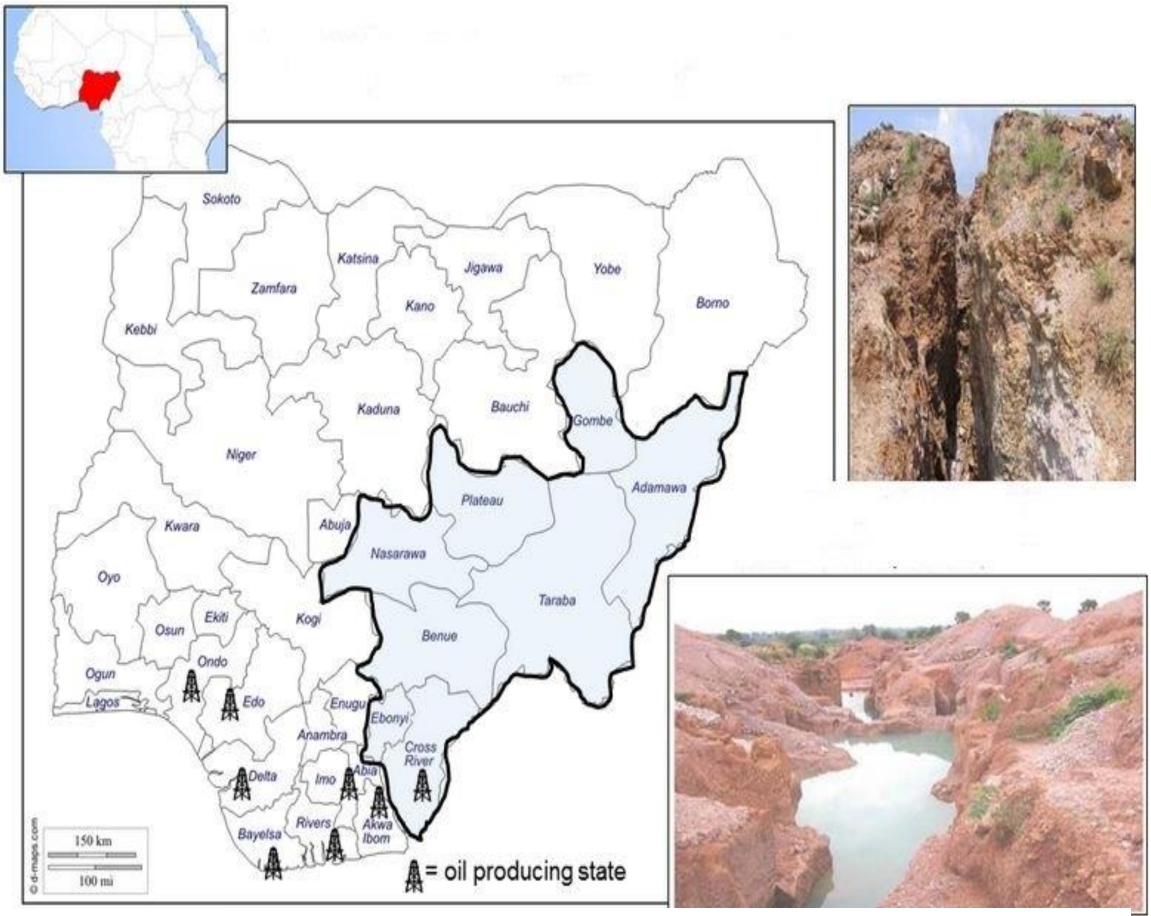

Image above to the right: Barite Vein at Azara, Nasarawa
Image below to the right: 6m wide mother vein, Gabu-Osina, Cross River

Figure 2. 1: Main Barite locations in Nigeria (Source: https://www.informed.com...accessed: 07/11/2018)

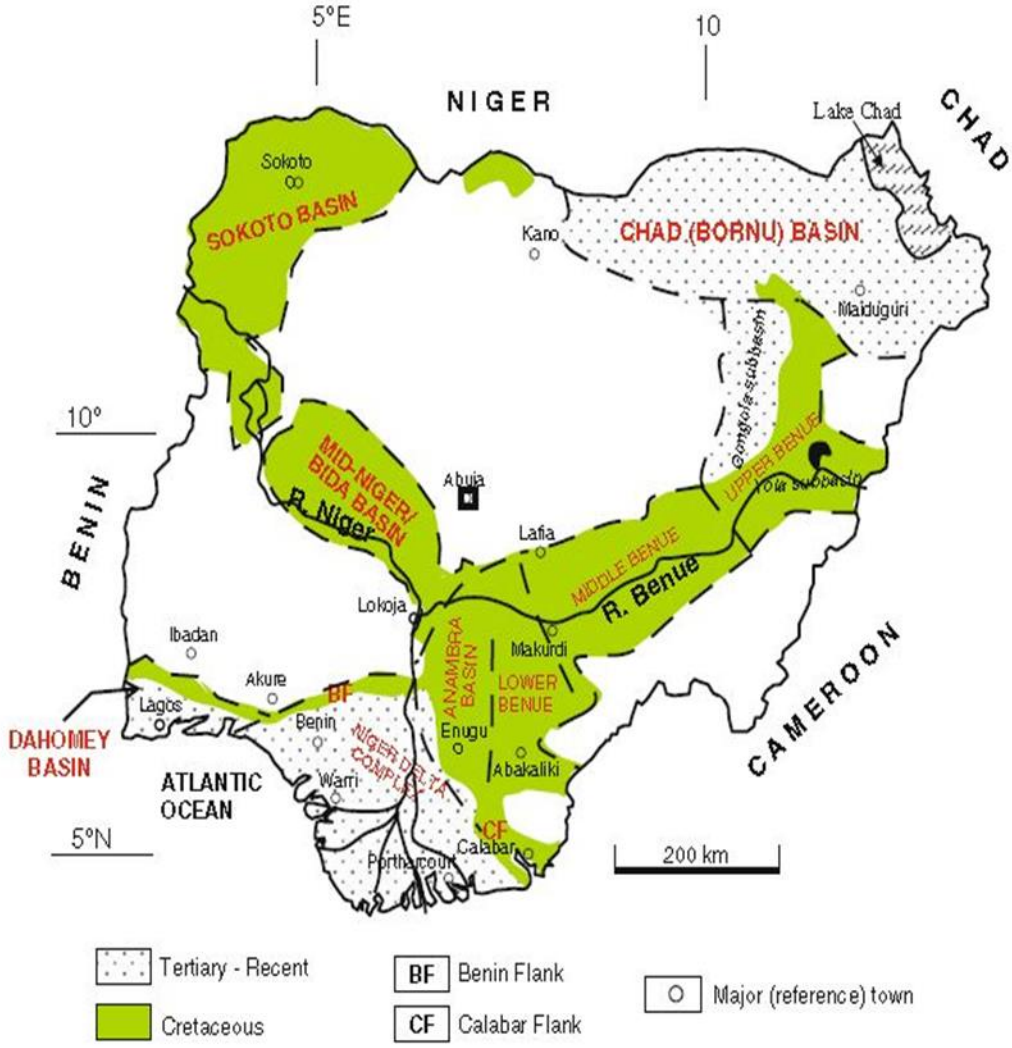

Figure 2. 2: Sedimentary basins of Nigeria (Source: Geology and Mineral Resources of Nigeria; Obaje, 2009)

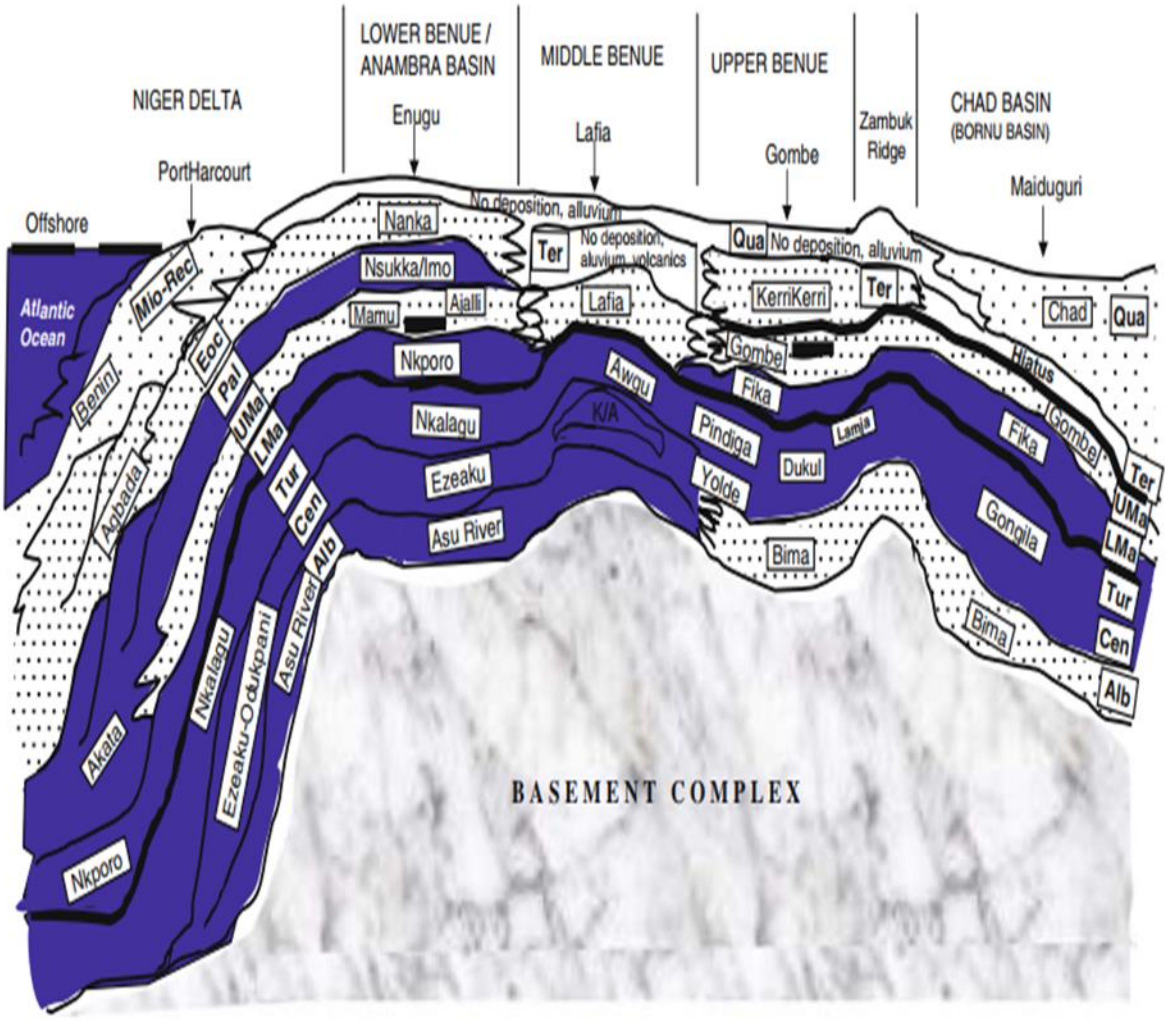

Figure 2. 3: Idealized N-S stratigraphic cross-section across the Chad Basin-Benue Trough-Niger Delta (Source: Geology and Mineral Resources of Nigeria; Obaje, 2009)

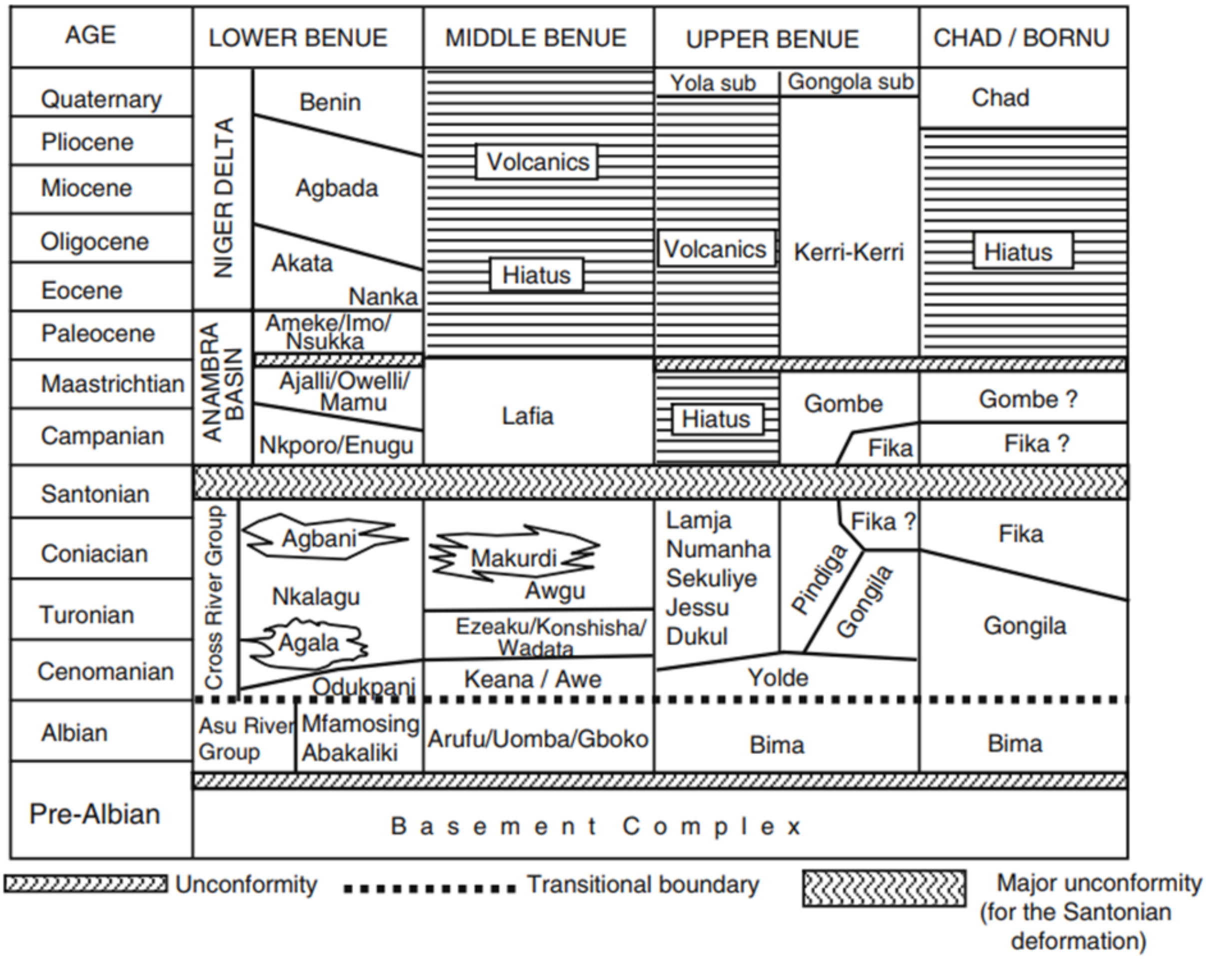

Figure 2. 4: Stratigraphic successions in the Benue Trough and the Nigerian sector of the Chad Basin (Source: Geochemical evaluation of the hydrocarbon prospects of sedimentary basins in Northern Nigeria; Obaje et al., 2006)

2.5 ARTISANAL MINING

Artisanal mining refers to mining by individuals, groups, families or cooperatives with little or no mechanization. Several criteria have been employed while classifying mining scale. The commonly used ones are production volume, number of people per produce, unit intensity (volume) of capital employed. Artisanal mining is characterized by a number of conditions viz: absence of or limited use of mechanization with lots of physically demanding work, low level of occupational safety and health care, poor qualification of personnel at all levels of the operation, periodic operation by local peasants by season or according to the market price development, lack of social security, inadequate consideration of environmental issues, persistent lack of working and investment capital, inefficiency in exploitation and processing of mineral production (low recovery value), exploitation of marginal and/or very small deposits which are not economically exploitable by mechanized mining, low level of productivity and low level of salaries and income. (Hentschel et al., 2003)

Despite the informal nature of this activity, a mine operator must often comply with the following legal conditions which includes: possession of a mining title (concession or valid contract with concession holder), compliance with environmental legislation, possession of an environmental operation license, registration of the company at the mining authority or other fiscal authorities and payment of taxes (royalties, company taxes).

Where governments do not have the resources to monitor the compliance of the laws or do not want to recognize artisanal mining activities, many operations remain informal. The most common reasons are: lack of knowledge about legal requirements, local traditional and cultural behaviour, little incentives from the government to operate legally, high tax burden, limited access to mining titles, demanding bureaucratic procedures to gain and remain a formal operation, and limited danger of sanctions in combination with possibilities to evade the imposition of the law by corruption are the most common.

Factors influencing the readiness of small-scale miners to operate legally include existence of coherent legal bases (mining code, legislation, etc. in force), existence of human, financial and material resources to enforce the laws (including decentralized structures), transparent and efficient mining administration (management of mining titles, etc.), access to mining technologies and specialized mining services, existence of direct (access to finance, direct subventions, etc.) and indirect (tax, technical assistance etc.) incentives to produce legally, economic opportunities with marketing using formal markets and local transformation. (Hentschel et al., 2003)

2.6 BENEFICIATION OF BARITE

Generally, most of the barite minerals have varying specific gravities from one location to another. To handle this variation brought about by the presence of gangue minerals, the mineral ores undergo beneficiation processes to improve them into higher grade products and to boost the economic value. The beneficiation process to be used depends on the type of gangue minerals present in the ore. The beneficiation processes are discussed in the following section.

Hand Picking: For a deposit location bearing ore of high grade and stable quality, simple handpicking method can meet the desired requirement. This process is simple and easy to operate requiring no large scale or sophisticated equipment and reagents. However, there is high misuse of human resources as well as low production efficiency.

Gravity Separation: This beneficiation method is suitable when the desired ore is based on the differences of barite and the gangue and other useful mineral density or particle size. By making use of fluid power and all kinds of mechanical force, gravity separation will result in an appropriate loose stratification and separation conditions to get the barite products, which is usually used to sort the ore of eluvial type deposits. This method is low cost, although there is low recovery of concentrate.

Magnetic Separation: Here, magnetic differences of barite and minerals containing iron is employed to conduct sorting to get rid of iron mineral impurities in order to obtain high grade barite concentrate (Wang et al., 2014).

Flotation: This method is used for fine distributed ore and tailings of gravity separation. It is mostly employed when barite ore and sulphide ore are in deposit or barite ore of hydrothermal origin associated with fluorite. This method conducts sorting according to the physical and chemical properties differences of the barite and associated minerals. (Mgbemere et al., 2018)

Flotation reagents of barite: Barite collectors are generally classified into two types: anionic collector and cationic collector.

Flotation collector is a chemical used to make the surface of minerals which is metallic, hydrophobic. The difference in the collectors are primarily in selectivity based on their strength. Based on their chemical compositions and affinities, some flotation collectors will tend to be attracted to one mineral more than another. These will produce a cleaner product but may tend to lose some of the values that are still bound with other minerals that they are not attracted to. Flotation relies on differences in surface properties of different minerals to achieve separation (Raju et al., 2012).

2.7 ENVIRONMENTAL CONSIDERATIONS

The behaviour of barite is discussed to demonstrate its reaction in the environment. The nature of waste generated at barite mining sites and its effect on the environment is also presented.

2.7.1 Barium Behaviour in the Environment

Barium's tendency to form insoluble compounds under familiar earth-surface conditions stems from the fact that the mineral possesses restricted mobility in the environment. Most often, barium precipitating as barite (barium sulphate, $BaSO_4$), witherite (barium carbonate, $BaCO_3$) or hydroxide are minerals formed from weathering processes. Barite is highly resistant to weathering and its solubility improves as conditions become reducing or acidic (Jaritz, 2004). Barium in the environment comes often from natural rock weathering but anthropogenic contributions can be vital, especially emissions connected to copper smelting, steel production and automobile manufacturing (Reimann and de Caritat, 1998). Barium concentrations in soil ordinarily mirror the composition of the bedrock, however dissemination of sludge from landfills and application of phosphate fertilizers can prompt increased levels of barium in the soil (Kabata-Pendias and Mukherjee, 2007).

The concentration of barium in natural waters is controlled by the solubility of barium compounds, the likelihood of barium to adsorb onto particulates and the availability of dissolved sulphate or carbonate to form insoluble salts (Agency for Toxic Substances and Disease Registry, 2007). The contents of barium and other elements in waters, sediments and soils in the vicinity of barite deposits can be above average, depending on the deposit type, the extent of the outcrop of ore and overburden, the climate and other factors.

2.7.2 Mine Waste Characteristics

Factors such as the variation in the types and sizes of deposit, compositions of host rock and gangue and ore processing methods contribute immensely in the mineralogy, chemistry and volume of solid waste generated at barite mines. With minimal processing, pure barite can be generally obtained from bedded deposit mines. Wastes from operations of this type consist of host rock and gangue minerals. Frequent gangue minerals include quartz, siderite, galena and sphalerite. Usually, for deposits closely associated with massive sulfide mineralization, froth flotation is often needed to separate barite from fluorite, galena, pyrite, sphalerite or other minerals. At these operations, waste rock and tailings can have higher sulfide contents and correspondingly greater potential for acidic metal-bearing drainage. The acid-neutralization capacity of host rocks and gangue minerals can be a significant control of acid damage. Barite resists dissolution since it is not particularly mobile in acid drainage. Dispersal of barium from mining operations is mainly by physical erosion and transport of barite particles (Johnson et al., 2017).

RESEARCH GAP IDENTIFIED

It is well known that majority of barite used by the petroleum industry are imported. Many studies (Aladesanmi et al., 2018, Akpeke et al., 2012, Ezekwesili et al., 2012, Obi et al., 2014) have looked at the properties of Nigeria’s barite and affirmed its suitability for use in the oil and gas industry. However, there has not been a lot of attention given to the potential economic and social benefits gained by local commercial production of this abundant mineral for use in the oil and gas sector.

This study is carried out to analyze barite exploration, production, supply and demand in Nigeria and also to evaluate the feasibility of commercial barite production in Nasarawa State, to promote local content, create jobs and improve the growth of income per capita.

CHAPTER 3
METHODOLOGY

This chapter describes the methodology used in this study. It includes data acquisition, data quality analysis and the approach used in the economic model to evaluate commercial barite production in Nasarawa State.

3.1 DATA ACQUISITION AND QUALITY CHECKING

3.1.1 Data Acquisition

Data pertaining to barite exploration and production was collected from government agencies, private sector, journal publications and internet sources. The data includes record of small-scale miners, estimated reserves and production history. Emphasis was placed on gathering data describing the supply, demand and import of barite resources in Nigeria. Some of this data served as input into more detailed analysis of barite resources in Nasarawa State. The records of small-scale miners and estimated reserves were collected from the Nigerian Geological Survey Agency (2009); data on barite production history was obtained from the Nigeria Mining Cadastre Office(2017); and annual rig count was derived from Baker Hughes International Rig Count Report (March 2019).

3.1.2 Data Quality Checking

The annual rig count used to infer the volume of barite consumed in Nigeria was validated using the barite consumption record of some wells drilled in the country. However, the reserves and production data collected were taken at face value. There was no independent validation of the data used to analyze the quantity and the quality of barite minerals in Nigeria.

3.2 ECONOMIC MODEL FOR EVALUATION OF BARITE PRODUCTION IN NASARAWA STATE

An economic model was formulated to evaluate barite production in Nasarawa. The input data and major assumptions used in the economic modeling are presented in the following section.

3.2.1 Economic Model Assumptions

Barite Consumption in Nigeria

Some of the assumptions made in building the economic feasibility model for Nasarawa are listed in Table 3.1. Note that data pertains to barite demand requirements in Nigeria. It provided some basis to evaluate how much of the nation’s annual barite requirement can be met using the supply from commercial barite production in Nasarawa State.

Table 3. 1: List of Assumptions to Determine Barite Consumption in Nigeria

Assumption	Data	Source
Amount of barite required to drill a well	200tons	Barite consumption record of some wells drilled in the country (April 2013)
Average number of wells drilled in Nigeria annually	77	Organisation of the Petroleum Exporting Countries Report, 2019
Average annual rig count	14	Baker Hughes Rig Count Report (March 2019)

Capital and Operating Expenditures

Tables 3.2 and 3.3 show the assumptions made to calculate the capital and operating expenditures used in the economic model.

Table 3. 2: CAPEX Estimates used in Economic model
(Source: Infomine Inc, 2018)

CAPEX	$3.063million USD
License	0.05% of CAPEX
Equipment purchase	42% of CAPEX
Road construction	28% of CAPEX
Buildings	21% of CAPEX
Electrical System	4% of CAPEX
Engineering tools	5% of CAPEX

Table 3. 3: OPEX Estimates for Economic Modeling
(Source: Infomine Inc, 2018)

Supplies & Materials	$1.05	Per metric ton ore
Labour	$2.96	Per metric ton ore
Equipment Operation	$1.67	Per metric ton ore
Salaried Labour	$0.97	Per metric ton ore
Miscellaneous	$0.67	Per metric ton ore

3.2.2 Economic Model Input Data

The input data fed into the economic model include price of barite, projected barite production, royalty and mineral taxes.

Projected Annual Barite Production in Nasawara

Table 3.4 summarizes the historical barite production data of Nasarawa state obtained from the Nigeria Mining Cadastre Office. This historical production data forms the basis for forecasting future production trends in the state. Assuming an exponential function, the plot of the production history vs. time shown in Figure 3.1 was used to forecast annual production for a period of 10 years.

Table 3. 4: Nasarawa State Barite Production History
(Source: Nigeria Mining Cadastre Office, 2017)

Year	Annual Production(Metric Tons)
2015	3276
2016	2952
2017	2880
2018	2736

To project barite production for 10 years, the following equation is used:

$P = P_o e^{rt}$……………………………………………………………...3.1

where P= Annual Production, P_o = Initial Artisanal Production

$r = production\ growth\ factor\ and\ t = time\ in\ years$

Take the logarithm of both sides in Equation 3.1 to get:

$\text{In } P = \text{In} P_o + rt$……………………………………………………….………3.2

Using the plot of production history data, we get:

$y = -0.0565x + 8.1324$……………………………………………...…….3.3

$\text{In } P_o = 8.1324$

$P_o = e^{8.1324} = 3402.9$

$r = -0.0565$

$P = 3402.9e^{-0.0565t}$…………………………………………….……...3.4

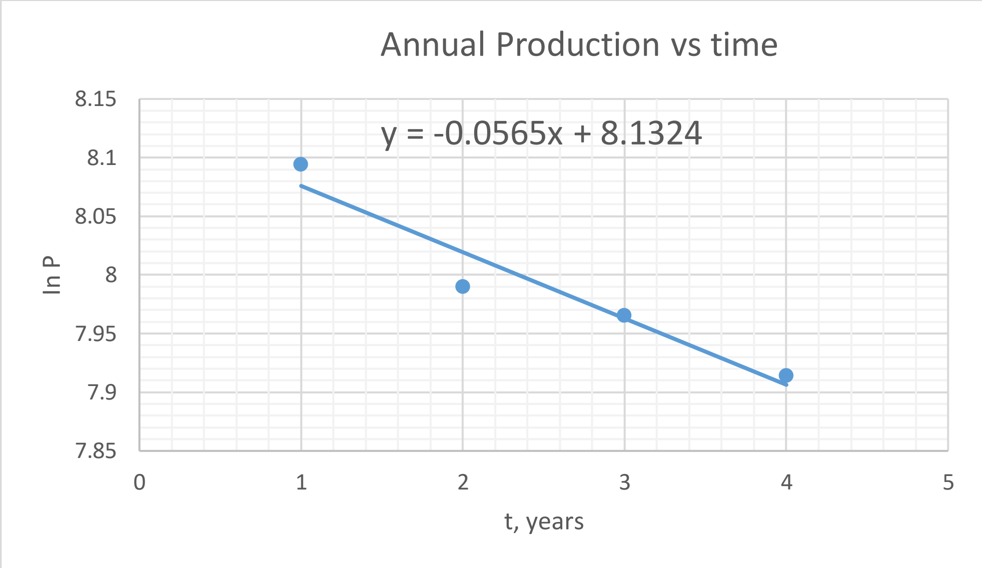

Figure 3. 1: Plot of annual production vs time (Source: Nigeria Mining Cadastre Office, 2017)

Barite Price Forecast

Table 3.5 lists the historical price per ton of barite obtained from the published literature. Using data of Table 3.5 and method of moving average, the barite price forecast was done. Figure 3.2 shows both the historical and forecast price of barite used in the study.

Table 3. 5: Barite Price history
(Source: Voyageur Minerals, 2017)

Year	Price, $
2010	260
2011	275
2012	300
2013	340
2014	420
2015	460
2016	450

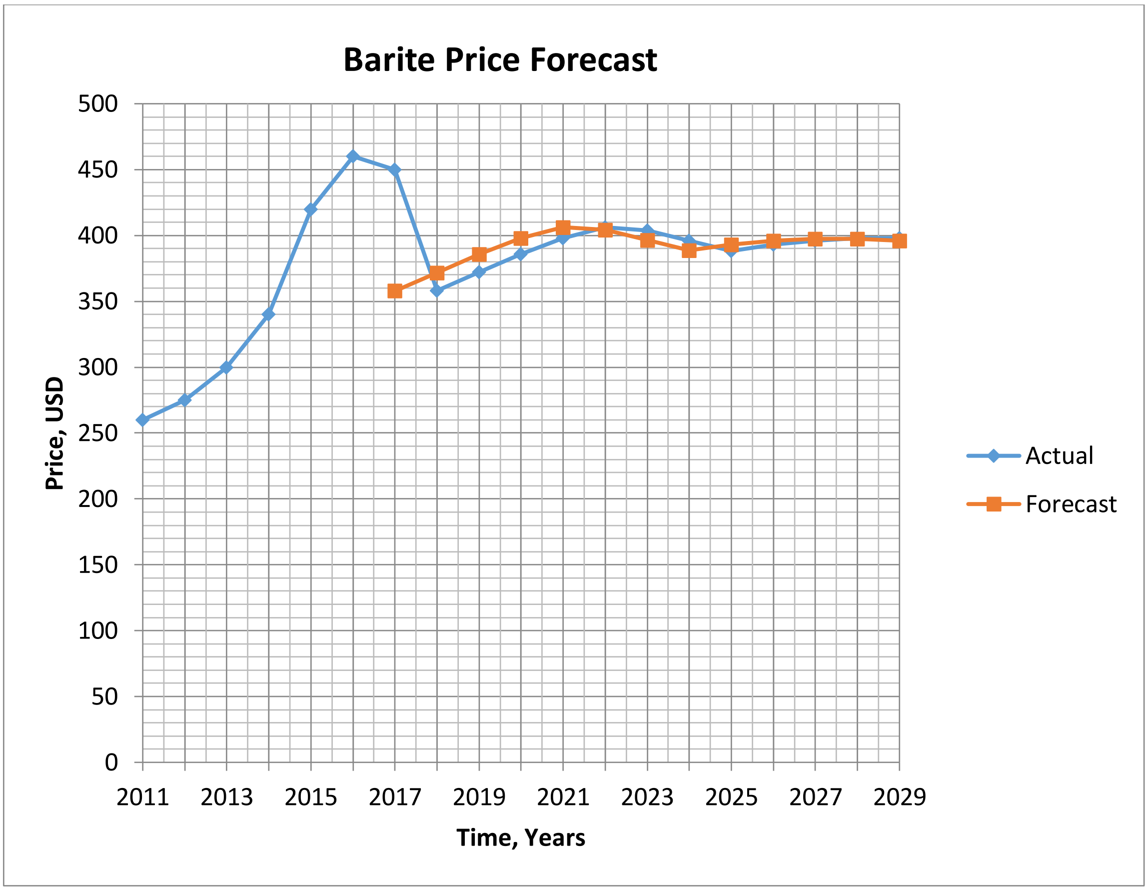

Figure 3. 2: Plot of price vs time (Source: Voyageur Minerals, 2017)

Fiscal Terms for Economic Model

The fiscal terms included in the economic model are listed in Table 3.6. The data was based on the Nigerian Minerals and Mining Act of 2007.

Table 3. 6: Fiscal terms
(Source: Nigerian Minerals and Mining Act, 2007)

Royalty	5%
Income tax	20%
Tax relief period	3years

3.2.3 Economic Model Key Equations

Other key model equations are described as follows:

$$Quantity\ consumed\ annually = Tons\ per\ drilling \times Wells\ drilled\ annually \text{ .....3.5}$$

$$Gross\ Revenue = Annual\ Production\ \times Price \ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.6$$

Economic Profitability Analysis

A profitability indicator, Internal Rate of Return (IRR), was used to measure and evaluate the ability of the projected investment to generate income relative to revenue, capital and operating costs. The internal rate of return refers to the discount rate at which the net present value of all cash flows equals zero and it is defined as:

$$0 = NPV = \sum_{n=0}^{N} \frac{CF_n}{(1+IRR)^n} \quad \ldots\ldots 3.7$$

Where

CF_0 = Initial investment

CF_1, CF_2, CF_3,…..CF_n = Cash Flows

n = each period (annually)

N = holding period

NPV = Net Present Value

IRR = Internal Rate of Return

Net Present Value (NPV) is the present value of the cash flows at the required rate of return of a project compared to the initial investment. In practical terms, it is a method of calculating returns on investment for a project. By looking at all the money expected to be made from the investment and translating the returns into today's money, a decision can be made whether the project is worthwhile. If the NPV is negative, the project is not a good one. If it is positive, the project should be accepted.

The discount rate is the rate of return that the investors expect or the cost of borrowing money. Although it is company specific as it is related to how funds are obtained but usually for a low risk project, discount rate is between 8.5%-10.5% (Source: Investopedia, 2019). Note, a discount rate of 10% was used in the economic model.

The payback period refers to the time required to earn back the amount invested in a project from its net cash flows. This indicator can be read from the plot of cumulative cash flows against time.

3.3 SENSITIVITY ANALYSIS OF FACTORS AFFECTING NET REVENUE AND COST

Sensitivity analysis was carried out to determine the impact of annual production, price, capital cost and operating cost on net revenue as well as how annual cost outlay is affected by changes in capital and operating costs.

In carrying out this task, assumptions were defined. This involves assigning a probabilistic distribution to each of the input parameters considered (costs, price, annual production). Triangular distribution was assigned to all costs, price and annual production. A forecast was then defined i.e. output measure which was net revenue in this case. A total of 20000 iterations in one simulation were performed and the results showing the impact of each of the input parameters on the net revenue was generated.

Similarly, the same process was repeated to analyze the effect of CAPEX and OPEX on the annual cost outlay. This time, the input parameters defined under assumptions were CAPEX and OPEX. Triangular distribution was also assigned to all costs. A forecast was then defined; in this case annual cost outlay. A total of 20000 iterations in one simulation were also performed and the results showing the impact of the different costs on the annual cost outlay was generated.

The above methodology was followed in this study to gather the data for production, supply, and demand of barite resources in Nigeria as well as in building the economic model of barite production in Nasarawa State; and the results obtained are presented in Chapter 4 and 5.

CHAPTER 4
BARITE MINERALS IN NIGERIA

An overview of the barite minerals in Nigeria is presented in this chapter. This chapter describes barite resource estimates, exploration, historical production, demand, imports and supply in Nigeria. This presentation is designed to give an overview of the barite resources in the nation with a view to promoting local production and associated benefits of local content.

4.1 BARITE EXPLORATION IN NIGERIA

Barites occur in Nigeria as vein infilling materials associated with lead-zinc lodes in both Pre Cambrian basement and Cretaceous sedimentary rocks of the lower and middle Benue valley. The mineral usually occurs as white, reddish brown and clear varieties with specific gravity fluctuating between 3.5 and 4.4. The widths of the veins ranges from a few centimetres to 5.3metres. Lengths of veins also vary from few metres up to 4500m.

Barite deposits are widespread in Nigeria. They are largely restricted to the eastern half of the country, specifically, within the Benue Trough (i.e., in Benue, Taraba, Adamawa States) and its fringes to the north (Nasarawa, Plateau and Gombe States) and the Southern fringe (Cross River and Ebonyi States). The inferred resource estimated for four of the states (Benue, Cross River, Nasarawa and Taraba) where mining is considered viable is 21million metric tons (Benkhelil, 1989). Table 4.1 shows the locations of barite in Nigeria. The detailed description of the resources in the major states is presented in the following sections.

Table 4. 1: Barite locations in Nigeria
(Source: Nigerian Geological Survey Agency,2009)

ID	LOCATION	LGA	STATE	GEOLOGY
1	Gambe	Mayo-Belw	Adamawa	Granite-gneiss and migmatite terrain
2	Iye	Guma	Benue	Sandstones
3	Tidza	Guma	Benue	Sandstones
4	Ukaa	Guma	Benue	Sandstones
5	Nyam Uka	Guma	Benue	Sandstones
6	Torkula A	Guma	Benue	Sandstones
7	Lessel	Ushongo	Benue	Shales sandstones of Awgu Indicator
8	Lukor/Ts	Guma	Benue	Sandstones
9	Fada	Buruku	Benue	Sandstones
10	Mbashabu	Ushongo	Benue	Granite-gneiss
11	Mbato-Gi	Ushongo	Benue	Granite-gneiss
12	Bunde	Ushongo	Benue	Granite-gneiss
13	Mbatoo	Ushongo	Benue	Granite-gneiss
14	Tse-Ande	Guma	Benue	Sandstones
15	Orgba	Ushongo	Benue	Granite-gneiss
16	Orgba	Ushongo	Benue	Granite-gneiss
17	Tyodugh-U	Makurdi	Benue	Sandstones
18	Tyodugh-U	Makurdi	Benue	Sandstones
19	Pilla-Ya	Gboko	Benue	Granite
20	Igumale	Ado	Benue	Sandstones
21	Ekukunela	Ikom	Cross River	Vertical veins with strike of 155/335
22	Gabu	Yalla	Cross River	Veins occuring within shale
23	Oshina	Yalla	Cross River	Veins occuring within shale
24	Iyametite	Obubra	Cross River	Veins occuring within shale
25	Edondo/O	Obubra	Cross River	Veins occuring within shale and sandstone
26	Akpet No	Biase	Cross River	Vein in schist and sandstone trend E
27	Gabu	Yalla	Cross River	Sandstone
28	Osina	Yalla	Cross River	Sandstone
29	Akpet	Biase	Cross River	Sandstone, siltstone
30	Ligi Hill	Gombe	Gombe	Granite gneisses
31	Wuse	Awe	Nasarawa	Occur as hydrothermal deposit formation
32	Dogon Daj	Awe	Nasarawa	Occur as hydrothermal deposit formation
33	Kumar	Awe	Nasarawa	Occur as hydrothermal deposit formation
34	Kumar	Awe	Nasarawa	Occur as hydrothermal deposit formation
35	Kumar	Awe	Nasarawa	Occur as hydrothermal deposit formation
36	Agana	Awe	Nasarawa	Occur as hydrothermal deposit formation
37	Azara	Awe	Nasarawa	Occur as hydrothermal deposit formation
38	Kumar	Awe	Nasarawa	Occur as hydrothermal deposit formation
39	Gidan Aga	Awe	Nasarawa	Occur as hydrothermal deposit formation
40	Jobe	Awe	Nasarawa	Occur as hydrothermal deposit formation

41	Jara	Awe	Nasarawa	Occur as hydrothermal deposit formation
42	Sauni	Awe	Nasarawa	Occur as hydrothermal deposit formation
43	Apebene	Awe	Nasarawa	Occur as hydrothermal deposit formation
44	Gidan Soj	Awe	Nasarawa	Occur as hydrothermal deposit formation
45	Gidan Soj	Awe	Nasarawa	Occur as hydrothermal deposit formation
46	Akiri Du	Awe	Nasarawa	Occur as hydrothermal deposit formation
47	Azara-W	Adudu	Nasarawa	Vein deposit within sequence of sands
48	Keana	Keana	Nasarawa	Black shale and siltstone of Ezeaku formation
49	Ribi	Awe	Nasarawa	Occur as hydrothermal deposit formation
50	Ribi	Awe	Nasarawa	Occur as hydrothermal deposit formation
51	Arugagwu	Awe	Nasarawa	Occur as hydrothermal deposit formation
52	Didango S	Karim Lam	Taraba	Sandstone, siltstone and shales of Awgu
53	Wukari	Wukari	Taraba	Black shale and siltstone of Ezeaku
54	Bakyu	Ibi	Taraba	Pure baryte in compacted sandstones
55	Gidin Way	Wukari	Taraba	Baryte occuring in clayey sandstone
56	Didango S	Karim Lam	Taraba	Clayey siltstone of the Benue Valley
57	Dareta	Anka	Zamfara	Occuring as vein in pelitic schist

4.1.1 Benue State

The barite resource of Benue State is hosted in the igneous-metamorphic rocks of the Pre-Cambrian as well as in sandstones and shale of the Benue trough sedimentary formations. Mineralization is in form of fissure filling, with hydrothermal solutions depositing barites in fissures formed by the closing in of the Benue trough during the Santonian.

The mineral occurs as white, reddish-brown and clear varieties with SG fluctuating between 3.7 and 4.4. Analysis revealed that majority of the samples contain between 76-87% $BaSO_4$, impurities of between 5 and 21% Silica and up to 3% iron oxide (Nigerian Geological Survey Agency, 2009).

Veins uncovered that do not hold on over long separation in the area and width of 3 meters and above are common. The inferred resource of barites for the state is 308 thousand metric tons based on an average SG of 4.0 and depth of vein up to 20 metres. Table 4.2 shows the distributions of barite resources within Benue State. It includes the GPS coordinates and the specific NGSA Sheet No. to identify the location in the records of the Nigerian Geological Survey Agency (NGSA).

Table 4. 2: Distributions of Barite in Benue State
(Source: Nigerian Geological Survey Agency, 2009)

S/NO	LGA	VILLAGE	GPS Coordinates	Host Rock	NGSA Sheet no and Name
1	Guma	Iye	7° 50' 34" N	Sandstone	1:50000 sheet
			8° 44' 28" E		251, Makurdi NW
		Tse-Ande	7° 50' 32" N	Sandstone	251 Makurdi NE
			8° 45' 08" E		
	,,	Tidza	7° 54' 30" N	Sandstone	251 Makurdi NE
			8° 47' 32" E		
		Ukaa	7° 56' 22" N	Sandstone	251 Makurdi NE
			8° 50' 08" E		
	,,	Ngam-Ukaa	7° 57' 08" N	Shale	251 Makurdi NE
			8° 50' 0" E		
		Torkulla	8° 01' 32" N	Sandstone	231 Lafia SE
			8° 53' 34" E		
	Guma	Zan-Zan	8° 00' 11" N	Sandstone	231 Lafia SE
			8° 54' 08" E		
		Hungwe	8° 01' 49" N	Sandstone	231 Lafia SE
			8° 56' 36" E		
2	Ushongo	Mbashabu-	7° 7' 55" N	Basement	272 Katsina Ala SW
		Lessel	9° 00' 53" E	rock	
	,,	Mbatoo-	7° 08' 57" N	Basement	272 Katsina Ala SW
		Lessel	9° 01' 05" E	rock	
	,,	Mbatoo-	7° 09' 20" N	,,	,, ,, ,,
		Bunde	9° 01' 27" E		
		Mbatoo	7° 09' 10" N	Basement	272 Katsina Ala SW
			9° 00' 55" E	rock	
	Ushongo	Ongba	7° 02' 12" N	Sandstone	271 Gboko SE
			8° 15' 16" E		
3	Makurdi	Tyodough	7° 48' 05" N	Sandstone	251 Makurdi SW
			8° 38' 07" E		
4	Gboko	Pila-Yan-dey	7° 28' 49" N	Shale	272 Katsina Ala NW
			9° 04' 16" E		
5	Vandeikya	Mbaakase	6° 55' 55" N	Basement	290 Ogoja NE
		Ihugh	8° 59' 39" E	rock	

4.1.2 Nasarawa State

The barite resource in Nasarawa is hosted by varied sedimentary rocks (shale, mudstones, siltstones, limestones). The barites occur in form of veins having width varying between a few centimeters to 3.5metres. Veins endure along strike for separations shifting between just shy of 1000 to more than 4,000 meters. Research studies directed on tests from the state demonstrate that Specific Gravity (SG) of mine materials is in the range of 3.9 and 4.4. This SG is within specification of the American Petroleum Institute (API). I should be noted that a few examples have SG estimates under 3.6. Such samples are silica rich varieties not appropriate to be utilized in drilling unless beneficiated. The contaminations reported for barites in Nasarawa include Quartz, Celestite ($SrSO_4$) and iron oxide. The inferred resource of barites in the State is 3.2 million metric tons calculated using an average SG of 4.0 and a vein depth projected to be 20 metres. The relatively high grade of the barites found in Nasarawa State was the basis for this study designed to evaluate the economic feasibility of local production in the state.

4.1.3 Cross River State

Barites veins in Cross River State are hosted in both hard and soft rocks. Of the 35 mineralized areas in the state, 11 are in sedimentary territories. The NGSA separated the mineralized regions into; North consisting of Obubra, Ikom and Yala LGA and the south comprising of Biase and Yakkur LGA. Barites is hosted more by sedimentary rocks in the North while in the South, just 2 out of 18 areas are in sedimentary rocks (Nigerian Geological Survey Agency, 2009).

The widths of the veins are regularly somewhere between 2.5 and 5.3 meters (veins with width under 0.2 meters were not considered by NGSA). SG ranges between 3.5 and 4.4. Cross River is one of the Nigerian States with high grade (high SG) barites. Total vein length varied between 1,000 and 6,000 metres. Gathered resource for the whole state is 8.7 million metric tons disseminated equitably among North and South. Resource extraction is simpler in the northern zones because of delicate host rocks. Resource estimate in this state is probably going to increase as new veins are located later (Nigerian Geological Survey Agency, 2009).

4.1.4 Taraba State

Barite resources in Taraba State are in five LGAs; Sardauna, Karim Lamido, Yoro, Lau and Ibi. Table 4.3 shows the distribution of barite in the state. The resources are hosted in porphyritic granites and fine-grained sandstones. Vein lengths are persistent over distances varying from 3,500 to 5,000 metres and width from 3.5 to 5 meters. Contaminations comprise of Quartz and sulphide minerals, for example, galena. The figure reported for the inferred resource is 8.9 million metric tons to depth of 20 metres. Nature of resource is great with most SG estimated near 4.2. Taraba is one of the Nigerian States with high grade (high SG) barites. Thinking about the measure of individual veins, interest in advanced machines to mine at more noteworthy depth is viewed as beneficial. Available analytical data show that the barite contains very low concentrations of mercury (Hg) and cadmium (Cd), making it very suitable for oil well drilling offshore (Nigerian Geological Survey Agency, 2009).

Table 4. 3: Distribution of Barite Mineralization in Taraba State
(Source: Nigerian Geological Survey Agency, 2009)

S/N	LGA	VILLAGE	GPS COORDINATE	HOST ROCK	ASSOCIATED MINERALS	NGSA SHEET NO AND NAME
1	Sarduana	Mbanga	6° 34.198" N	Fine grained granite	Amethyst quartz	1:250000 sheet 76
		Petel	011° 12.111" E			(Mayo Daga)
		Mbang 3	06° 34' 209" N	Fine grained granite	Amethyst quartz	1:250000 sheet 76
		corner	011° 12' 109" E			(Maya Daga)
		Mbang 3	06° 34.209" N	Fine grained granite	,,	
		corner	011° 12.109" E			
		Juo	06° 43.449 N	Porphyroblastic	,,	1:250000 sheet 76
			011° 12.471 E	gneiss		(Maya Daga)
		Juo	06° 43.146 N	Porphyroblastic	,,	1:250000 sheet 76
			011° 12.762 E	gneiss		(Maya Daga)
2	Ibi	Gidin Waya	8° 05.862' N	Fine grained	Amethyst quartz	1:100,000 sheet 233(lbi)
			009° 47.001' E	sandstone		
		Gidin Waya	08° 05.891' N	Fine grained	,,	1:100,000 sheet 233(lbi)
			009° 46.903' E	sandstone		
		Kauyen Isa	08° 10.797'N	Fine grained	,,	1:100,000 sheet 233(lbi)
			009° 45.649' E	sandstone		
		Kauyen Isa	08° 10.991' E	Fine grained	,,	1:100,000 sheet 233(lbi)
			009° 45.689' E	sandstone		
		Kauyen Isa	08° 08.092' N	Fine grained	,,	1:100,000 sheet 233(lbi)

			009° 48.040' E	sandstone		
		Kauyen Isa	08° 05.110' N	Fine grained	,,	1:100,000 sheet 233(lbi)
			009° 48.012' E	sandstone		
		Bakuyu	08° 06.083' N	Fine grained	None	1:100,000 sheet 233(lbi)
			009° 49.382' E	sandstone		
		Bakuyu	08° 05.888' N	Fine grained	None	1:100,000 sheet 233(lbi)
			009° 49.298' E	sandstone		
		Ibua	08° 07.084' N	Fine grained	Galana	1:100,000 sheet 233(lbi)
			009° 47.696' E	sandstone		
		Kumar	8° 19.145' N	Bauxitic sandstone	Galana Amethyst	1:100,000 sheet 232
			009° 28.040' E		quartz	(Akiri)
		Kumar	08° 19.932' N	Bauxitic sandstone	Galana Amethyst	1:100,000 sheet 232
			009° 28.392' E		quartz	(Akiri)
		Kumar	08° 20.263' N	Bauxitic sandstone	Galana Amethyst	1:100,000 sheet 232
			009° 29.418' E		quartz	(Akiri)
			Host rock sample			
3	Yorro	Kwaliang	09° 02.447' N	Porphyritic granite	Galana	1:250,000 sheet 47 (Lau)
		(Pupule)	011° 37.334' E			
4	Lau	Apawa (I)	09° 07.011' N	Porphyritic granite	Galana	1:250,000 sheet 47 (Lau)
			011° 30.318' E			
		Apawa (II)	09° 07.014' N	Fine grained granite	Galana	1:250,000 sheet 47 (Lau)
			011° 30.320' E			
5	Karim-Lamido	Didango	09° 10.089' N	Fine grained	Galena	1:250,000 sheet 47 (Lau)
			010° 59.009' E	sandstone	sphalerite	
			09° 09.938' N	Fine grained	Galena	1:250,000 sheet 47 (Lau)
			010° 59.123' E	sandstone	sphalerite	

4.1.5 Adamawa State

Barite deposits can be found in this state around Gban and Mayo-Kpoki areas. Table 4.4 shows the distribution of barite in Adamawa state. The geology of this deposit is associated with fissure and cavities infilling by hydrothermal fluids associated with faults and fracture zones of the Upper Benue trough. The colour of the mineral alter from white to pink and some have vitreous luster with S.G. values varying between 4.0 and 4.36. The deduced resource of the state is 332 thousand metric tons (Nigerian Geological Survey Agency, 2009).

Table 4. 4: Barite Prospect Areas in Adamawa State
(Source: Nigerian Geological Survey Agency, 2009)

DIGITAL MAP NO	PROSPECT AREA	LOCATION	GPS COORDINATE	NGSA SHEET NO AND NAME
A	GAMBE	Nyami-Warwar Hill	08 35 17N	Sheet 216 (1:50,000)
			011 48 03E	Monkin SE
B	GANGJARI	Burumkusum Hill	08 32 03N	Sheet 216
			011 54 02E	Monkin SE
C	TOLA	Pela Village	08 54 15N	Sheet 216
			011 56 84E	Monkin SE
D	TOUNGO	River Dasasar bank	08 10 19N	Sheet 238
			012 04 16E	Toungo SW
E	DIRIMA &	Dirima Village	09 48 31N	Sheet 175
	PURAMBE		012 20 00E	
		Koti-Dirima Village	09 46 54N	Shellen NE
			012 22 12E	
		Gbenre Hills	09 47 54N	
			012 18 41E	
F	GBAN &	Gban Village	09 50 02N	Sheet 175
	MAYO-KPOKI		012 15 31E	Shellen NE
G	WALTANDI &	Waltandi Hills	09 47 30N	Sheet 175
	LEME		012 15 00E	Shellen NE
		Leme Hills	09 45 40N	
			012 16 00E	

4.1.6 Plateau State

Most barite deposits initially discovered in the state were found to be veins of Calcite and Celestite $SrSO_4$ with lower SG values. The Calcite and Celestite may be contaminations in the barites, thus lowering the SG. The location with the best quality barites in Plateau State is Faya where a principal well-formed vein was estimated to contain about 500,000 metric tons of resource with SG varying between 4.0 and 4.2. Some sections reportedly contain Fluorite as impurities and the vein is hosted by sandstones of the Keana Formation of Cenomanian age (Nigerian Geological Survey Agency, 2009).

4.1.7 Gombe State

The barite mineral in Gombe State is being hosted in gneiss-migmatite complex and coarse sandstone of the Benue trough. The mineralized zones in the state are Gombe and Liji slopes found 10Km North East of Gombe town (Nigerian Geological Survey Agency, 2009). The thicknesses of the veins fluctuate in the range of 0.3m and 1.2m and some achieving 1.5m and some can be followed along strike for up to 400m. The colour of the barites is velvety to dark white with specific gravity in the range of 4.09 and 5.3. Gangue minerals related with the mineralization are fluorite, quartz and chalcopyrite. Major element analysis gives BaO content to be between 45.0% - 59.5%. The inferred resource estimate for the two locations in Gombe State is 353 thousand metric tons (Nigerian Geological Survey Agency, 2009).

4.1.8 Zamfara State

The barites in Zamfara state is extensive. Barites mineralization in the state is connected to epigenetic hydrothermal fluids, which leached barium from adjacent rocks and precipitated in the vein. The vein deposits demonstrate incredible varieties in their properties particularly thickness. The veins have variable widths from a few centimetres up to several metres (0.6m-2m), and lengths greater than 100m. Majority of veins have probably formed from rising hydrothermal solution which precipitated the barites in the veins. (Nigerian Geological Survey Agency, 2009).

4.2 RESOURCE ESTIMATES OF BARITE DEPOSITS IN NIGERIA

The resource estimates of major barite locations in Nigeria obtained from data collected are summarized in Table 4.5. As shown in Figure 4.1, Cross River, Nasarawa and Taraba are the states with significant volumes of barite resources.

Table 4. 5: Inferred Resources of Nigerian Barite Deposits (Source: Nigeria Geological Survey Agency, 2009)

States	Inferred Resources (tons)
Benue	307, 657
Cross River	8,612,880
Nasarawa	3,243,376
Taraba	8,960,000
Plateau	500,000
Adamawa	332,130
Gombe	352,800

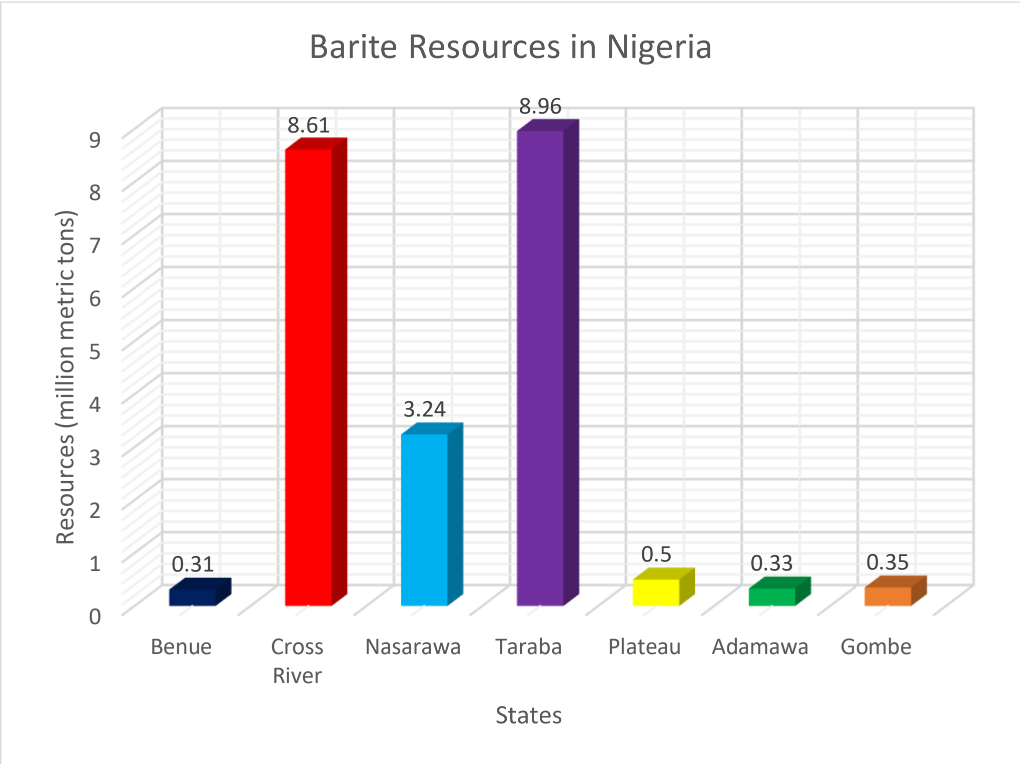

Figure 4. 1: Nigerian Estimated Barite Resources (Source: Nigeria Geological Survey Agency, 2009)

Table 4. 6: Barite Mining Leases operating in Nigeria
(Source: Nigeria Mining Cadastre Office, 2017)

State	Number of Exploration Leases	Number of Mining Leases	Number of Small Scale Leases
Benue	11	1	34
Cross River	3	1	22
Nasarawa	19	2	10
Taraba	10	3	6
Plateau	5	0	0
Adamawa	11	0	2
Gombe	1	1	0
Zamfara	1	0	1

Table 4.6 shows that there are predominantly more small scale operators in Benue and Cross River states. This could be attributed to the presence of simpler geological formation in the barite location consequently making open pit mining which is relatively cost effective desirable. Often, these small-scale operators due to their lack of resources necessary for commercial operations would avoid complex geological formations that might require underground mining which is cost intensive. Table 4.6 shows that small scale operators are also predominant in Nasarawa with only two recognized commercial operators. Extensive studies (Aladesanmi et al., 2018, Michael Oladapo and Oluwakemi Adeoye-Oladapo, 2011, Mgbemere et al., 2018) done on barite resources and characteristics in Nasarawa State provides great motivation for firms to carry out barite mining operations in the state. Plateau, Zamfara and Gombe states with virtually no mining or small scale leases despite their huge barite resources could be as a result of paucity of well documented study of their field characteristics, grade, dimension and abundance and this continues to constitute a major impediment towards their economic exploitation and utilization. The data presented in Tables 4.6 shows that majority of the operators are small-scale operators, and this could explain the low level of local barite production as they lack the necessary resources required to operate commercially. As a result of this constraint, these small-scale operators, despite the abundance of this mineral and its usefulness, over time become more interested in more precious minerals where they can generate higher turnover for minimal time and effort.

4.3 VARIATION OF BARITE QUALITY ACROSS LOCATIONS

Figure 4.2 is a plot of average specific gravity versus barite deposit locations.

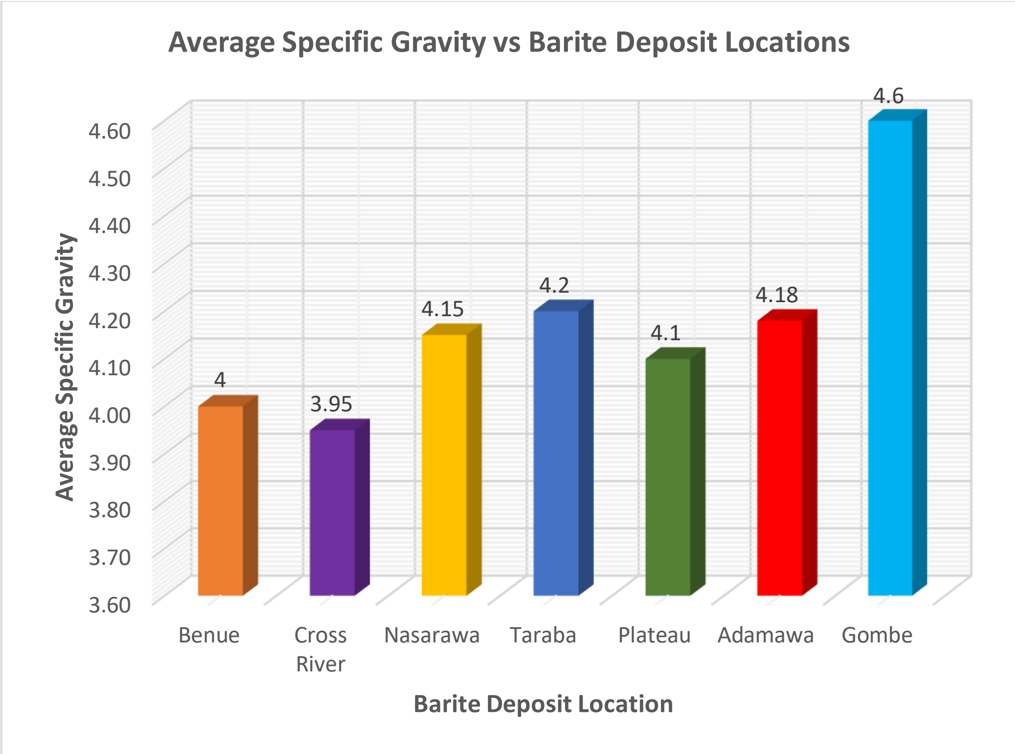

Figure 4. 2: Variation of Barite Quality across locations (Nigerian Geological Survey Agency, 2009)

Figure 4.2 shows the variation of barite quality across the states. Geologically, depositional processes involving chemistry of the hydrothermal fluid and host rock/wall rock interaction brings about this variation. The ore constituents are transported by one or more high temperature fluids that are channeled along structurally controlled pathways. Depending on the location, the source of ore constituents vary from predominantly sedimentary rocks to predominantly igneous rocks. From the variations observed, the mechanism by which fluids were heated could have also varied from one location to another. Some could have been heated as they circulated to deep levels in an extensional tectonic setting where the geothermal gradient was elevated, whereas others could have been heated by igneous intrusions.

Generally, quality of barite mineral varies from location to location and with depth in a mine. Studies (Ezekwesili et al., 2015, Oden, 2012) showed that the quality of barite mineral from the deepest part of a vein is always higher than that from the top part of the same vein.

4.4 ANALYSIS OF NIGERIAN BARITE PRODUCTION, EXPORT AND IMPORT DATA

Annual production, export and import data obtained from the United States Geological Survey is plotted in Figure 4.3. The data covers the period 2006 to 2015.

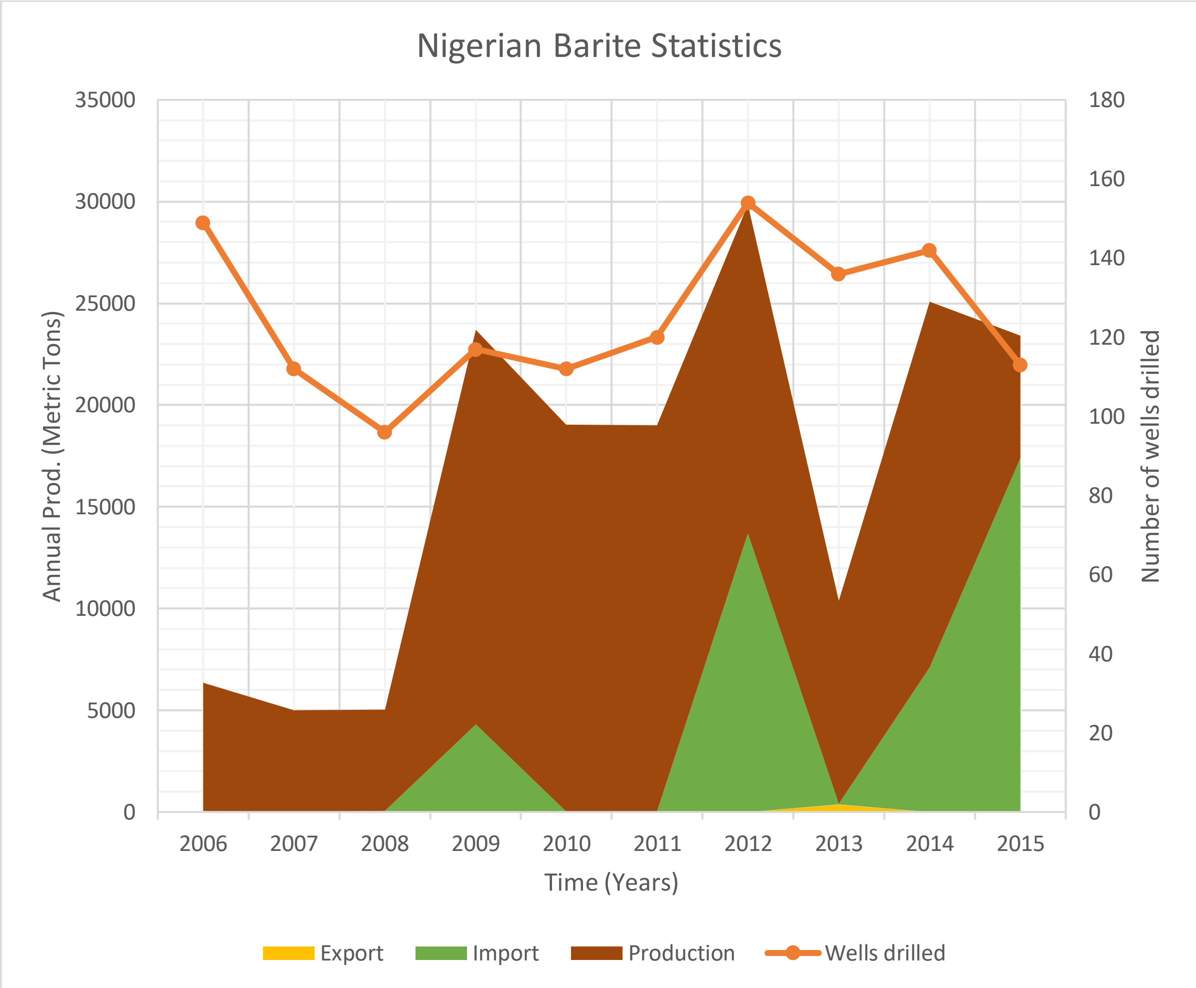

Figure 4. 3: Nigerian Barite Production, Export and Import Statistics
(Sources: USGS, World Trade Centre, 2018 and DPR Oil & Gas Annual Report, 2016)

Figure 4.3 shows export has been nearly non-existent. Despite experiencing occasional dips, production and import have steadily increased over the years. The production trend was similar to the trend of number of wells drilled. Increase in number of wells drilled between 2008 and 2009 coincided with production increase within the same period. Similar trend also occurred between 2011 and 2012. The peaks could be as a result of favourable oil prices during the period which brought about more crude oil exploration and production activities. Period of dips experienced between 2009 and 2010 and between 2012 and 2013 could be as a result of oil price fall. However, the significant amount of import within those period of production rise as indicated in Figure 4.3 shows that domestic production was not meeting local demand. Considering the abundance of this mineral in the country, efforts towards increased domestic production will help to minimize the huge import expenditures for this mineral and ultimately promote local content.

CHAPTER 5

ECONOMIC FEASIBILITY ANALYSIS OF BARITE PRODUCTION IN NASARAWA STATE

This chapter discusses the barite production history in Nasarawa State and the results of the investigation of economic viability of barite production in the state. The interest in Nasarawa is because the state is close to Abuja, where the research is conducted from and has the highest number of artisanal miners already in operation; this has created a footprint to follow in assessing the activitvies already in place. The state also has huge barite resource estimated to be 3.2million metric tons with an average specific gravity of 4.0.

5.1 BARITE PRODUCTION IN NASARAWA STATE

Nasarawa state hosts some of the prominent barite fields in the Benue Trough such as the Azara field. Production over the years have not been steady due to the fact that exploration and mining activities have been dominated by artisans and small-scale miners who possess low work force with little or no mechanization utilized for operations, lack of strong technical know-how, low finance as well as lack of incentive from government to operate legally. Table 5.1 lists the annual production for Nasarawa State in the past four years.

Table 5. 1: Production History
(Source: Nigerian Mining Cadastre Office, 2017)

Year	Annual Production(Metric Tons)
2015	3276
2016	2952
2017	2880
2018	2736

Table 5.1 shows that production have decreased over the past four years. This could be as a result of poor technical knowledge of the artisans. The nature of their work schedule could also be a factor. These artisans work periodically and usually rely on market price development for operations. Just as the name suggests, one of the major limitation of artisanal scale of mining is lack of organization and documentation. They rarely keep good records of operations such as volume of barite obtained daily or monthly. Statistics in Table 5.1 were obtained from a few small scale miners currently in operations.

Mineral Title Holders in the State

Table 5.2, 5.2 and 5.3 is a list of firms registered and recognized by the government as having obtained the rights to carry out exploration and mining of barite in the state.

Table 5. 2: Exploration Licenses (Source: Nigerian Mining Cadastre Office, 2017)

Title holders	Cadastral Unit	Area (sq km)	LGA	State
Vanic Global Concept Limited	448	89.6	Toto	Nasarawa
Optimum Minerals Resources Ltd	35	7	Awe	Nasarawa
Optimum Minerals Resources Ltd	54	10.8	Obi	Nasarawa
Usaled Bros Nig Ltd	156	31.2	Awe	Nasarawa
Usaled Bros Nig Ltd	132	26.4	Awe	Nasarawa
Forward Ever Global Ventures Business Ltd	88	17.6	Awe	Nasarawa
Hadman Resources Int'l Ltd	189	37.8	Awe	Nasarawa
Manor Star Logistics Ltd	70	14	Keana	Nasarawa
Fortunesprings Energy Ltd	36	7.2	Awe	Nasarawa
Fortunesprings Energy Ltd	94	18.8	Awe	Nasarawa
Strategic Metals Ltd	143	28.6	Awe	Nasarawa
Strategic Metals Ltd	16	3.2	Awe	Nasarawa
Pioneer Spectrum Minerals Nigeria Ltd	30	6	Obi	Nasarawa
Liberty Redstone Ltd	240	48	Keana	Nasarawa
Liberty Redstone Ltd	144	28.8	Keana	Nasarawa
Dic Materials Ltd	38	7.6	Awe	Nasarawa
African Overseas Services Ltd	59	11.8	Keana	Nasarawa
Optimum Minerals Ltd	54	10.8	Obi	Nasarawa
Hibiscus Mining Ltd	168	33.6	Toto	Nasarawa

Table 5. 3: Mining Leases (Source: Nigerian Mining Cadastre Office, 2017)

Title Holders	Cadastral Unit	Area (sq km)	LGA	State
Kaffo Mines Nigeria Limited	5	1	Awe	Nasarawa
Nigerian Mining Corporation	625	125	Asaza	Nasarawa

Table 5. 4: Small Scale Mining Leases (Source: Nigerian Mining Cadastre Office, 2017)

Title holders	Cadastral Unit	Area (sq km)	LGA	State
Resources Improvement & Manufacturing Nig. Ltd	4	0.8	Keana	Nasarawa
Resources Improvement & Manufacturing Comp. Ltd	4	0.8	Keana	Nasarawa
Akyana Salt Mining Association	3	0.6	Keana	Nasarawa
Othmani Mining Company Nig. Ltd	15	3	Keana	Nasarawa
Amfani Farm Nig. Ltd	15	3	Keana	Nasarawa
Resources Improvement & Manufacturing Co. Ltd	2	0.4	Keana	Nasarawa
Mairago Miners Multipurpose Society Azara	8	1.6	Awe	Nasarawa
Rimco Mining Co. Ltd	15	3	Keana	Nasarawa
Delphi Earthworks Ltd	15	3	Awe	Nasarawa
M. Maifata Nigeria Ltd	10	2	Awe	Nasarawa

Table 5.2 shows list of firms with barite exploration licenses. These are licenses granted over land area not exceeding 200 square kilometres which is not already subject to an existing exploration license, mining lease or small scale mining lease. Table 5.3 presents a list of firms with barite mining leases. These are exclusive permit granted in respect of an area not exceeding 50 square kilometres which is not within an Exploration license area or a Small Scale Mining area. Table 5.4 presents a list of firms with barite small scale mining leases. These are firms with the right to exploit barite minerals in an area not exceeding 3 square kilometres. It is also seen that small scale operators are predominant in the state and this could explain the low level of production in the state.

The annual barite requirement for drilling was computed to estimate the quantity of barite consumed yearly and the results are presented in Table 5.5

Table 5. 5: Annual Barite Requirement for Drilling

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Tons required per drilling operation	200	200	200	200	200	200	200	200	200	200
Rig count	14	14	14	14	14	14	14	14	14	14
Wells drilled in a year	77	77	77	77	77	77	77	77	77	77
Quantity consumed (Metric Tons)	15400	15400	15400	15400	15400	15400	15400	15400	15400	15400

Table 5.5 shows the estimated annual barite requirement for drilling. The tons of barite required to drill a well and the number of wells drilled annually were used to compute the quantity of barite consumed annually. Statistics in Table 5.5 was used to determine how much of the nation's barite demand for drilling that Nasarawa State can provide. In the absence of number of wells drilled, the rig count, historically a good barometer of barite consumption could as well be used for the evaluation.

5.2 ECONOMIC FEASIBILITY ANALYSIS

Given the data discussed in the methodology, the economic model was developed. The model was used to perform economic feasibility analysis of commercial barite production in Nasarawa State. This analysis was used to determine whether an investment in commercial barite production in the state is attainable within an estimated cost and as well profitable. The model assumed capital costs and operating costs. The input data into the model were barite price, projected annual production, royalty and mineral taxes. The model output were Net Present Value, Internal Rate of Return and Payout Period which were then used to make economic decisions. The results of the economic model are presented in Table 5.6.

The computed internal rate of return(IRR) is 28%. Intuition tells us that if a project has a high IRR then it is a good project. However, this IRR must be referred to some benchmark. This benchmark is the cost of capital. This cost of capital also refers to the rate of return (NPV discount rate) required to persuade an investor to make a given investment. Since the computed IRR of 28% is greater than the discount rate of 10% used and the NPV is positive, it is a good project to pursue.

To obtain the payback period, the cumulative cash flows was plotted against time as shown in Figure 5.1.

Table 5. 6: Economic Model

ECONOMIC FORECAST											
Year		**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**
Prod. Factor		-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06
Price, $		398	406	404	396	388	393	396	398	398	396
Annual Prod., metric-tons		2425	2291	2165	2046	1934	1828	1727	1633	1543	1458
Gross Revenue, M$		964.95	930.28	874.84	810.41	750.42	718.34	684.06	649.75	614.05	577.40
Royalty, M$		48.25	46.51	43.74	40.52	37.52	35.92	34.20	32.49	30.70	28.87
Capital Expenditure											
Equipment purchase, M$		1284.00	0	0	0	0	0	0	0	0	0
Road Construction, M$		850.00	0	0	0	0	0	0	0	0	0
Buildings, M$		644.40	0	0	0	0	0	0	0	0	0
Electrical System, M$		132.70	0	0	0	0	0	0	0	0	0
Engineering tools, M$		150.80	0	0	0	0	0	0	0	0	0
Mining Licenses, M$		1.40	0	0	0	0	0	0	0	0	0
Total Capital Expenditure, M$		3063.3	0	0	0	0	0	0	0	0	0
Operating Expenditure											
Supplies & Materials, M$		2.55	2.41	2.27	2.15	2.03	1.92	1.81	1.71	1.62	1.53
Labour, M$		7.18	6.78	6.41	6.06	5.72	5.41	5.11	4.83	4.57	4.32
Equipment Operation, M$		4.05	3.83	3.62	3.42	3.23	3.05	2.88	2.73	2.58	2.44
Salaried Labour, M$		2.35	2.22	2.10	1.99	1.88	1.77	1.68	1.58	1.50	1.41
Miscellaneous, M$		1.62	1.54	1.45	1.37	1.30	1.22	1.16	1.09	1.03	0.98
Total Operating Expenditure, M$		17.75	16.77	15.85	14.98	14.16	13.38	12.64	11.95	11.29	10.67
Amortization, M$			0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Depreciation, M$			153.10	145.44	138.17	131.26	124.70	118.46	112.54	106.91	101.57
Total Depreciation, M$			153.10	145.44	138.17	131.26	124.70	118.46	112.54	106.91	101.57
Net Income Before Tax, M$		898.96	713.74	669.65	616.59	567.33	544.19	518.59	492.61	464.99	436.14
Income Tax, M$					(123.32)	(113.47)	(108.84)	(103.72)	(98.52)	(93.00)	(87.23)
Net Income After Tax, M$		898.96	713.74	669.65	493.27	453.86	435.35	414.87	394.09	371.99	348.91
(+) Depreciation, M$			153.10	145.44	138.17	131.26	124.70	118.46	112.54	106.91	101.57
(+) Amortization, M$			0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Less CAPEX, M$		3063.30									
NCF, M$		(2164.34)	866.99	815.25	631.59	585.28	560.20	533.49	506.79	479.06	450.63
IRR		28%									
NPV @ 10% disc., MM$		1.36									

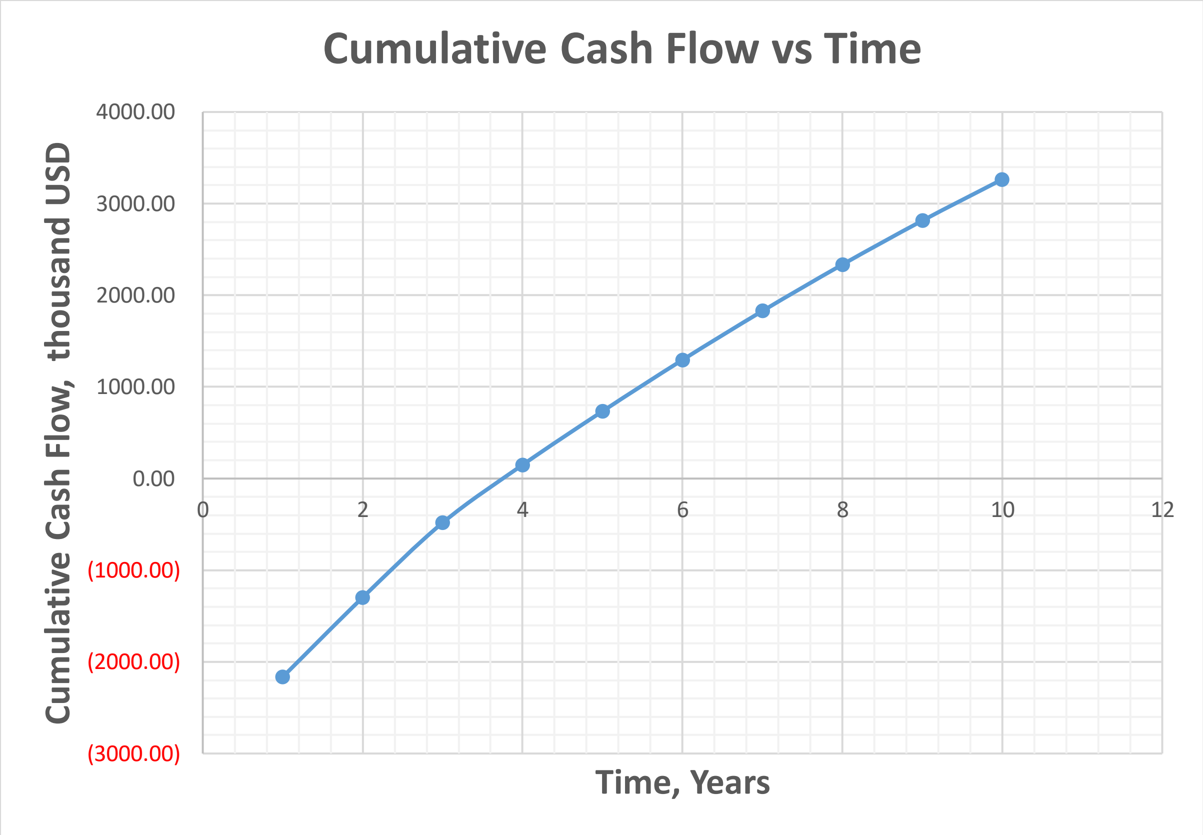

Figure 5. 1: Plot of cumulative cash flows vs time

Figure 5.1 shows that the payback period is about 4 years. This indicates that it will take about 4 years to earn back the amount invested in this proposed project from the net cash flows. Payback period helps to evaluate the risk associated with a project. This relatively short payback period makes the project appealing because it shows that the investor's initial outlay is at a risk only for a relatively short period of time.

As outlined in the methodology, some of the input data (i.e., CAPEX, OPEX, Annual Production, Price) was subjected to sensitivity analysis to evaluate their impact on the net revenue and cost. Sensitivity analysis provided information on what may happen if forecast assumptions are varied one by one. It was used to evaluate the influence each assumption has on a forecast output. Cost, price and annual production were assumed and used as the input data. The sensitivity analysis was done on factors (input data) affecting net revenue and cost in the first and second year. This is because net revenue gives investors the confidence they will get a return while cost analysis is important in making decisions in areas such as pricing and capital investment.

The results of the sensitivity analysis are presented in the following section. Figure 5.2 is a Tornado plot to show the sensitivity of net revenue to CAPEX, OPEX, price and annual production at the end of the first year.

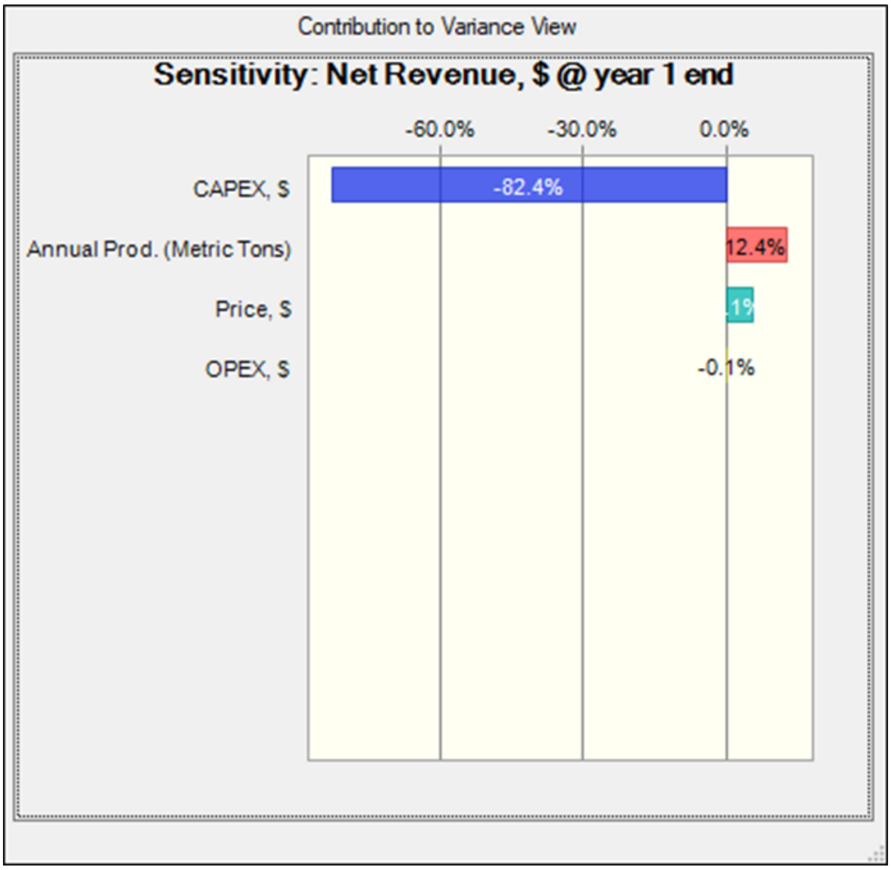

Figure 5. 2: Net Revenue Sensitivity Analysis at end of first year

Figure 5.2 shows that the capital expenditure tends to have the greatest influence on the net revenue in the first year. This was similar to the results obtained by Orire(2009) on “the techno-economics of bitumen recovery from oil and tar sands as a complement to oil exploration in Nigeria”. This was also expected as huge capital costs such as equipment purchase are expended during the starting year. It is also seen that the net revenue during the first year does not significantly depend on the operating costs and market price of barite; and it is slightly dependent on annual barite production. The results show that the major concern during initial investment is to provide for capital expenditures as increase in capital cost reduces the profitability of the project. Hence, all efforts should be channeled towards maximizing production and to minimize capital expenditures to achieve more profitability from executing the project.

Figure 5.3 shows the results of the sensitivity analysis of first year project cost. Expectedly, the items included in the initial capital expenditures are the cost drivers. This is also similar to the results presented by Orire(2009).

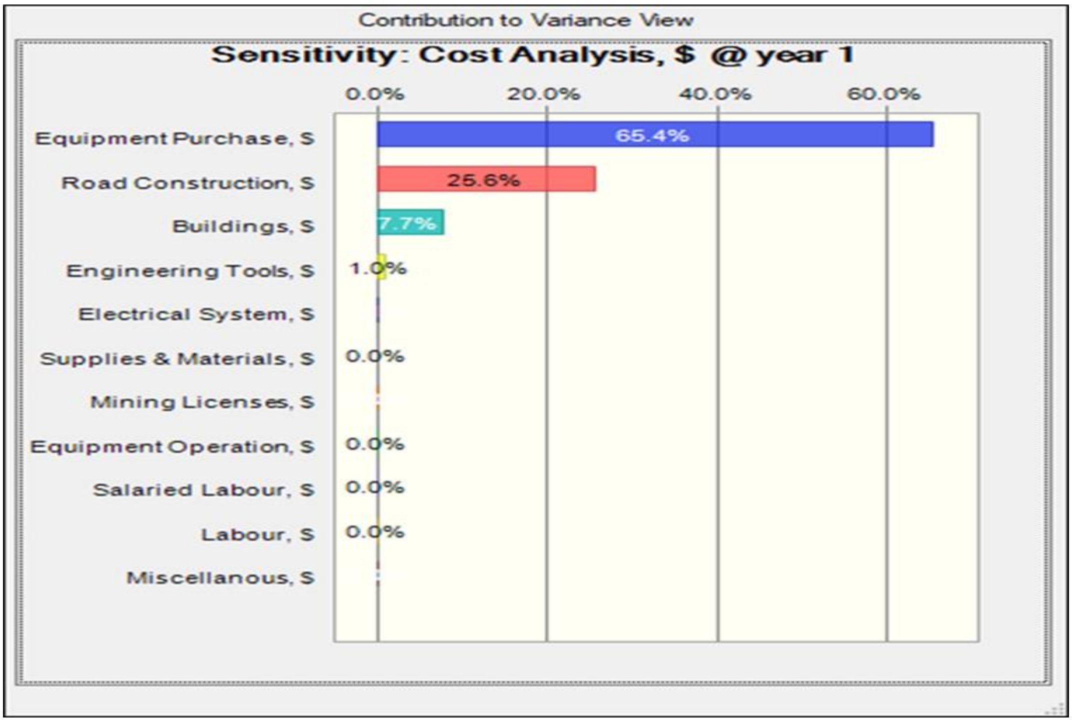

Figure 5. 3: First year Cost Sensitivity Analysis

The result indicates that attention should be paid to the procurement of equipment, building and road construction as any increase in these costs will greatly impact the total project cost and ultimately affect net revenue. For example, considering that equipment has the greatest effect on initial cost outlay, detailed economic analysis should be carried out to determine if renting or outright purchase of some of the equipment is more suitable. However, it is important to note that the actual cost of a capital expenditure does not immediately impact the income statement, but gradually reduces profit on the income statement over the asset's life through depreciation.

For the second year sensitivity analysis, the assumptions used as input data were annual production, price and OPEX. CAPEX which are long term investments with expected long asset life were omitted as their costs were incurred during the first year. The sensitivity analysis was then performed to evaluate the impact of the assumptions on the forecast output, net revenue.

The results of the sensitivity analysis are presented in the following section. Figure 5.4 is a Tornado plot to show the sensitivity of net revenue to OPEX, price and annual production at the end of the second year.

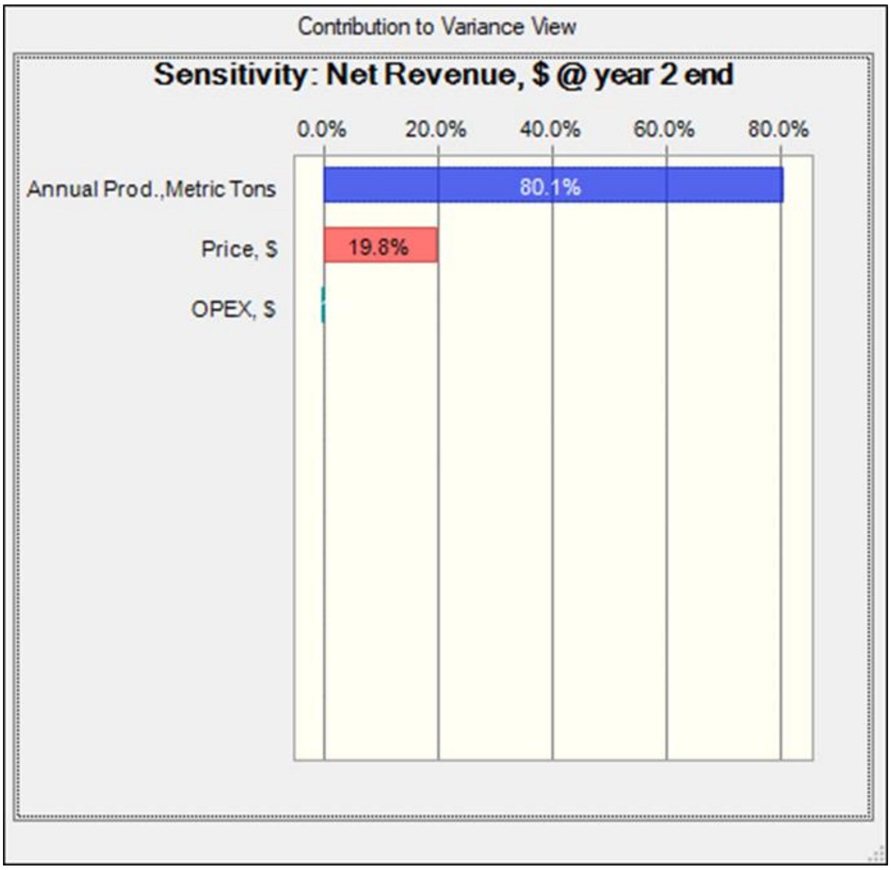

Figure 5. 4: Net Revenue Sensitivity Analysis at end of second year

Figure 5.4 shows that at the end of the second year, net revenue tends to be most sensitive to annual production, followed by price. This indicates that optimal production at this stage becomes paramount.

Sensitivity analysis was also done to evaluate the effect of OPEX and CAPEX on second year's cost outlay. The results of the sensitivity analysis are presented in the following section. Figure 5.5 is a Tornado plot to show the sensitivity of annual cost to OPEX and CAPEX at the end of the second year.

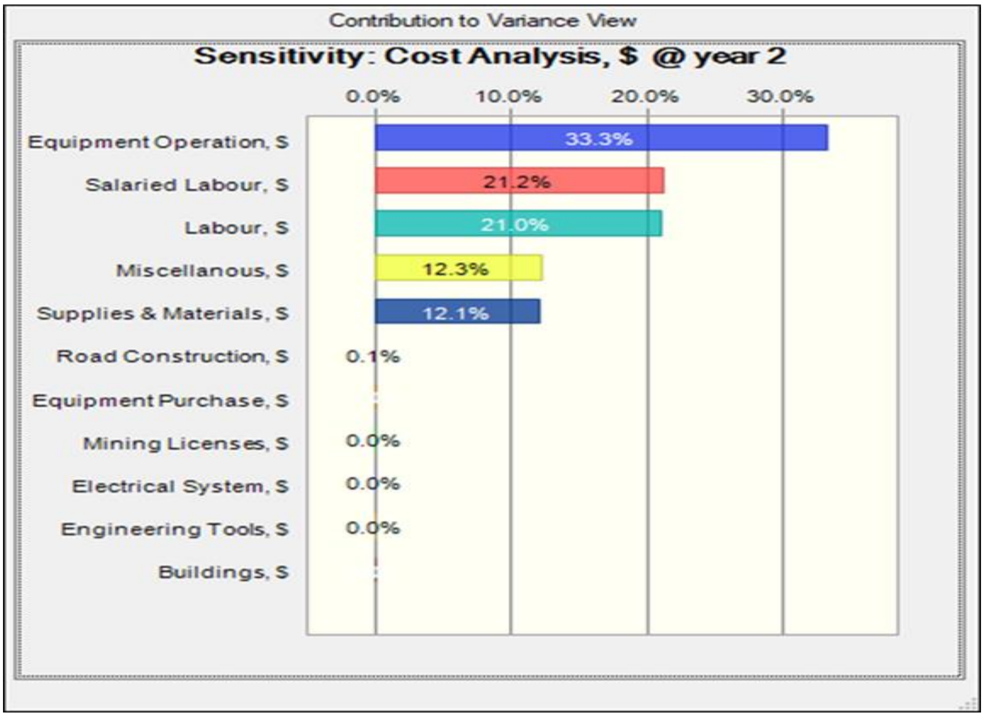

Figure 5. 5: Second year Cost Sensitivity Analysis

From the second year, factors such as price and annual production start to become more impactful on the net revenue as seen in Figure 5.4. It is important to note that the higher the percentage of the contribution to variance, the greater the impact the input(assumption) has on the forecast. Figure 5.5 indicates that factors such as equipment operation and labour should be given more priority during business decisions in the second year as they have greater effect on cost outlay.

5.3 ANALYSIS OF A PRODUCTION GROWTH CASE SCENARIO

The sensitivity analysis indicated that net revenue is dependent on production. Investigation was also carried out to examine the effect of increasing barite production on project economics. The rationale is to examine ways Nasarawa can provide more barite to meet the local demand. It is assumed in this analysis that the growth in barite production will be realized when the government provides incentives to attract commercially viable miners to Nasarawa State.

Two case scenarios were examined in this study. We considered a 20% and 50% increase in the annual production of barites in Nasarawa and calculated the IRR, payback period and NPV. The results of this analysis are shown in Table 5.7.

Table 5. 7: Results of Economic Analysis Considering Production Growth Scenarios

Production increase	IRR, %	Payback period, years	NPV, MM$
20% increase	40	3	1.94
50% increase	63	2	2.81

From the IRR, payback period and NPV values, it is observed that the presence of additional commercially strong companies in the state would greatly increase the profitability of this investment. For example, a 20% increase in annual barite production yields shorter payback period (3 years instead of 4 years); IRR increases from 28% to 40% and a higher NPV. A 50% increase in annual barite production reduces the payback from 4 to 2 years; doubles the NPV; and the IRR is more than doubled, from 28% to 63%.

It should be noted that considering the annual barite requirement for drilling, the barite production growth scenarios proposed in this study will further propel Nasarawa State to meet about 25% of the demand for barites by oil and gas industry in Nigeria.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

This work sought to evaluate the value chain of barite minerals in Nigeria. It also sought to investigate the economic viability of barite production in Nasarawa State. Data pertaining to barite exploration and production in Nigeria such as estimated reserves, production history and annual rig count were collected and analyzed. Production history from Nasarawa, barite price, fiscal terms (royalty and mineral taxes) and assumptions for capital and operating costs were then used to develop a model to evaluate the feasibility of commercial barite production in the state. Sensitivity analysis was then carried out on factors affecting net revenue and cost. Based upon the study, the following conclusions are drawn.

- Nigeria has an estimated 21million metric tons of barite resources with majority of the resources found in Cross River, Taraba and Nasarawa states.
- Nasarawa state has an estimated 3.2million metric tons of barite resources with an average specific gravity of 4.0. Current annual production level is about 2500metric tons and this is likely as a result of the predominant artisanal operations in place.
- Economic analysis indicated a payback period of about 4years with an IRR of 28% and an NPV of $1.36million USD using a 10% discount rate.
- The analysis showed that investment in commercial barite production in Nasarawa state is feasible.

6.2 RECOMMENDATIONS

To improve this work, real figures pertaining barite consumption should be used for evaluating barite demand instead of rig count. This is because some rigs are used for workover and would not require as much units of barite. Real cost data for development and operating expenses should also be used as cost control is necessary for increasing profit. Future study should also be carried out to investigate the economic viability of barite production in other states where barite resources are found.

NOMENCLATURE

API	American Petroleum Institute
S.G.	Specific Gravity
N-S	North-South
NW-SE	North West-South East
NNE-SSW	North North East-South South West
CAPEX	Capital Expenditure
OPEX	Operating Expenditure
IRR	Internal Rate of Return
NPV	Net Present Value
CF	Cash Flows

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APPENDIX

APPENDIX A : OTHER MODEL EQUATIONS

Below are other equations incorporated into the economic model

Net Income Before Tax (NIBT):

$$NIBT = Gross\ Revenue - Royalty - OPEX - Depreciation - Amortization$$

$$Income\ Tax = 20\% \times Net\ Income\ Before\ Tax$$

$$Net\ Income\ After\ Tax = Net\ Income\ Before\ Tax - Income\ Tax$$

$$Net\ Cash\ Flow = Net\ Income\ After\ Tax + Depreciation + Amortization - CAPEX$$

APPENDIX B: PRODUCTION GROWTH CASE SCENARIO RESULTS

Table B- 1: Model Output of 20% Production Increase Scenario

ECONOMIC FORECAST											
Year		2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Prod. Factor		-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06
Price, $		398	406	404	396	388	393	396	398	398	396
Annual Prod., metric-tons		2909	2750	2599	2456	2321	1828	1727	1633	1543	1458
Gross Revenue, M$		1157.94	1116.33	1049.81	972.49	900.50	718.34	684.06	649.75	614.05	577.40
Royalty, M$		57.90	55.82	52.49	48.62	45.03	35.92	34.20	32.49	30.70	28.87
Capital Expenditure											
Equipment purchase, M$		1284.00	0	0	0	0	0	0	0	0	0
Road Construction, M$		850.00	0	0	0	0	0	0	0	0	0
Buildings, M$		644.40	0	0	0	0	0	0	0	0	0
Electrical System, M$		132.70	0	0	0	0	0	0	0	0	0
Engineering tools, M$		150.80	0	0	0	0	0	0	0	0	0
Mining Licenses, M$		1.40	0	0	0	0	0	0	0	0	0
Total Capital Expenditure, M$		3063.3	0	0	0	0	0	0	0	0	0
Operating Expenditure											
Supplies & Materials, M$		3.05	2.89	2.73	2.58	2.44	1.92	1.81	1.71	1.62	1.53
Labour, M$		8.61	8.14	7.69	7.27	6.87	5.41	5.11	4.83	4.57	4.32
Equipment Operation, M$		4.86	4.59	4.34	4.10	3.88	3.05	2.88	2.73	2.58	2.44
Salaried Labour, M$		2.82	2.67	2.52	2.38	2.25	1.77	1.68	1.58	1.50	1.41
Miscellaneous, M$		1.95	1.84	1.74	1.65	1.55	1.22	1.16	1.09	1.03	0.98
Total Operating Expenditure, M$		21.30	20.13	19.02	17.98	16.99	13.38	12.64	11.95	11.29	10.67
Amortization, M$			0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Depreciation, M$			153.10	145.44	138.17	131.26	124.70	118.46	112.54	106.91	101.57
Total Depreciation, M$			153.10	145.44	138.17	131.26	124.70	118.46	112.54	106.91	101.57
Net Income Before Tax, M$		1078.75	887.14	832.70	767.57	707.07	544.19	518.59	492.61	464.99	436.14
Income Tax, M$					(153.51)	(141.41)	(108.84)	(103.72)	(98.52)	(93.00)	(87.23)
Net Income After Tax, M$		1078.75	887.14	832.70	614.06	565.66	435.35	414.87	394.09	371.99	348.91
(+) Depreciation, M$			153.10	145.44	138.17	131.26	124.70	118.46	112.54	106.91	101.57
(+) Amortization, M$			0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Less CAPEX, M$		3063.30									
NCF, M$		(1984.55)	1040.39	978.30	752.38	697.08	560.20	533.49	506.79	479.06	450.63
IRR		40%									
NPV @ 10% disc, MM$		1.94									

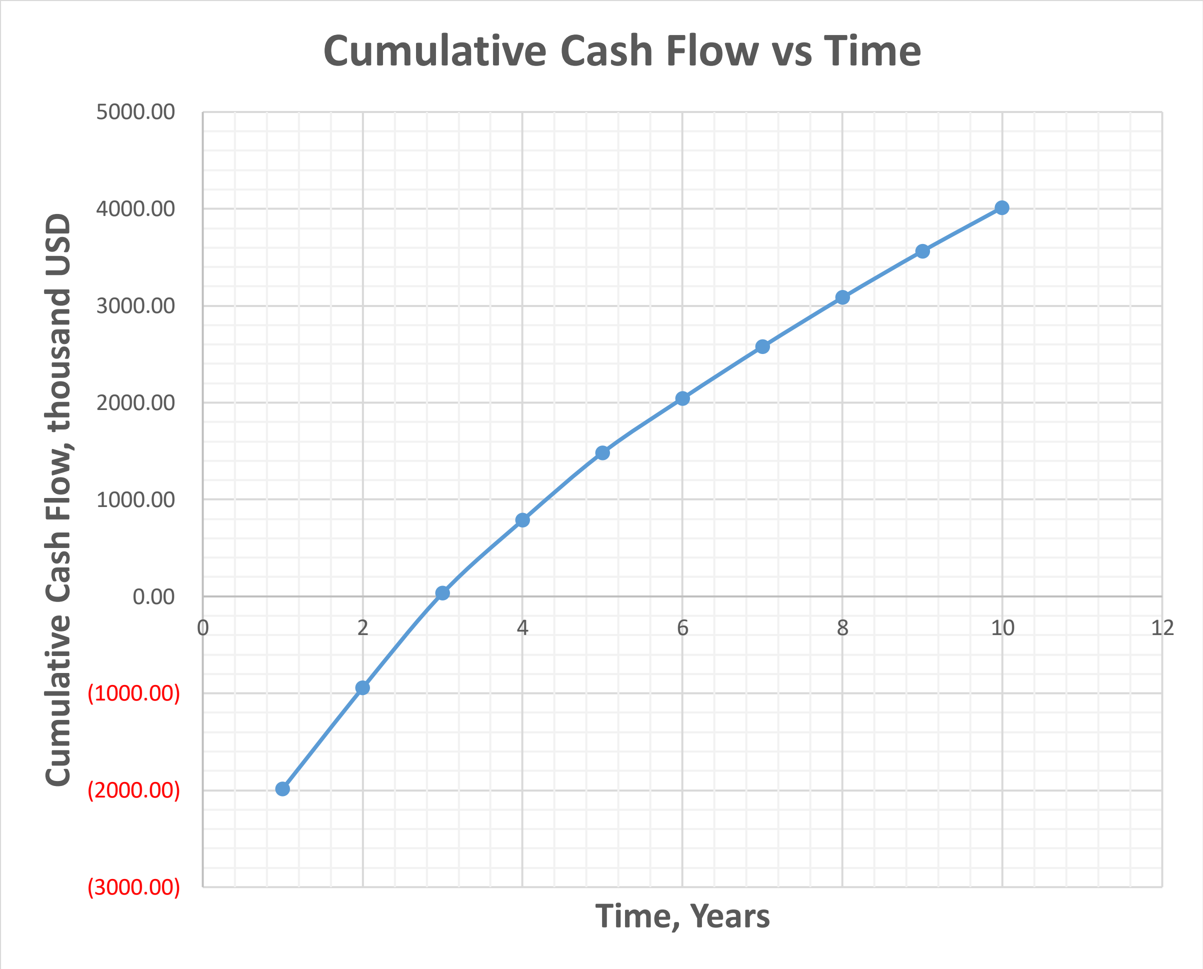

Figure B- 1: Plot of Cumulative Cash Flows vs Time (for 20% Production Increase)

Table B- 2: Model Output of 50% Production Increase Scenario

ECONOMIC FORECAST											
Year		2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Prod. Factor		-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06
Price, $		398	406	404	396	388	393	396	398	398	396
Annual Prod., metric-tons		3637	3437	3248	3070	2901	1828	1727	1633	1543	1458
Gross Revenue, M$		1447.43	1395.41	1312.26	1215.62	1125.63	718.34	684.06	649.75	614.05	577.40
Royalty, M$		72.37	69.77	65.61	60.78	56.28	35.92	34.20	32.49	30.70	28.87
Capital Expenditure											
Equipment purchase, M$		1284.00	0	0	0	0	0	0	0	0	0
Road Construction, M$		850.00	0	0	0	0	0	0	0	0	0
Buildings, M$		644.40	0	0	0	0	0	0	0	0	0
Electrical System, M$		132.70	0	0	0	0	0	0	0	0	0
Engineering tools, M$		150.80	0	0	0	0	0	0	0	0	0
Mining Licenses, M$		1.40	0	0	0	0	0	0	0	0	0
Total Capital Expenditure, M$		3063.3	0	0	0	0	0	0	0	0	0
Operating Expenditure											
Supplies & Materials, M$		3.82	3.61	3.41	3.22	3.05	1.92	1.81	1.71	1.62	1.53
Labour, M$		10.76	10.17	9.61	9.09	8.59	5.41	5.11	4.83	4.57	4.32
Equipment Operation, M$		6.07	5.74	5.42	5.13	4.84	3.05	2.88	2.73	2.58	2.44
Salaried Labour, M$		3.53	3.33	3.15	2.98	2.81	1.77	1.68	1.58	1.50	1.41
Miscellaneous, M$		2.44	2.30	2.18	2.06	1.94	1.22	1.16	1.09	1.03	0.98
Total Operating Expenditure, M$		26.62	25.16	23.78	22.47	21.24	13.38	12.64	11.95	11.29	10.67
Amortization, M$			0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Depreciation, M$			153.10	145.44	138.17	131.26	124.70	118.46	112.54	106.91	101.57
Total Depreciation, M$			153.10	145.44	138.17	131.26	124.70	118.46	112.54	106.91	101.57
Net Income Before Tax, M$		1348.44	1147.23	1077.28	994.04	916.70	544.19	518.59	492.61	464.99	436.14
Income Tax, M$					(198.81)	(183.34)	(108.84)	(103.72)	(98.52)	(93.00)	(87.23)
Net Income After Tax, M$		1348.44	1147.23	1077.28	795.23	733.36	435.35	414.87	394.09	371.99	348.91
(+) Depreciation, M$			153.10	145.44	138.17	131.26	124.70	118.46	112.54	106.91	101.57
(+) Amortization, M$			0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Less CAPEX, M$		3063.30									
NCF, M$		(1714.86)	1300.48	1222.87	933.56	864.77	560.20	533.49	506.79	479.06	450.63
IRR		63%									
NPV @ 10%, MM$		2.81									

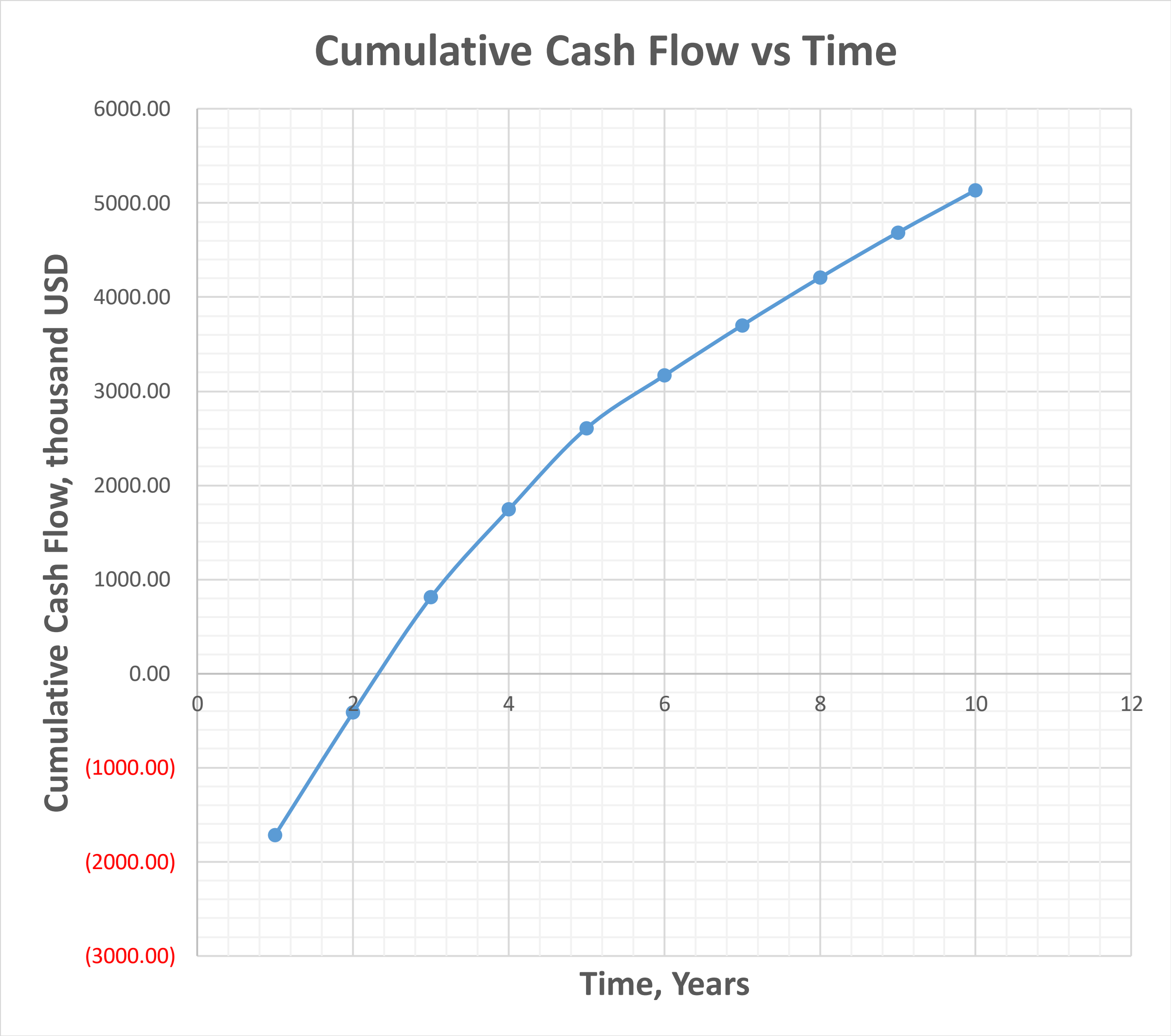

Figure B- 2: Plot of Cumulative Cash Flows vs Time (for 50% Production increase)